

DLRmagazine

German Aerospace Center (DLR) · No. 164 · April 2020



ROLLING OUT THE RED CARPET

ISTAR – THE LATEST MEMBER OF DLR'S AIRCRAFT FLEET

More topics:

- ▶ **WHITE SPOTS MUST DISAPPEAR**
Research for improved broadband connectivity
- ▶ **TIMELESS SPACES**
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About DLR

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

Climate, mobility and technology are changing globally. DLR uses the expertise of its 47 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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SUDDENLY, EVERYTHING IS DIFFERENT

While this DLRmagazine was being prepared, the societal landscape in Germany and around the world was faced with massive change. Schools, universities, businesses, restaurants and cultural institutions were shut down, and public life came to a standstill. Trade fairs and events were postponed or cancelled. Under normal circumstances, our colleagues would have been busy preparing for upcoming events – gearing up to showcase the results of DLR's research and new developments, whether at the Hannover Messe, the ILA Berlin Air Show, the Space Symposium in Colorado Springs or the Space Show for young people. Meeting people, maintaining a dialogue with other research institutions and industry, and interacting with individuals from all walks of life is a particularly important part of what we do. While the first few cancellations may have caused some disappointment among those planning to attend, with each passing day and the emergence of new information, such feelings are giving way to an understanding that what is happening in spring 2020 is leaving nobody unaffected. Preventing the spread of the Coronavirus is a matter for each and every one of us. Everything is different in 2020.

No matter how frustrating – and indeed, how costly – it is for society to shut down so radically, it is important to think of all those who are particularly at risk, as well as those in the frontline of the battle against the virus. These include people working in medicine and care, in providing people with essential goods, in crisis management, and, last but not least, in the laboratories, where research into a vaccine is being carried out as rapidly as possible.

DLR's 9000 employees are now demonstrating their capabilities in a completely different way. Outside of their usual routine, they are reacting flexibly to unfamiliar working conditions and demonstrating their solidarity at home – with level-headedness and self-discipline. The Coronavirus pandemic is a challenge for all of us. Over the coming weeks, DLR will continue to do everything it can to make it through this unprecedented situation in the best possible way.

Stay healthy and look after yourself
and your loved ones!

Dear reader,

It's showtime! The star of this show is undoubtedly very special indeed. Unique, multifaceted, a real workhorse – and without any airs or graces, despite being so eagerly anticipated. We are talking about none other than ISTAR. Born as a Falcon in Bordeaux-Mérignac, its career was initially that of a conventional mid-range Dassault aircraft, dutifully flying as a testbed for type certifications. But things took a different turn three years ago, when DLR became interested in the smart French aircraft. For two years, the Falcon was prepared for its new role, which would see it become a versatile test aircraft for studying aerodynamics, flight guidance and flight control systems. At long last, the red carpet was rolled out for it in February 2020, now under the name of ISTAR, which stands for In-flight Systems & Technology Airborne Research. It marks the start of a new chapter in DLR aeronautics research. ISTAR has a bright future, but it is unlikely to see such an unveiling again.

Helga and Zohar are just as unique. These two phantoms will fly to the Moon – their plastic bodies equipped with thousands of sensors. They are designed to provide information about the radiation dose to which humans are exposed during a journey in space and the efficiency of protective measures.

This issue also looks at air transport and the climate, energy from waste tyres, and traffic research in the Test Field in Lower Saxony. And if you are interested in the sort of down-to-Earth stars who are doing remarkable things on a daily basis, then you will enjoy reading about Jessika Wichner. As an archivist who puts her heart and soul into her work, she keeps a close eye on everything going on at DLR.

Happy reading!

Your DLRmagazine editorial team

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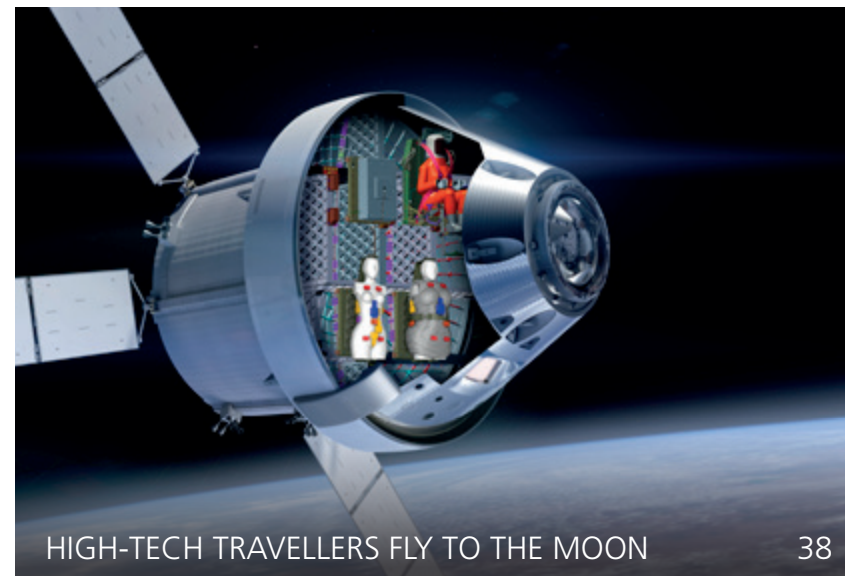
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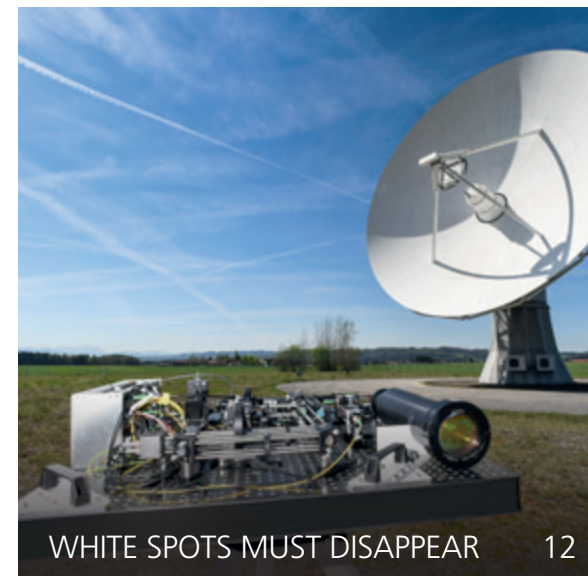
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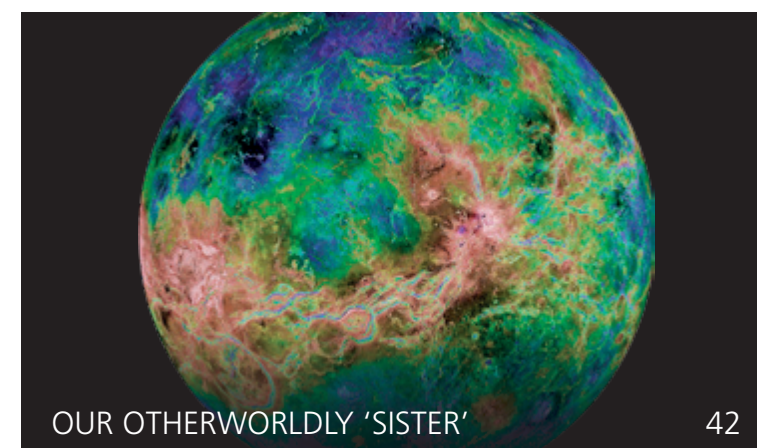
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MORE THAN SMART ALGORITHMS

By Mark Azzam

A 2018 study commissioned by the German Digital Association, Bitkom, forecast that the European artificial intelligence (AI) market would experience significant growth in the coming years – from three billion euro in 2018 to 10 billion euro by 2022. Increasing storage capacities, computing power and connectivity are making it possible to acquire, merge and analyse vast quantities of data and are opening up a new world of possible applications for AI. Given the strong international competition, the future success of German industry will undoubtedly depend on how well we position ourselves for these new opportunities.

Smart algorithms can improve condition-based monitoring and maintenance of industrial plants by predicting malfunctions before they occur. They can also make production chains more efficient, safer and more sustainable. DLR has played a significant role in shaping these developments for many years. A recent example is the cross-sectoral project 'Factory of the Future'. It brings together 10 DLR institutes and facilities active in the fields of space, aeronautics and transport to realise the vision of a fully networked production – centred around the effective collaboration of humans and robots.

The potential applications for AI, however, extend far beyond modernising industrial production. In Earth observation, the information obtained by using AI to process satellite data is proving a vital asset in the monitoring of the Earth system during this crucial period of global change. AI analysis of satellite data has also become very important for regional and urban planning, agriculture and efficient resource management. Here, DLR is a world leader, particularly with its Earth Observation Center (EOC).

AI is also the key to the future of mobility. At DLR, our researchers are laying the foundation for safe, highly automated and networked mobility by conducting research into intelligent traffic management systems and digitally mapping traffic routes. In aeronautics research, we are working on an intelligent personal assistant for air traffic controllers that will listen to conversations between controllers and pilots and recommend appropriate courses of action.

While we have come a long way, it is clear that there is still work to be done. We are seeing a growing demand for intelligent and safe technology in important economic sectors like the aeronautics, space, automotive or energy sectors. At the same time, a study by the technology association VDE revealed that only one percent of the companies and universities surveyed believe that Germany is playing a pioneering role in the field of artificial intelligence. This should serve as a warning.

With the integration of AI into safety-critical systems, smart algorithms must be coupled with a traditional safety engineering approach and the fundamental knowledge of physical systems. Germany's expertise in these areas is precisely what sets it apart from other countries. Weaknesses in AI designed to play games such as Go or Chess are cause for disappointment. When it comes to autonomous vehicles, they can be a matter of life and death. Proving that it really works is therefore essential. A rigorous safety engineering mindset is what is needed and DLR can draw upon its extensive expertise here. Together with German industry, we are working to ensure the competitiveness, reliability and economic success of safety-critical AI applications 'made in Germany'.

© DLR/David Senkic



Mark Azzam, Executive Board Representative Digitalisation at DLR

SUPERPOWER FOR AEROSPACE IN DRESDEN

On 5 February 2020, DLR acquired a new high-performance computer. CARA – Computer for Advanced Research in Aerospace – is located in Dresden. Its almost 150,000 processing cores make it one of the most powerful supercomputers in international comparison available for aerospace research. For instance, it can be used to simulate all of the properties and components of an aircraft based on highly precise physical and mathematical models – a vital prerequisite for their virtual development, testing, operation and certification. Thus, CARA will, among other things, accelerate the introduction of new technologies for more economical, environmentally friendly and safer flight.

The new computer can also be used in space and transport research, including in fields such as space transport and next-generation trains. CARA was installed in the data centre of the Lehmann Center (LZR) at the Technische Universität Dresden (TU Dresden) and is operated by the Center for Information Services and High Performance Computing (ZIH).

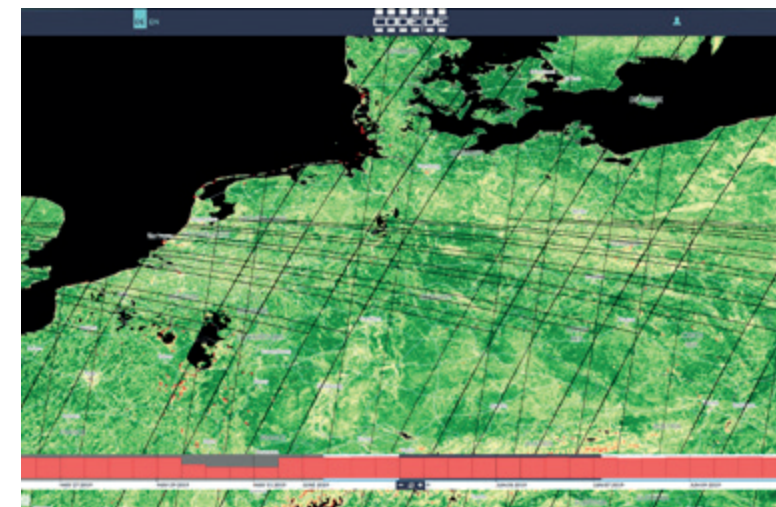


The CARA supercomputer

CODE GERMANY – CREATE YOUR OWN MAPS

Earth observation data helps us gain a better understanding of environmental processes. Anyone – be it agencies, scientists or lay people – can access satellite data for free via the web service CODE-DE (Copernicus Data and Exploitation Platform – Deutschland). The data mainly originates from the Sentinel satellites of the European Copernicus programme and covers Germany and the rest of the world. In addition, the portal offers complete information packages that show aspects such as the development of agricultural land over time, along with programs that enable anyone to edit and download their own maps online. Those who want to try out more can integrate their own processing programs and automated process chains into the portal.

A team from the DLR Earth Observation Center (EOC) has been constructing and operating CODE-DE over the last three years on behalf of the German Federal Ministry of Transport and Digital Infrastructure. The Polish cloud computing firm CloudFerro will take over operations from April 2020 onward. CloudFerro is looking to develop the platform into a cloud-based service.



Germany in CODE-DE from the view of the Sentinel-3 OLCI vegetation index, which indicates plant health; dark green equates to dense, healthy vegetation.

BARTOLOMEO PLATFORM EXPANDS USAGE OF THE ISS

Built and tested in Germany, Europe’s first commercial external platform on the International Space Station (ISS) – Bartolomeo – was launched on 6 March 2020. Bartolomeo offers companies and research institutions ideal conditions for experiments and technological developments under space conditions and is therefore a major step towards commercial ISS use in Europe.

The platform is installed on the outside of the European Columbus laboratory with a clear view of Earth. Its uses will be diverse and cost-effective, as the different experiments and payloads can be accommodated on routine supply flights to the ISS. Airbus developed the platform in cooperation with the European Space Agency (ESA) and will sell flight opportunities to research and industrial organisations.



The Airbus Bartolomeo platform is attached to the European Columbus module on the International Space Station (ISS)

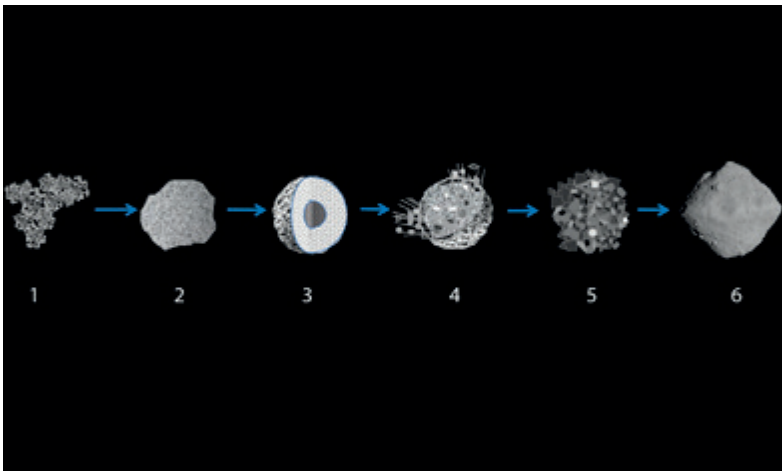
© Airbus



Remote monitoring using Virtual Reality can help small airports to offer improved services at a lower cost

LIKELY LINK IN PLANETARY FORMATION

Asteroid Ryugu witnessed the formation of the Solar System approximately 4.5 billion years ago. Today, this cosmic ‘rubble pile’ is being intensively studied by numerous researchers. Infrared images acquired by the Japanese Hayabusa2 orbiter reveal that the asteroid consists almost entirely of highly porous material and was formed largely from fragments of a parent body that was shattered by impacts. The investigation of the asteroid’s global properties confirms and complements previous findings of its landing environment. Hayabusa2 mapped the asteroid from orbit at high resolution and acquired samples of the primordial body, which are currently traveling to Earth with the spacecraft. Analyses of the samples, some of which will be carried out at DLR, could lead to a better understanding of the processes at play during the early history of the Solar System.



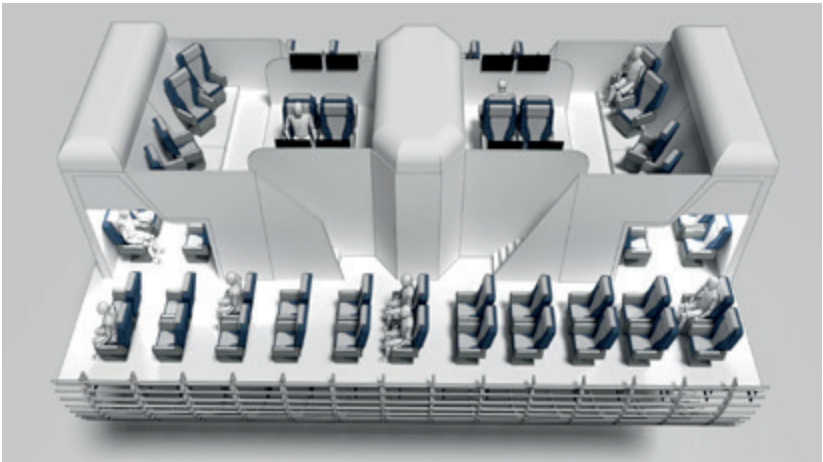
This image shows the formation scenario for Ryugu. Fragile, highly porous asteroids like Ryugu are probably the link in the evolution of cosmic dust into massive celestial bodies.

© Okada et al. Nature 2020

INNOVATIONS FOR TOMORROW’S PASSENGERS

To meet the need for new, agile cabin designs and fuselage concepts, aeronautics research is placing a stronger emphasis on the digitalisation of the aircraft cabin. DLR’s Innovative Digital Cabin Design (InDiCaD) project for the digital linking of design and layout of cabin concepts uses an approach that is new in aeronautics research. Here, the cabin will be the starting point of aircraft development. This is possible since new designs can be flexibly adapted to future requirements using computers.

InDiCaD will create the technological prerequisites for incorporating requirements into the cabin design concepts at an early stage in the development phase, whilst researchers are developing revolutionary design solutions for the efficient use of the entire fuselage space of an aircraft. In addition, InDiCaD is also concerned with cabin acoustics which, until now, have been the subject of very little research.



Design freedom thanks to modular cabin concepts – these offer new, tailored solutions to future passenger requirements. This image shows an option for spreading passengers across two levels according to their needs.

AROUND EARTH AND ON TO VENUS

On 10 April 2020, the BepiColombo spacecraft conducted an Earth flyby before heading towards Venus. The main purpose of the Earth flyby was to slow down the orbiter somewhat without expending propellant, in order to bring it onto a trajectory towards Venus.

This time around, however, the flyby offered additional research opportunities, such as observing the Moon in the thermal infrared for the first time using the Mercury Radiometer and Thermal Infrared Spectrometer (MERTIS), developed and built by DLR. This gave scientists the chance to demonstrate its unique optical properties in orbit and to test the instrument for later operations in Mercury orbit. Bepi-Colombo is the most extensive European project to explore a planet in the Solar System. Its mission: to analyse the surface and composition of Mercury, the innermost planet in the Solar System.



On 10 April 2020, ESA’s BepiColombo spacecraft passed Earth at a distance of 12,677 kilometres and embarked on its journey towards the inner Solar System and its final destination, Mercury.

© ESA/ATG medialab



DLR institutes are working on intelligent transport technologies that make fast and safe communication between human and machine possible

ON THE ROAD TO AUTOMATED DRIVING

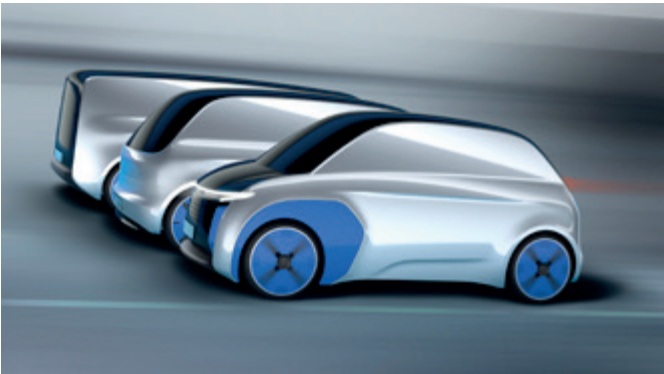
In the project CADJapanGermany, DLR is conducting research into the communication between humans and vehicles and the socio-economic consequences of networked and automated driving with partners from Germany and Japan.

The ‘CADJapanGermany: Human Factors’ project aims to develop novel interfaces that will enable networked and automated vehicles to communicate with their occupants and other road users. A successful cooperation of a diverse range of players is necessary in order to establish networked and automated driving. The participating research institutes and universities are looking to promote technological innovations and encourage social dialogue on this important future topic for the two automotive nations of Japan and Germany.

LIGHT ELECTRIC VEHICLES FOR URBAN TRANSPORT

Electrically powered small and light vehicles, collectively called light electric vehicles (LEVs), could be used for the majority of private local transport and delivery traffic in urban areas. This is shown by a study by the DLR institutes of Vehicle Concepts and Transport Research and the Institute for Codetermination and Corporate Governance (Institut für Mitbestimmung und Unternehmensführung; IMU), a research and consulting institute with locations in Stuttgart, Nuremberg, Munich, Berlin and Dresden.

According to the study, LEVs could be used for up to half of all private journeys, including commuting to work. The researchers believe that e-vehicles would not only enhance the public local transport network – by shuttling passengers to train and bus stations, for example – but would also make an appealing and sustainable substitute for conventional cars and vans, especially for small-scale commercial transport and courier, express delivery and parcel services.



Next-generation cars from the DLR Institute of Vehicle Concepts. These cars of the future are designed to be energy-efficient, emission-free, safe and cost-effective.

MOULD SPORES COULD SURVIVE ON MARS

Bacteria and fungi are part of nature and human life – whether on the outside of our bodies or inside us. In September 2019, DLR astrobiologists sent an entire ‘zoo’ of microorganisms, including bacteria and moulds, on a nine-hour journey up to an altitude of 30 kilometres. They travelled under a stratospheric balloon operated by NASA for the ‘Microbes in Atmosphere for Radiation, Survival and Biological Outcomes Experiment’ (MARSBox). At that altitude, the temperature, radiation and pressure are akin to the conditions on Mars. The preliminary biological findings show that most of the bacteria have been killed, with the strong ultraviolet radiation proving to be particularly problematic for them. These results are of huge interest for future journeys to the Moon and Mars, not to mention for the field of planetary protection. After all, if landers, rovers or other space vehicles covered in mould spores set down on planets and celestial bodies, there is a risk that they could contaminate the surface.



DLR sample carrier on board the NASA stratospheric balloon. Another testing campaign is scheduled to be transported to the International Space Station (ISS) in summer 2020, in order to investigate how microorganisms are affected in the short and long term by microgravity conditions.

HOW CLOUDS AFFECT CLIMATE

Clouds are an important factor in climate. The six-week EUREC4A campaign examined their impact on global climate change and the resulting effect on cloud cover. Five research aircraft and four research vessels were deployed to the east and south of the Caribbean island of Barbados for that purpose, where they were supported by various ground measuring stations and satellites. The low-level clouds over Barbados are typical of the cloud cover that can be found in trade-wind regions throughout the tropics.

The team studied the ‘life cycle’ of the clouds on measuring flights. Using measurements taken in the ocean, the researchers analysed how eddies and fronts interact with the atmosphere. Using a laser-based lidar system on the HALO research aircraft, scientists from the DLR Institute of Atmospheric Physics studied smaller clouds and the layers of water vapour around them. This will serve as a benchmark for improving the modelling and satellite-based remote sensing of clouds and circulation.

Over 40 partners are involved in EUREC4A. This particular campaign was led by the Max Planck Institute of Meteorology in Hamburg and the Laboratoire de Météorologie Dynamique in Paris.



DLR's HALO research aircraft at the airport on the Caribbean island of Barbados. Shallow cumulus clouds can be seen in the background. These reflect the sunlight, thus cooling Earth's surface, and are particularly prevalent in the tropics.

AN ELECTRICALLY-POWERED 19-SEATER FLIES FROM BERLIN TO MANNHEIM

© Bauhaus Luftfahrt/DLR



Visualisation of an electrically powered commuter-class aircraft

Electrically powered small aircraft are already being used for isolated applications, such as training flights for flying schools. Together with the Bauhaus Luftfahrt, DLR has been examining the potential of a 19-seater hybrid-electric commercial aircraft. The project CoCoRe (Cooperation for Commuter Research) shows that electric propulsion systems can be used to good effect over short distances. Roughly 3000 commuter-class aircraft are currently in use worldwide. When used for scheduled services, these 19-seaters fly routes under 200 kilometres 56 percent of the time, and under 350 kilometres 83 percent of the time. The researchers' concept for a range of 200 kilometres flown using electric power alone is limited by the weight of the batteries. As such, they looked at the technology that is currently being used. In order to increase the range, they expanded their concept by adding two gas turbines, which can be coupled to the propellers if necessary. Implementing the concept would also prevent the majority of the carbon dioxide emissions caused by commuter aircraft.

A PLACE IN THE SUN

© ESA/AOES



Artist's impression of the Solar Orbiter space probe

Extreme heat and particle storms make the immediate vicinity of the Sun a truly inhospitable place. Yet that is exactly where the Solar Orbiter spacecraft has been heading since 10 February 2020. Its mission is to explore our star and its inner heliosphere. This area is strongly defined by the solar wind, with its magnetic field and energetic particles. One key question that remains to be answered is how the Sun generates and affects the heliosphere.

With that in mind, the Solar Orbiter is equipped with 10 instruments that will examine the physical properties of the solar wind in the immediate vicinity of the probe, while also monitoring the surface of the Sun and its atmosphere with high-resolution remote sensing instruments. The heat shield has to withstand temperatures of up to 500 degrees Celsius, as the probe will come within 42 million kilometres of the star. The mission is being led by the European Space Agency (ESA), with the involvement of the US space agency NASA. The DLR Space Administration is providing funding for the mission, drawn from financing from the German Federal Ministry for Economic Affairs and Energy (BMWi).

DLR ACROSS GERMANY

BRAUNSCHWEIG: Researchers from the DLR Institute of Aerodynamics and Flow Technology have used a special engine simulator to make noise generated by the impingement of engine exit flows on high-lift devices acoustically measurable. The test not only revealed the engine noise, but also the acoustic output generated by the flaps on the DLR wind tunnel model.

COLOGNE: On 6 February 2020 the Italian ESA astronaut Luca Parmitano returned from the ISS. Over the course of his ‘Beyond’ mission, which began in July 2019, he helped to conduct over 50 European and 200 international experiments and performed a spacewalk. After landing, Parmitano spent his first few days back on Earth at the DLR :enviHab research facility, where he received medical care.

GÖTTINGEN: The Bartolomeo payload platform for the International Space Station (ISS) was tested at the DLR Institute of Aeroelasticity. The Airbus platform is to be used for research in the fields of radiation biology, technology testing, climate and Earth observation, astronomy, solar physics and laser communications. A robotic arm allows experiments to be installed and changed from Earth.

STADE: At the start of 2020, seven different robotic units at the DLR Center for Lightweight-Production-Technology worked together to make a wing shell for the first time. The robot collaboration encompassed automated fibre placement in different material widths, a mobile robotic platform, scanning to monitor surfaces during manufacture, and automated quality assurance.

STUTTGART: Electric cars do not need their full charge capacity all the time; it is often enough simply to charge the vehicle before the next journey. As part of the eLISA-BW pilot project, DLR and the Center for Solar Energy and Hydrogen Research Baden-Württemberg are developing and testing predictive charging.

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WHITE SPOTS MUST DISAPPEAR



Antenna at the DLR site in Weilheim. The optical ground terminal in the foreground is used to exchange data with a satellite.

Research into high-performance satellite communications is being conducted as part of the DLR cross-sectoral project 'Global Connectivity via Satellite'

By Sandro Scalise

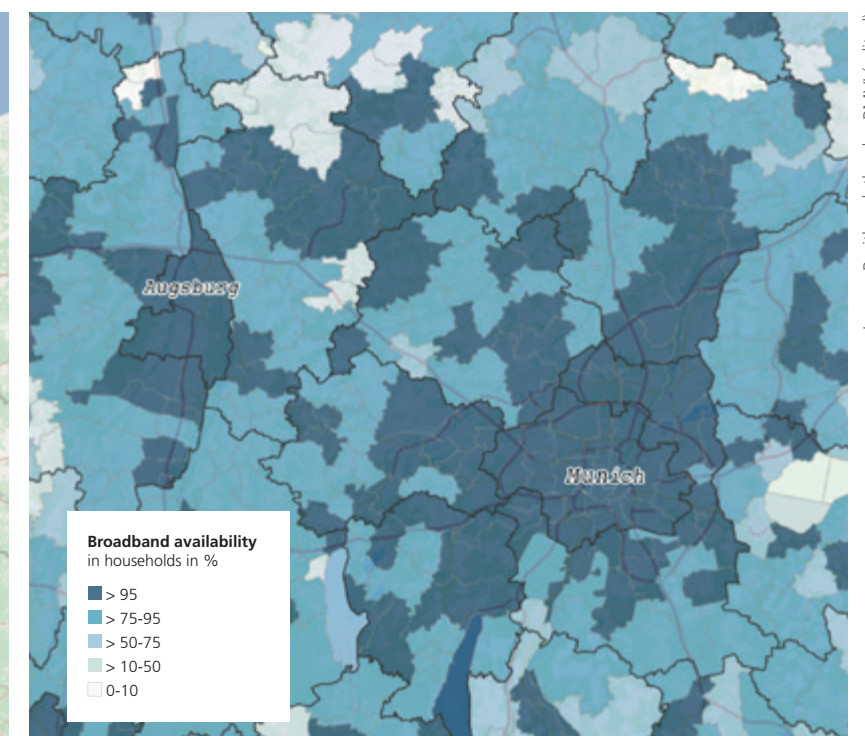
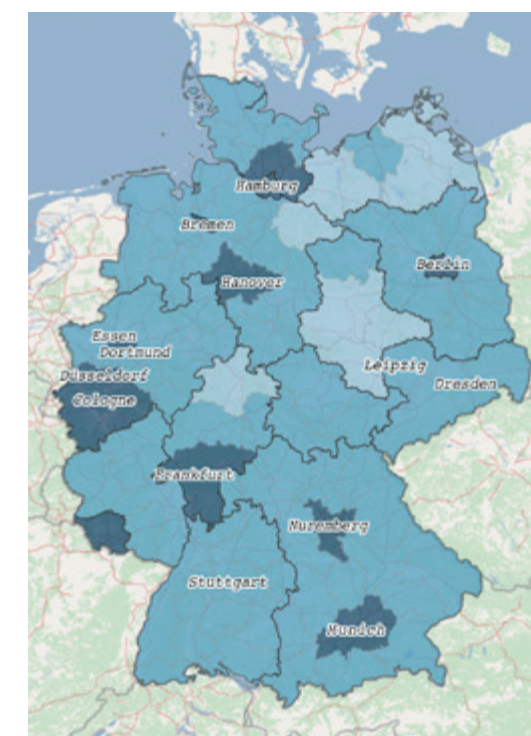
No network! High-speed internet? No chance. Complaints can be heard in the German state of Mecklenburg-Western Pomerania. Even in the greater Munich area, there are districts in which less than half of all households have broadband access. If it is less than 10 percent of households, these are referred to as 'white spots'. And what might be irritating within one's own home can threaten the very existence of companies. White spots must be eliminated. The various German political parties and authorities are united on this issue. The targets of 'ensuring that all regions in Germany have universal access to high-speed internet' and 'a legal right to this by 1 January 2025' were specifically addressed as essential elements for the creation of a 'gigabit society' in the 2018 coalition agreement between the CDU, CSU and SPD. DLR has initiated the 'Global Connectivity via Satellite' cross-sectoral project for this very purpose.

Industry 4.0 is difficult to imagine without widespread, reliable broadband internet. Companies in regions with poor infrastructure should not be excluded from networked production processes and business models that rely heavily on the internet. In addition, people want to be able to access information, communicate and, increasingly, work online in a reliable fashion. In many cases, this is not yet possible in sparsely populated regions. A lack of broadband access hinders the economic development of such areas and contributes towards domestic migration to the major urban areas. Also, lives may be at risk if sufficient network capacity is not available during major events or when a disaster occurs.

Fibre optics and 5G technology are suitable techniques for closing the gaps in broadband coverage. 5G is not simply a more powerful mobile telecommunications system, but rather a network of networks with specific solutions tailored to individual key sectors such as transport, media and manufacturing. The 3rd Generation Partnership Project (3GPP), a global collaborative venture between various committees

on standardisation in mobile communications, is responsible for 5G standardisation. In December 2019 it decided to make 'non-terrestrial networks' (NTNs) an integral part of 5G. NTNs are based on two types of technology, namely communications via airborne platforms and communications via satellite.

The German Federal Ministry of Transport and Digital Infrastructure (BMVI) maintains an interactive and openly accessible tool for monitoring actual broadband coverage in Germany. To date, the average availability of at least 16 MB/s internet access has ranged from 75 to 95 percent in most of the German federal states. However, a more detailed view of the Munich area reveals numerous scattered locations where availability extends to less than half of households and is, in some cases, lower than 10 percent.



Private broadband availability (≥ 16 Mbit/s) for Germany (left) and for the Munich area (right)

Image: Breitbandatlas des BMVI (edited)

Great expectations for space technologies

Until now, communications satellites have been used primarily for television and radio transmission, narrowband mobile services in remote areas and communications at sea. Broadband internet access via satellite has previously been a niche market (particularly in Europe) with proprietary solutions from various satellite operators that have not been integrated into 3G and 4G mobile networks. This situation is expected to change, mainly driven by two factors. Firstly, the inclusion of non-terrestrial networks as part of 5G will make the complete integration of satellite communications into the next-generation mobile network possible. Secondly, a completely new economic sector for space technology is currently being created with what is referred to as New Space. A large number of private space companies, which operate independently of governments and traditional telecommunications corporations, have been founded. These companies are developing faster, better and more economical access to space assets, thereby extending the scope of existing business models. Although not all the New Space initiatives that have been announced are likely to come to fruition, this trend is set to increase connectivity offered via satellite and lead to significant price reductions. This will remove one of the barriers to the use of satellite communications for broadband services.

Data rates in the terabit range

DLR initiated its ‘Global Connectivity via Satellite’ cross-sectoral project in light of these future prospects. As part of this project, the institutes of Communications and Navigation, Atmospheric Physics and Flight Systems are investigating key technologies for what are referred to as Very High Throughput Satellites (VHTS). This next generation of satellites will enable throughputs in the order of terabits per second – enough to transmit approximately 62,500 video streams at 4K resolution simultaneously. Powerful feeder links for connecting satellites to terrestrial networks are an essential technological component. They allow communication satellites to meet the constantly increasing demand for high data rates and keep up with the corresponding expansion in the connectivity requirements for mobile communications systems.

It is likely that non-terrestrial 5G networks will be formed using satellites in different orbits, with Low Earth Orbit (LEO) satellites being the preferred choice for delay-sensitive applications such as

voice services or online gaming. Geostationary Earth Orbit (GEO) satellites are, in turn, well-suited for bandwidth-intensive applications, such as streaming or video uploading. Unlike LEO satellites, GEO satellites do not require tracking antennas on the ground. As a GEO satellite rotates at the same angular velocity as the Earth, it can always be seen from Earth in a fixed position. To achieve high data rates with LEO or Medium Earth Orbit (MEO) satellites, ground antennas with tracking capabilities are required.

Advantages of laser technology

The DLR cross-sectoral project is investigating the use of optical feeder links. Existing high-performance satellites such as Eutelsat’s KA-SAT and ViaSat-1 can now offer throughputs in the range of 100 to 150 gigabits per second. However, the existing satellite system architecture is not arbitrarily scalable, and the current generation of high-throughput satellites is already nearing its limits. Due to the limited spectrum availability in the microwave frequency range, such satellites require too many ground stations to be able to offer throughputs in the terabit-per-second range.

Optical communications technologies can provide point-to-point connections with very low power consumption. More importantly, the available bandwidth is almost unlimited and is not subject to any licensing or frequency-related regulatory hurdles. This makes laser communication an ideal candidate to replace microwave-based technologies in feeder links. Since a single optical link can provide a sufficiently high data rate to support the entire satellite throughput, a single optical ground station would be sufficient – provided it is visible to the satellite. The number of necessary ground stations would then be based solely on cloud coverage statistics. This is because at least one ground station in the network needs clear sky conditions. Simulation results show that approximately 10 optical ground stations can achieve an availability of 99.9 to 99.99 percent. This is the range required for commercial satellite communication systems.

Laser communication technologies are already being successfully used in the European Data Relay System (EDRS) to transmit the Earth observation data collected by LEO satellites to a GEO relay satellite, and from there to Earth via a microwave link. However, its use in direct connections between space and Earth and vice versa still poses a number of technical challenges, mainly due to the



Satellite terminal emulator at Hohenpeißenberg, Upper Bavaria, near Weilheim. DLR scientist Juraj Poliak prepares the testbed for the next communications experiment.

propagation through the atmosphere. Along with the effect of clouds, atmospheric turbulence causes severe signal distortion. Even if the sky is clear, this can lead to significant fluctuations in the received signal power. This effect must be mitigated by countermeasures such as signal predistortion combined with adaptive optics, a technique used in astronomy to correct wavefront distortions using a deformable mirror. The uplink from the ground station to the satellite is particularly challenging due to the physical limits on the size of the telescope on the satellite. In other words, a higher received signal power cannot be achieved by simply using a larger telescope.

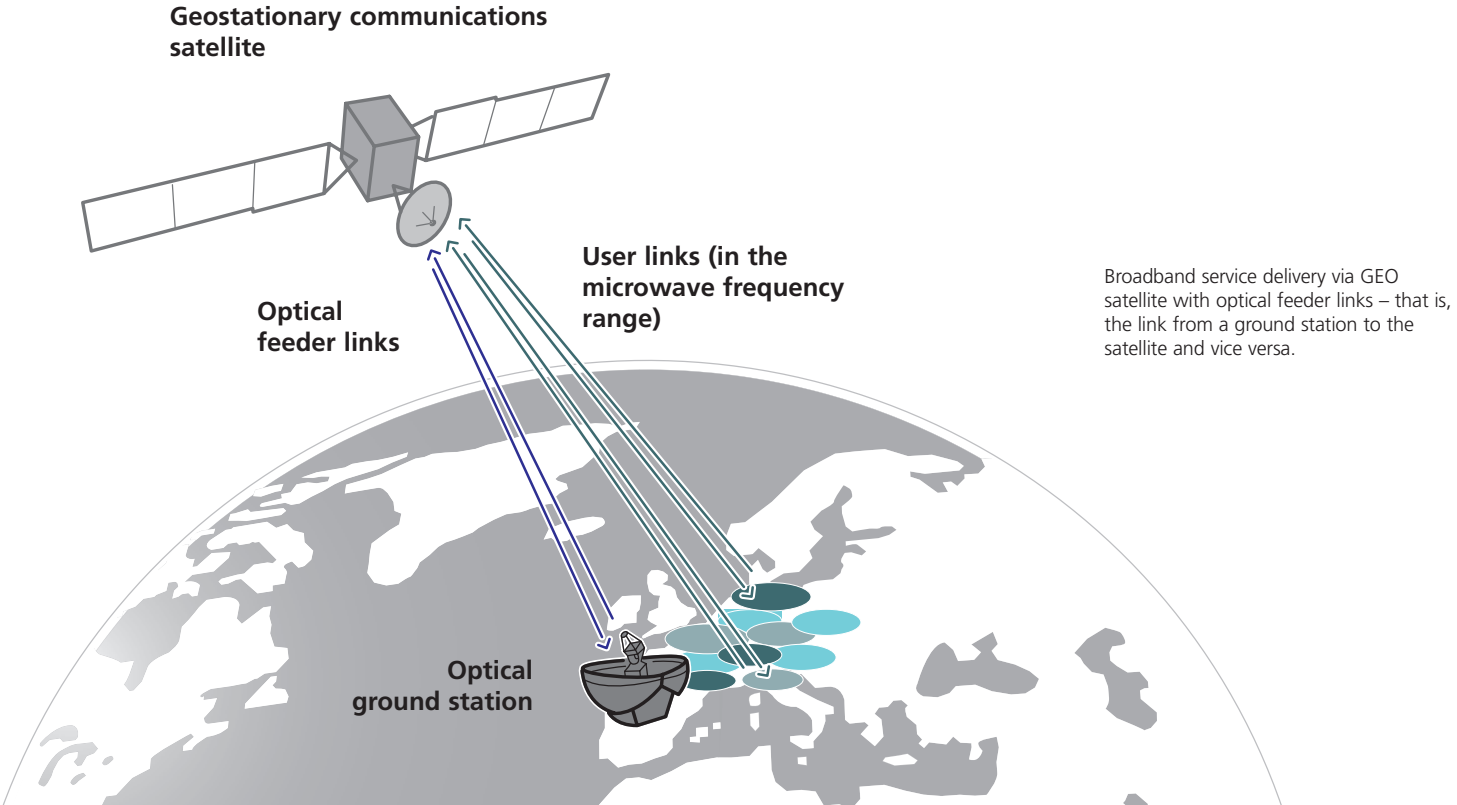
Companies are on board

In their work on the ‘Global Connectivity via Satellite’ cross-sectoral project, DLR’s team of researchers is able to draw upon the findings from previous projects. In 2017, for example, the THRUST (Terabit-throughput satellite system technology) project demonstrated a stable optical connection at 13.16 terabits per second between DLR’s

Weilheim site and a virtual satellite terminal in Hohenpeißenberg. The propagation characteristics of this 10.5-kilometre test route are comparable with a satellite uplink at a low elevation angle. This experimental test system is now being further developed as part of the cross-sectoral project, with more advanced modulation schemes and new reception techniques. These will increase the spectral efficiency, stability and reliability of the connection.

The DLR researchers are also working with industry. One example of this collaboration is the development of a suitable satellite payload for converting optical signals into electrical signals and vice versa, while satisfying the requirements regarding power, mass and volume. Companies such as Tesat Spacecom, a leading German manufacturer of laser communications terminals, ADVA Optical Networking, a provider of telecommunications equipment, especially fibre-optic transmission technology, and Airbus Defence and Space, one of the largest European satellite manufacturers, are all partnering with the DLR in this field. Together, they are pursuing the goal of demonstrating broadband access via GEO satellites with optical feeder links, thus paving the way for a major technological breakthrough in the provision of broadband connectivity via satellite. This would be an important element in being able to offer broadband internet access to citizens across Germany.

Sandro Scalise is Head of the Satellite Networks Department at the DLR Institute of Communications and Navigation.





A CREATIVE DRIVE FOR THE FUTURE OF FLIGHT

Bringing e-mobility to the sky requires whole-system thinking

By Jana Hoidis

Global mobility is facing society's ever more pressing need to significantly reduce the environmental effects of air transport and bring its impact into line with the Paris climate goals. Air transport is currently responsible for approximately 2.8 percent of all carbon dioxide emissions worldwide. DLR is conducting a concept study with a view to bringing an ecologically efficient, medium-haul aircraft into commercial service by 2040.

There are high demands for future aircraft. They must operate without negatively impacting the climate, while remaining cost-effective in both production and use – two often contradictory goals. “DLR has all of the necessary skills to determine which aircraft are the most environmentally friendly for which application, with which propulsion systems and at which altitudes,” says Johannes Hartmann, Head of the Exploration of Electric Aircraft Concepts and Technologies (EXACT) project, which was launched in January 2020. Twenty DLR institutes from the fields of aeronautics, energy and atmospheric research are contributing their expertise to the study. In the past, the primary consideration during the development of an aircraft was the associated production, maintenance and operating costs. With EXACT, the environmental impact, together with cost-effective operations, are incorporated into the conceptual aircraft design from the very beginning. “We are turning this process around for the first time,” adds Hartmann. “And this is revolutionary.”

Johannes Hartmann

studied aerospace engineering at the Technical University of Berlin. After several years of research and development work at Airbus in the field of virtual product design, he moved to the DLR Institute of System Architectures in Aeronautics in Hamburg in 2018. Here he is engaged in the design and development of system architectures for hybrid-electric flight. Hartmann is the overall manager of the EXACT project and coordinates work across Germany at the participating DLR locations. He is married and has three children who share his passion for aircraft. In his free time, he enjoys flying model aircraft with his family.



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Towards climate-neutral aircraft

Conventional aircraft engines have been continuously developed and improved since their introduction. As a result, they are much more energy-efficient today than they were just a few years ago. However, with the development of lightweight materials and the optimisation of aerodynamics and propulsion systems, the potential for further reducing carbon dioxide emissions has been almost completely exhausted. An entirely new approach is therefore necessary. Electric, hybrid-electric or hydrogen-based propulsion concepts, utilising batteries, hydrogen fuel cells and synthetic fuels, could help the air transport system to operate in an environmentally friendly yet economical manner. DLR researchers are aiming to develop an aircraft with at least 70 seats that can cover a distance of 2000 kilometres by 2040.

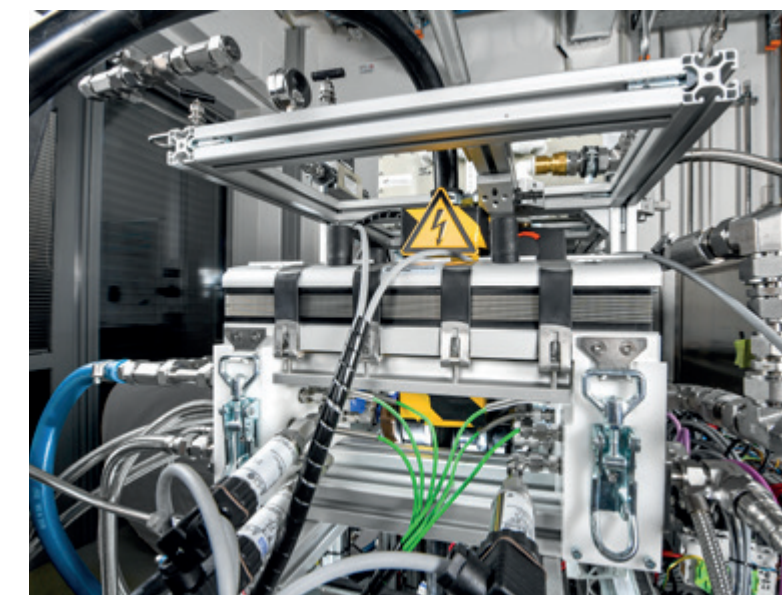
Using various modern technologies, small aircraft are already flying short routes almost emissions free. In September 2016, the world's first four-seater passenger aircraft powered by a hydrogen fuel and cell battery system alone, the HY4, took off from Stuttgart Airport. The HY4 was developed by the DLR spin-off company H2Fly in conjunction with the Slovenian aircraft manufacturer Pipistrel. The first aircraft powered purely by electric propulsion – the two-seater Extra 330LE aerobatic plane powered by a Siemens electric motor – was also officially approved and certified in 2016.

However, aircraft with up to 19 seats are responsible for less than one percent of all emissions generated by aviation. “We want to be as creative and radical as possible in our approach to the aircraft development process,” explains Hartmann. “So, we are looking at various configurations with 19 to 200 seats. We may gain groundbreaking knowledge for small aircraft that can also be scaled and applied to larger ones.” Aircraft the size of an Airbus A320, with approximately 150 seats, account for around 50 percent of aircraft emissions. This presents considerable opportunities for savings on short- and medium-haul routes. Such aircraft currently burn kerosene in their engines, not only to provide propulsion, but also to supply their on-board electrical systems. These systems could be powered by batteries relatively easily. Longer flights, on the other hand, could probably only be accomplished by the burning of energy-dense fuels. The Power-to-Liquid process produces fuel from renewable forms of energy, while also removing carbon dioxide from the atmosphere. This carbon dioxide reacts with hydrogen to form a mixture of hydrocarbons, from which gasoline, diesel or kerosene can be derived. During subsequent combustion, these fuels release only as much carbon dioxide into the atmosphere as was previously removed. Could this be the win-win solution we need?

Both environmentally friendly and economical

Reductions in emissions are already possible by mixing conventional kerosene with synthetic fuels. However, these new fuels are currently only available in small quantities and are disproportionately expensive. Using a mixture containing 10 percent Power-to-Liquid fuels would raise the operating costs of an airline operating primarily from Germany by 11 percent. If we are to ensure that environmentally friendly air transport becomes a reality, aircraft must continue to be economically viable.

As hydrogen is already being used as a raw material for synthetic fuels, the EXACT project will also investigate propulsion systems that burn hydrogen directly. While Power-to-Liquid fuels are inherently climate-neutral, fossil fuels are still required to produce and transport them today. Using hydrogen directly as a fuel could remove some intermediate steps and reduce costs. But there is a catch; although hydrogen is very light, it has such a large volume for a given energy content that aircraft would have to be completely redesigned to accommodate it.



Fuel cells for use in aviation are being researched in the laboratory of the DLR Institute of Engineering Thermodynamics in Hamburg

For economic reasons, aircraft manufacturers are guided by the principle of commonality. They ensure that components are compatible for installation in all aircraft of the same family. Airbus has always used this concept to optimise its production. The A319, A320 and A321 aircraft, for example, all use the same vertical stabiliser despite the different lengths of their fuselages. Hybrid-electric propulsion systems are fundamentally different from their conventional counterparts and will place completely new demands on aircraft structures. So, the question becomes – when a hybrid-electric short-haul aircraft

is being designed, how can these technologies be adapted for the corresponding medium-haul aircraft while ensuring that their production is still cost-effective?

A completely new air transport system

Changing the nature of the commercial aircraft fleet could be a relatively simple way of moving towards environmentally friendly flight. At present, airlines like to purchase a ‘universal aircraft’ that they can

CONFIGURATIONS STUDIED IN THE EXACT PROJECT

Propulsion systems and associated aircraft concepts

A completely battery-powered propulsion system is feasible for smaller, 19-seater aircraft for flights of up to 200 kilometres. Fuel would be carried only as a reserve in case of emergencies, or if the aircraft were required to fly longer routes.

Medium-sized, short-haul aircraft flying up to 2000 kilometres could reduce CO₂ emissions through a clever combination of different propulsion systems. Hydrogen fuel cells power the aircraft during cruise and when taxiing on the ground. Batteries supply the on-board electrical systems. Hydrogen gas turbines provide the necessary thrust for take-off and potential go arounds.

Larger aircraft carrying 150 passengers or more on medium-haul routes of over 2000 kilometres require greater propulsive power. Fuel cells are used when taxiing on the ground, while gas turbines that burn synthetic fuels allow for faster cruising flight. When used in parallel, both systems combined can generate enough power for take-off.

Hydrogen fuel cell Battery Gas turbine | **Con:** Converter **Inv:** Inverter **PDS:** Power distribution system



Project meeting at the DLR site in Hamburg: (from left to right) Berit Gerlinger, Kai Wicke, Johannes Hartmann and Giuseppa Donelli work together on developing visionary aircraft configurations.



use for both short- and medium-haul flights. This way, pilots, flight attendants and maintenance staff only need to be trained to deal with a single type of aircraft. Although this is practical and saves time and money, it is not ideal from an environmental point of view. There is enormous potential for improvement here and Hartmann envisages adapted fleet concepts as the solution to this issue: “Depending on the route, aircraft with more environmentally friendly propulsion systems could be used for shorter flights.”

DLR aeronautics researcher Kai Wicke is currently studying the operational and ecological integration of new aircraft configurations as part of the EXACT project. He is also considering their impact on the air transport system as a whole. “Whether a new aircraft is powered by hydrogen, fuel cells or batteries, it will be interesting to see its impact on both the environment and the air transport system,” he says. “How will it affect airports, airlines, air traffic control and the atmosphere?” A new type of aircraft will influence these systems, and vice versa. If aircraft are to be refuelled with hydrogen, new fuel delivery systems will be required. How do contrails generated by the combustion of hydrogen affect the atmosphere? Would they lead to greater cloud formation, and could this affect the climate? Extensive use of batteries will require dedicated areas for charging and storage. What will our energy system look like in the future when coal-fired power plants are shut down? Can renewable forms of energy consistently provide the amount of power we need? How will energy prices develop? How can enough batteries be produced? Can they be recycled at the end of their life?

All of these questions need to be answered over the next four years, during which an initial strategy will be developed. Aircraft engineers, atmospheric researchers and electrical engineers from 20 different DLR institutes are working together to establish reliable models and answer as many of these questions as possible. Hartmann is enthusiastic: “The EXACT project is giving DLR an opportunity to demonstrate its unique expertise.”

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

PARTICIPATING INSTITUTES

- Institute of Aeroelasticity
- Institute of Aerodynamics and Flow Technology
- Institute of Propulsion Technology
- Institute of Structures and Design
- Institute of Composite Structures and Adaptive Systems
- Institute of Flight Systems
- Institute of Air Transport and Airport Research
- Air Transportation Systems
- Institute of Aerospace Medicine
- Institute of Maintenance, Repair and Overhaul
- Institute of Atmospheric Physics
- Institute for Software Technology
- Institute of System Architectures in Aeronautics
- Institute of Software Methods for Product Virtualization
- Institute of System Dynamics and Control
- Institute of Engineering Thermodynamics
- Institute of Networked Energy Systems
- Institute of Combustion Technology
- Institute of Materials Research
- Center for Lightweight-Production-Technology

ARCHITECTS OF A NEW AIR TRANSPORT SYSTEM

How unmanned aircraft systems are 'taking off', where they are useful and what remains to be done for them to enter everyday service.

Christian Eschmann talks to the DLRmagazine

They are becoming an increasingly familiar sight in the sky. Whether in the transport sector, among amateur enthusiasts or in disaster relief, Unmanned Aircraft Systems (UAS) are increasingly changing the image of the airspace. And they are now also the subject of widespread debate. The impact that these technologies will have on the future air transport system depends on achievements in research and development as well as policy decisions, but also on the level of public acceptance. In this interview with Christian Eschmann, DLR's UAS Coordinator, the DLRmagazine examines what hurdles still need to be overcome before the use of UAS becomes commonplace and when, for example, air taxis will really 'take off'.

Christian Eschmann

is DLR's Coordinator for Unmanned Aircraft Systems. He is the initial point of contact for government bodies, research institutions and industry. In this capacity, he is the representative for this area both within DLR and for external customers and partners from Germany and further afield. In addition, he serves as the DLR liaison officer at the European Union Aviation Safety Agency (EASA) and heads the 'Urban Air Mobility' theme as part of the European Research Establishments in Aeronautics (EREA) 'Future Sky' research initiative.

A few months ago, Volocopter GmbH, a company based in the German state of Baden-Württemberg, made headlines with its first public flight of an unmanned air taxi in Europe. Was this just a successful marketing operation?

UAS are becoming increasingly important in the civilian sector. A completely new industry is emerging thanks to a number of technological advances. It is very exciting to witness the speed at which innovations are occurring, particularly when compared to the long development cycles that we are used to in the mainstream aeronautics industry. The pace is more like that of IT companies. Enterprises such as Volocopter and the southern German start-up Lilium GmbH, which have already taken some initial steps towards the development of air taxis with prototypes and feasibility studies, are part of this new innovation landscape. However, public acceptance is key to the success of air taxis, so this has to be taken into account. Although the Volocopter flight certainly had a marketing component, it served as a test for opinions amongst the public.

How are UAS being used today?

They are used for acquiring images and recording videos, conducting surveying tasks, and for aerial inspections – all primarily within the commercial sector. However, national authorities and organisations dealing with security and safety, such as the police, fire brigades and rescue services, are increasingly integrating UAS into their standard procedures. Hospitals have also recognised their benefits for transporting blood and tissue. In humanitarian missions or disaster relief operations, UAS can deliver the necessary supplies and support services quickly and flexibly. DLR and the United Nations World Food Programme worked together in July 2018 to demonstrate the effectiveness of UAS in such situations under realistic operational conditions in the Dominican Republic.

What is the next step in the use of UAS?

Some of these examples are ready for the market. The obvious goal, however, is 'Urban Air Mobility', which means the introduction of an entirely new form of transport. An unmanned and, in this case, pilotless mode of passenger transport enables the introduction of new urban modes of transit, as well as better connections with outlying districts and economically underdeveloped regions.

The German Federal Government has selected five cities and regions – Aachen, Hamburg, Ingolstadt, Münster and North Hesse – for practical trials with air taxis and other forms of UAS transport. In doing so, they are taking particular account of regional differences relating to the suitability of and need for unmanned aircraft systems.

What remains to be done before air taxis can be introduced?

It goes without saying that passenger transport via air taxis is of great interest to cities and regions as a new form of mobility. However, if these are to enter service at some point in the future, new infra-

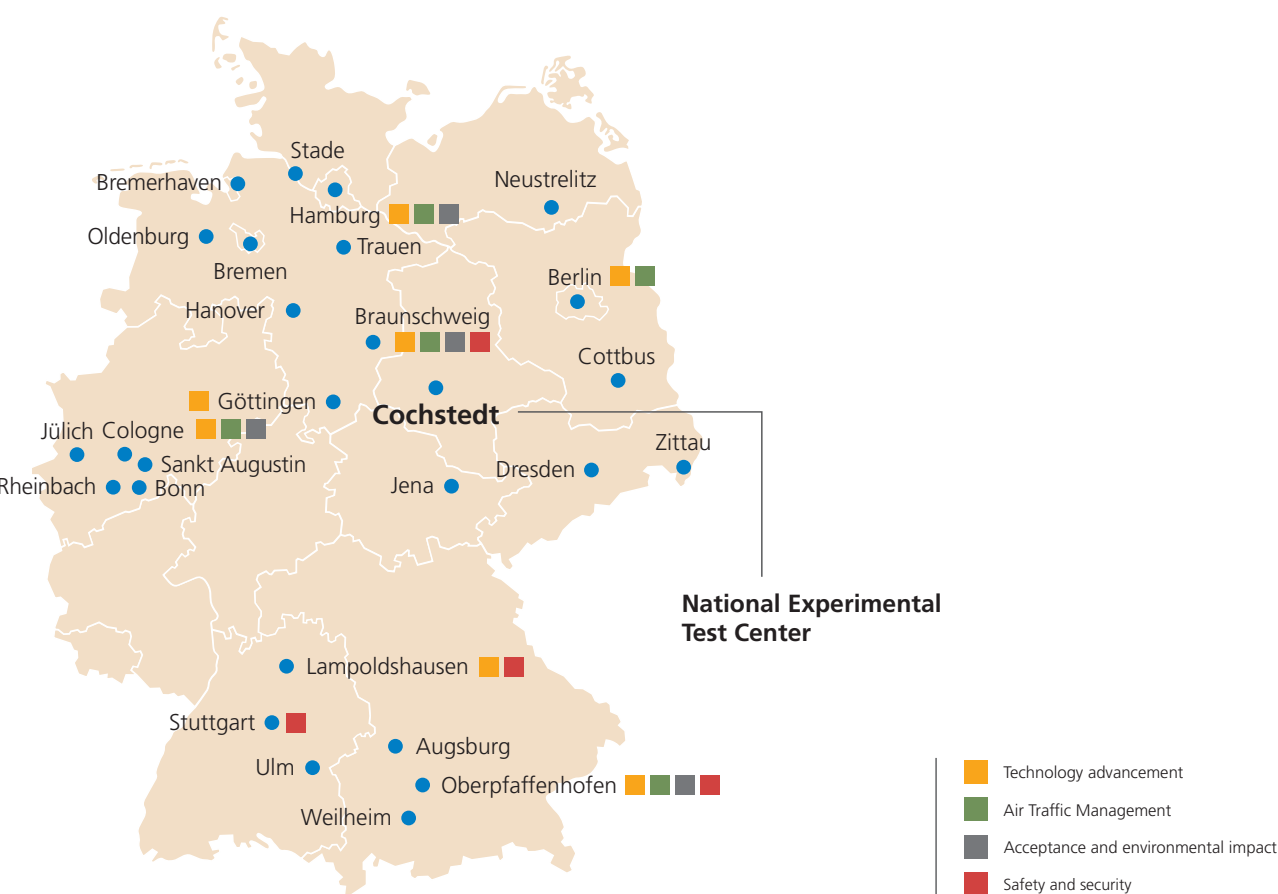
"Public acceptance is key to the success of air taxis."

structure as well as transport and service models need to be created, alongside the development of new aircraft systems. DLR is also investigating the extent to which UAS are gaining public acceptance. Fortunately, such investigations have now become an integral part of aeronautics research all over the world, when addressing future concepts and business models for UAS mobility.



With the unmanned helicopter superARTIS, DLR is researching topics such as aircraft and environment recognition, flight path planning and flight control. It has also been used for humanitarian aid and research missions over the sea.

DLR RESEARCH ON UNMANNED AICRAFT SYSTEMS



Are there any clear trends in terms of acceptance?
■ An acceptance study conducted by DLR revealed that there was clear approval in Germany for the use of civilian UAS in disaster management, rescue missions and research activities. In contrast, commercial flights directed towards advertising, recreation or parcel delivery were still regarded critically by at least half of those surveyed.

In the case of air taxis, concerns about safety, noise and light emissions were also raised. DLR's research findings will also be taken into account in future legal frameworks that will regulate the use of UAS in everyday life. DLR is working closely with the European Union Aviation Safety Agency (EASA) in this area. This body establishes the regulatory foundations that will determine when air taxis will be allowed to fly in Germany and the rest of Europe.

What is DLR's role in the research and testing of UAS?
■ Here, I should mention the bigger picture. A large number of companies and research institutions around the world are working on the topic of UAS – from miniaturised multicopters to helicopter systems weighing several tonnes. Even when it comes to air taxis,

“The concepts have to be assessed in terms of their suitability and feasibility. This is where DLR comes in.”

the concepts and design studies could hardly be more different. For some time, established aeronautical groups and young start-ups alike have been demonstrating that practically anything is possible, at least in theory. The concepts range from more conventional approaches to futuristic flight systems. However, the next step involves varying degrees of difficulty, as the concepts have to be assessed in terms of their suitability and feasibility. This is where DLR comes in, by taking on something of an architectural role.



Christian Eschmann knows that before new air taxis take off, there is much to be done – the route from design to integration into airspace.



THE DLR NATIONAL EXPERIMENTAL TEST CENTER FOR UNMANNED AIRCRAFT SYSTEMS IN COCHSTEDT

Developing unmanned aircraft systems on a commercially profitable scale and operating them alongside manned aircraft in common airspace poses unfamiliar challenges for researchers, manufacturers, users and legislators alike. In addition to the technical aspects, legal and procedural issues must also be investigated and redefined. With the National Experimental Test Center for Unmanned Aerial Systems in Cochstedt, DLR is creating a unique test facility in Europe that will combine DLR-wide, interdisciplinary skills and expertise in the field of UAS. It is intended to function as the hub of a national network that

will combine all of Germany's future test activities, while also coordinating with DLR's European partners for the purpose of testing UAS. In addition, it offers support to industrial and scientific researchers on technological issues and verification management, as well as advising policymakers and government authorities on matters relating to legislation and regulation. In terms of structural funding at a German state level, the National Experimental Test Center also functions as an incubator and enabler for start-ups and small and medium-sized enterprises.

Other areas of focus include research into highly automated and autonomous systems, along with their seamless integration into the airspace.

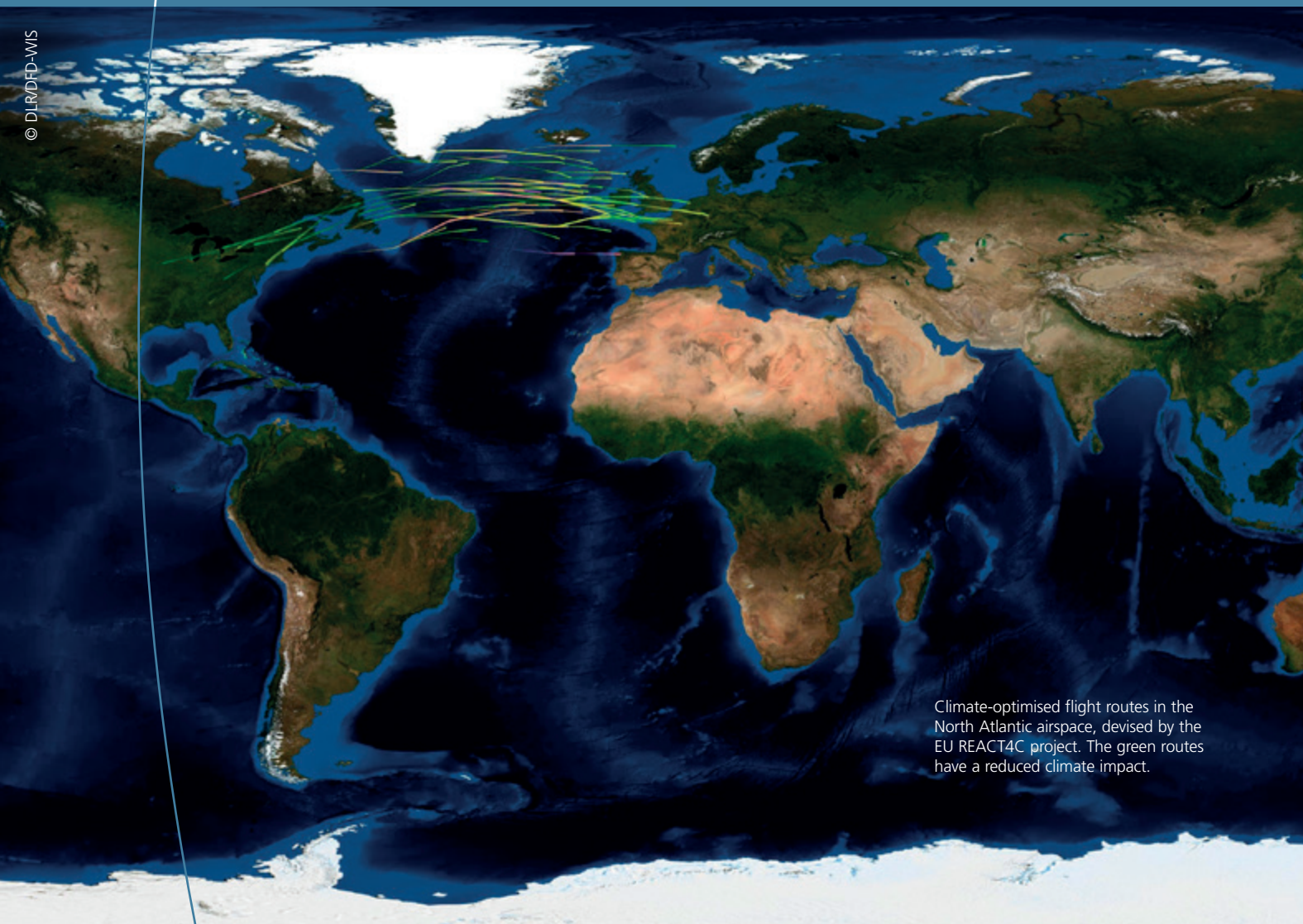
DLR has been building the National Experimental Test Center for Unmanned Aircraft Systems at the airport site in Cochstedt, Saxony-Anhalt since 2018. What is the intention here?
■ Until now, the global testing of UAS was restricted to a manageable number of tests. Due to the rapid growth of the entire industry, the number of system tests will now have to increase significantly. This will require the development of new testing procedures. The National Experimental Test Center in Cochstedt offers a unique facility for that very purpose, providing both research institutions and industry

with a space specifically designed for the safe and extensive study of UAS technology in a unique environment. This will take account of the fact that such complex subjects have to be treated as a whole, rather than separately. In the past, vehicle design has been addressed independently from flight guidance, and also separately from the legal regulatory framework. Neither researchers nor lawmakers can investigate and resolve all of the issues alone. As such, large-scale, whole-system research is becoming increasingly important as a link between technical and regulatory matters. DLR thus sees itself as playing a dual role as a service provider and a pioneer for new and beneficial technology.

FOLLOWING THE YELLOW BRICK ROAD

In this interview, a DLR atmospheric researcher explains possible routes towards more climate-friendly air transport.

By Bernadette Jung



Climate-optimised flight routes in the North Atlantic airspace, devised by the EU REACT4C project. The green routes have a reduced climate impact.

Global change is transforming aviation. Atmosphere physicist Sigrun Matthes talks to DLR editor Bernadette Jung about how atmospheric research can contribute to making air transport more environmentally friendly over the next 30 years and what challenges still need to be overcome.

Sigrun Matthes

works at the DLR Institute of Atmospheric Physics in Oberpfaffenhofen. Her particular research interest is numerical modelling of the climate impact of air transport using the global Earth system model EMAC. Matthes is especially interested in the quantification of the climate effects of anthropogenic emissions. She is currently leading interdisciplinary research work as part of the Horizon 2020 ACACIA and ClimOP projects, which focus on the climate impact of air transport. Matthes is also Chair of the Environmentally Compatible Air Transport System (ECATS) research association and network of excellence, which is developing pathways towards sustainable air transport. As part of ECATS, she chairs the 'Aviation Climate Impact and Mitigation Options' working group.



© DLR

As air traffic increases, so do emissions. How are you addressing this in your research?

■ Air transport still relies on fossil fuels and its emissions are contributing to climate change. The processes in the atmosphere that cause this climate impact are highly complex and sometimes very difficult to measure. In order to enable aircraft to fly in the most climate-optimised way possible, research has to provide information about the impact of specific emissions and their interaction with the atmosphere. Those working in this field rely on a highly interdisciplinary approach. I am currently working on various national and European research projects. DLR has been awarded the contract for the Horizon 2020 research project ACACIA (Advancing the Science for Aviation and Climate), which is investigating the impact of air traffic emissions on the climate. We are paying particular attention to what are referred to as non-carbon-dioxide effects. These are not yet sufficiently understood, so they have not yet been taken into account for emissions trading schemes. The climate impact of non-carbon-dioxide effects is more complex and possibly also stronger than that of carbon dioxide itself. As atmospheric researchers, we want to investigate this area and reduce the uncertainties in our estimates.

What is known about these non-carbon-dioxide effects?

■ Aircraft emit different trace substances, each of which has an impact on the atmosphere and thus on the radiation balance and climate. For example, the nitrogen oxides that are emitted interfere with atmospheric chemistry. This produces ozone, which causes warming of the atmosphere. However, the processes triggered by the nitrogen oxides also lead to a reduction in atmospheric methane and this has a cooling effect. Other impacts include long-lasting condensation trails and contrail cirrus clouds – the only non-carbon-dioxide effects of air transport that are visible in the sky. These can spread in the atmosphere over several hours and, depending on the situation, can have a cooling or a warming radiative effect. In total – over day and night and across the globe – they have a warming effect.

One effect that may have been underestimated until now is the 'indirect aerosol effect', which has been the subject of little research. This effect is caused by the emission of aerosols during the combustion of kerosene. Aerosols are tiny particles floating in the air – soot and sulphate droplets, in particular. These continue to influence natural cloud formation long after they have been emitted and far from the

flightpaths. They can change the extent of cloud cover and the properties of the clouds. It is thought possible that such aircraft aerosols have a climate impact that is at least equal to that of carbon dioxide. At present, however, the impact of these non-carbon-dioxide effects

"The climate impact of non-carbon-dioxide effects is more complex and possibly also stronger than that of carbon dioxide itself."

has not been proven by measurements and observations, and existing estimates of the indirect aerosol effect are still very uncertain. We want to change this.

So, you are tracking them down. What comes next?

■ As part of ACACIA, we are developing a measurement strategy to identify the mechanisms and processes of the indirect aerosol effect and estimate the severity of its impact. In order to do this, we have to determine whether and in what way existing measurement data can be used for this purpose. This includes data from long-term measurements on scheduled aircraft, from observations made during airborne measurement campaigns, including those conducted by our DLR research aircraft, and data acquired by satellite missions. The ACACIA team will also investigate where data are still missing or where they are imprecise. We would like to close these gaps and further refine the forecasts produced by climate models.

How can these findings contribute towards more climate-friendly air transport?

■ We need to obtain a more accurate understanding of how the atmosphere reacts to the different emissions produced by air traffic. Only then will we be able to develop sustainable strategies for air transport and optimal measures for protecting the climate. As part of the ACACIA project, we will be looking at the interactions between the various effects. This will allow us to ensure that a measure aimed at mitigating the climate impact of one type of emission will not inadvertently exacerbate that of another. The DLR Institute of Atmospheric Physics is also involved in the European ClimOP research project, which began at the start of this year. In this case, we are looking for technological and operational measures that are suitable for reducing



How condensation trails form and develop and how nitrogen oxide emissions affect atmospheric chemistry is being investigated with, among others, DLR's High Altitude and Long Range (HALO) research aircraft.

the climate impact of air transport. To this end, we are systematically examining previously proposed measures and new ideas for their climate benefits and feasibility, as well as determining the steps necessary to introduce those that appear promising.

What needs to be considered when developing such measures?

■ Let us say, for example, that we want to avoid the formation of condensation trails because, on average, these lead to warming of the atmosphere. A high level of humidity promotes cloud formation and thus the creation of contrails. However, it would not make sense to route planes only through drier and warmer regions, because this would result in long detours and additional fuel consumption. Care must also be taken with measures to reduce fuel consumption. Increasing combustion temperatures in the engine, for example, increase the efficiency of the engine, so that it uses less fuel. So far so good. At the same time, however, more nitrogen oxides are produced, correspondingly larger quantities of which are therefore emitted into the atmosphere. This would not result in the desired effect. In order to devise the best possible measures, we have to 'play through' scenarios in the atmosphere in their entirety. As such, our knowledge of atmospheric processes needs to be as detailed as possible.

Your research topic transgresses national borders – how important is cooperation?

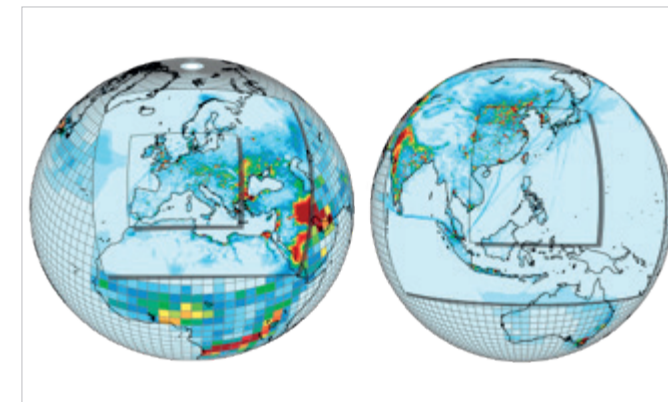
■ The Environmentally Compatible Air Transport System (ECATS) was formed around DLR 10 years ago, with the aim of developing pathways towards sustainable air transport. One of its working groups is investigating the effect of air transport on the climate and what mitigation strategies are available. Thanks to the complementary research activities being undertaken at the Institute and as part of collaborative efforts, we are generating greater synergy effects at DLR. While in the ACACIA project we are expanding our understanding of complex atmospheric processes, we can also use findings from projects such as ClimOP to develop recommendations for action. In the interests of climate protection and sustainable air transport, we will thus continue to pursue the evidence in and questions about the atmosphere through joint efforts.

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

IN BRIEF

MODELLING THE EFFECTS OF AIR TRAFFIC

The interactions in the Earth system are extremely complex. Therefore, it is difficult to calculate the impact of air transport on the atmosphere or to establish how aviation can be made more climate friendly. Simulation models can help to describe and understand these processes. With the help of the EMAC climate chemistry model, scientists at the DLR Institute of Atmospheric Physics are studying the effects of aircraft emissions and investigating the way in which the climate reacts to anthropogenic influences. EMAC is also proving helpful in optimising flight routes interactively, under both current and future climate conditions. This is now possible on a regional and global scale. At present, the DLR team is working on researching and modelling the effects of air-traffic induced aerosol emissions on clouds. The EMAC model system, which employs a modular design, has been made available as part of an international research consortium and is supported by leading supercomputing centres in Germany.



The EMAC climate model allows the representation of processes in the atmosphere, their interactions with oceans and land surfaces, and anthropogenic influences.

GREEN PATHWAYS

The Greener Air Traffic Operations (GreAT) project, which is being coordinated by the DLR Institute of Flight Guidance and was launched in January 2020, is aimed at establishing new strategies for environmentally friendly flight routes. An international team of scientists is working on new methods for more sustainable air traffic control. To this end, the team of researchers is testing out new algorithms and concepts that are intended to improve flight guidance in terms of cross-country flight, arrival at and departure

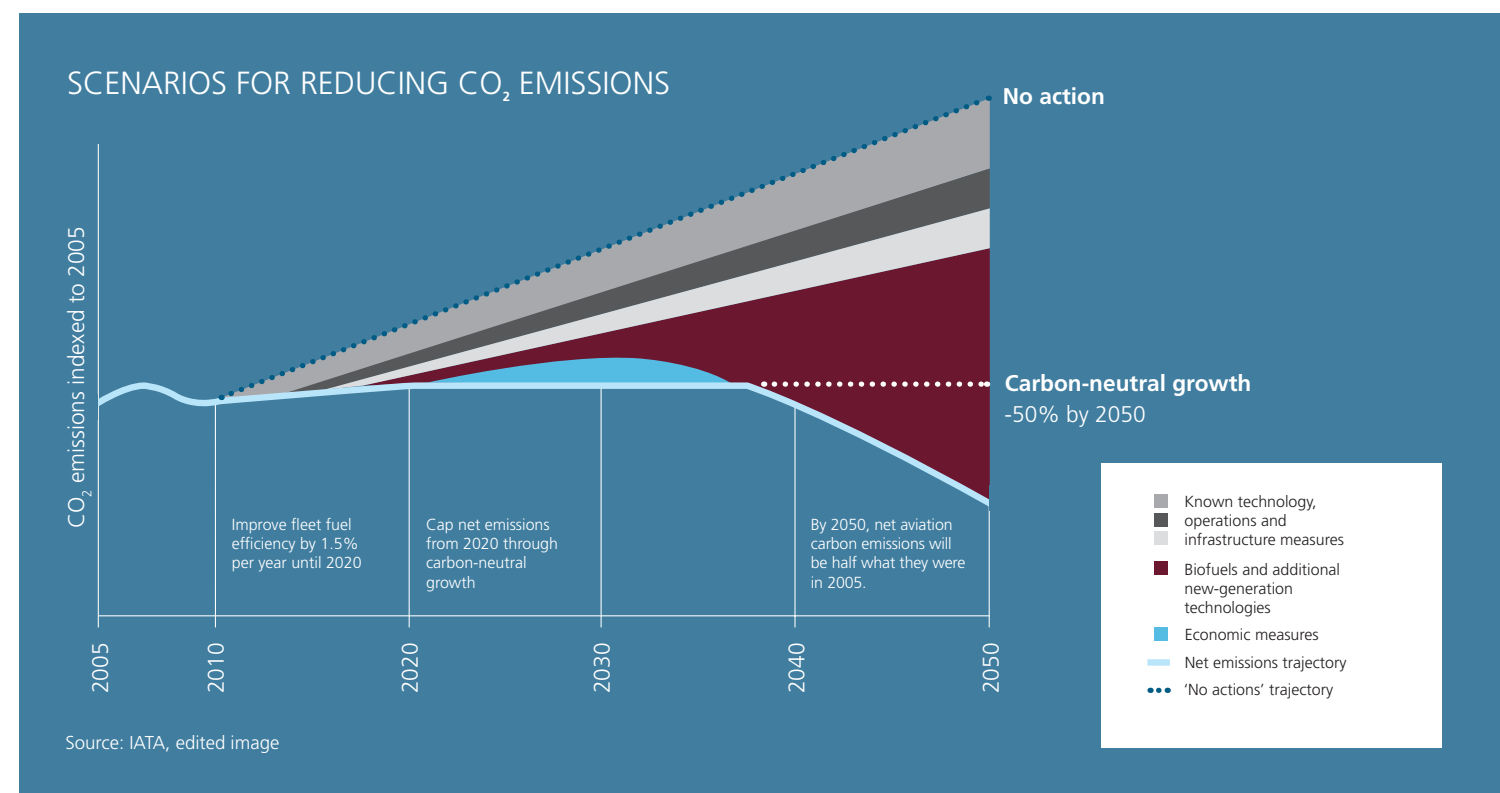
from airports, and ground movements. This would allow busy airspace and airports to continue to be used efficiently. The researchers can also use fast-time and real-time simulations to determine the limits of the new concepts when it comes to saving on fuel and cutting emissions. European and Chinese partners are working together on GreAT, among them air traffic control organisations, aviation research institutes, universities and airspace users. The project will run for 3.5 years.

A COMMON EUROPEAN AIRSPACE

Europe's air transport system now carries more than 1.6 billion passengers on over 10 million flights every year, and these numbers are still rising. The aim of the SESAR2020 programme is to develop new systems for standardising European airspace and bring them to market readiness, in order to meet the needs of growing air traffic. DLR is involved in several SESAR projects. Among other things, it has developed an air traffic management solution that can be used to inform pilots of predicted contrails. The researchers are currently developing a concept that allows flight routes to be analysed in terms of their climate impact and optimised accordingly. For this, DLR is working with industry partners to provide a meteorological service that quantifies the effect of air transport emissions on the climate.



As part of SESAR, scientists at the remote tower facility at DLR in Braunschweig are conducting research into remote airport monitoring by controllers.





MANNED MEETS UNMANNED

How will autonomous cargo deliveries be made in future? Experts from DLR's Unmanned Aircraft department are investigating possible answers to this question – from the initial concept through to trial operations. The spectrum of applications ranges from time-critical delivery of components for manufacturing to the transport of cargo for humanitarian aid. On the left in the image is DLR's Flying Helicopter Simulator. Pilots use this to test new flight control systems. The small, uncrewed helicopter to the right – Autonomous Rotorcraft Test bed for Intelligent Systems (ARTIS) – is used for testing new technology for unmanned flight, for example collision avoidance systems or laser-based perception of the surrounding environment.

More images like this one can be downloaded at a printable resolution at [DLR.de/Poster](https://www.dlr.de/Poster)

The materials researchers' idea is to extract soot for use in lithium-ion batteries from tyres such as those used in mining vehicles

USED TYRES STILL HAVE SOME LIFE IN THEM

Researchers harness a new source of material for energy storage

By Marina Schwan and Somi Doja

It is estimated that five million tonnes of waste tyres are generated annually in North America and Europe alone. They are dumped in landfill sites or recycled for other purposes. Fires or chemical leaching into the groundwater, which can occur on landfill sites, pose a significant risk to humans and the environment. But recycling waste tyres also comes with major ecological and economic challenges.

One of the main components of tyres is soot, making up just under one third of their composition. This also makes waste tyres particularly interesting for researchers at DLR and the University of British Columbia (UBC). They are investigating how soot or carbon black can be extracted from them. For instance, recycled carbon black can be used as an additive for plastics, paint pigments and coatings. The researchers are particularly interested in the production of batteries. Against the backdrop of future e-vehicles and e-aircraft, there is a growing need for more powerful and cost-effective energy storage technologies. In conventional lithium-ion batteries, the electrode materials account for a large part of the costs. By looking at the use of recycled carbon from old tyres, the researchers are addressing two key problems: the costs and the environmental impact.

Batteries instead of landfills

The joint project between the DLR Institute of Materials Research and a team from UBC aims to convert approximately 80 percent of the soot from waste tyres into carbon black and use it for anode material of lithium-ion batteries. The tyres used by the researchers come from the mining industry. They can measure up to 2.5 metres in diameter, allowing the scientists to extract a great deal of soot from them. The process can also be applied to other tyres, but must be individually adapted for each type of tyre, as their chemical composition may differ.

The soot extraction process is currently being developed at UBC. DLR materials researchers are combining the carbon from the waste tyres with aerogels to produce the battery anodes. There are significant benefits to this. Aerogels are highly porous and light materials. Their density can be 50 to 80 percent lower than that of carbon black, depending on the chemical composition of the aerogel used. This makes the batteries much lighter than models that use pure carbon anodes. The idea of using recycled materials also makes them sustainable.

New 'recipes' for the electrode mix

The team has achieved some initial successes: they have developed light lithium-ion half-cells with a high discharge capacity and constant power using recycled carbon and aerogels. The scientists are currently developing and testing new formulations for combining carbon black and aerogels. In addition, the team is working on transferring battery



Somi Doja from the University of British Columbia (left) and Marina Schwan from DLR during joint experiments on the analysing instrument at the Institute of Materials Research at the DLR site in Cologne

production from the laboratory to an industrial scale. To do this, they have to be able to produce several kilograms of electrode material to a uniform level of quality.

Marina Schwan works in the Aerogels and Aerogel Composite Materials Department of the Institute of Materials Research in Cologne. She is responsible for the development of innovative aerogels for battery research.

Somi Doja is a PhD student at the UBC in Kelowna. For her doctoral thesis, she is developing methods for extracting carbon black from waste tyres and its use for lithium-ion batteries.

AN ALL-PURPOSE TEST FIELD

DLR's research facility in Lower Saxony facilitates analyses of automated and networked driving

By Eva-Maria Dobriloff

Less congestion, fewer accidents and lower emissions – the expectations for automated vehicles are high. But what does a car need in order to be able to drive independently? What kind of situations will it have to cope with? DLR's Test Field in Lower Saxony is allowing researchers to address these questions and helping to get the necessary technologies from the computer onto the road. Its most visible features are the 71 masts that line the roadside of the A39 motorway near Braunschweig. These are equipped with state-of-the-art communications technology. With their assistance, the first automated vehicles could soon make it onto the road here. Most of the 280-kilometre-long test field, however, goes somewhat unnoticed.

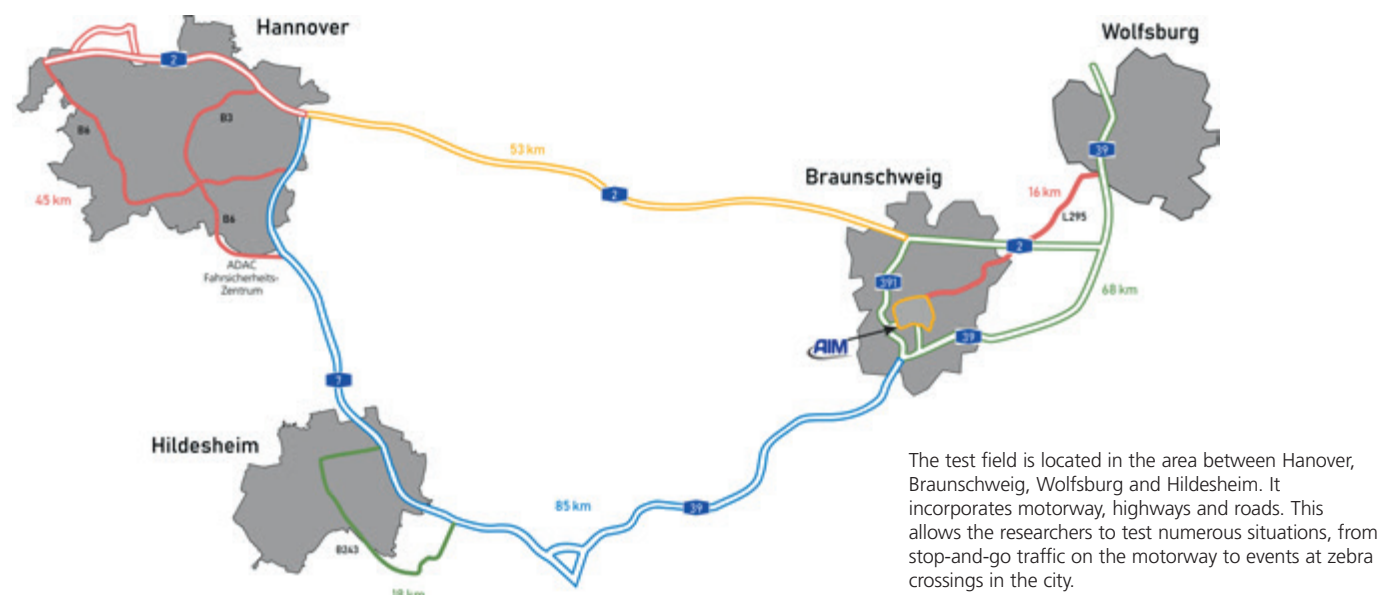
The Test Field in Lower Saxony was officially inaugurated on 8 January 2020. Standing on a bridge directly above the A39 motorway, DLR Executive Board Member for Energy and Transport, Karsten Lemmer, presented the complex technical infrastructure of the test field to Lower Saxony ministers Bernd Althusmann and Björn Thümler. It is operated by the DLR Institute of Transportation Systems and can be seen particularly well from here, between Braunschweig and the Wolfsburg-Königsutter intersection. Seventy-one masts, each eight metres tall, line a 7.5-kilometre section of road. Their sensor heads are equipped with tracking and communications technology that allows all relevant traffic data to be recorded around the clock while still adhering to strict data protection regulations. This gives researchers a detailed insight into the behaviour of vehicles and other traffic-related objects. In particular, it enables scientists to generate a continuous movement path for vehicles from when they enter the detection area until they leave it. This provides information on the requirements of future assistance and automated systems, and the normative and non-normative behaviours they will have to address.

Networked vehicles can navigate traffic more safely and bring both drivers and passengers to their destination in a more relaxed fashion. Communications technology makes it possible for vehicles to be warned of roadworks or black ice in advance, and to coordinate efficient traffic merging manoeuvres. Developers can test these technologies at the Test Field in Lower Saxony. Vehicle-to-everything (V2X) communication units installed on the masts along the A39 motorway allow cars to exchange standardised messages informing each other of overtaking manoeuvres or warning of dangerous situations. Despite very few vehicles currently being equipped with the necessary technology, the test field's combined tracking and communications technology also enables scientists to simulate a scenario in which all road users travelling along the A39 motorway communicate with each other. This makes it possible to predict and further investigate future networked mobility scenarios.

More than just a motorway

The conspicuous camera and communications technology on the A39 motorway are restricted to a particular section of the test field. The entire course extends over 280 kilometres and encompasses stretches of motorway, highways and roads. It also integrates the routes of the Application Platform for Intelligent Mobility (AIM), operated by DLR since 2014, in the Braunschweig urban area. Mobile platforms equipped with the same tracking and communications technology as the fixed masts can also be deployed in locations with no permanent sensors, allowing even test sites, car parks and industrial estates to be used for research. Such areas, and the transitions between different types of roads, are interesting for the development of automated driving functions and cooperative function networks.

Traffic on the A39 motorway is recorded around the clock. The high-resolution stereo camera systems anonymously monitor passing vehicles travelling in both directions from a height of eight metres.



The test field is located in the area between Hanover, Braunschweig, Wolfsburg and Hildesheim. It incorporates motorway, highways and roads. This allows the researchers to test numerous situations, from stop-and-go traffic on the motorway to events at zebra crossings in the city.



Look out: traffic jam! The communications technology warns drivers about traffic jams and accidents in real time.



The tracking and communications technology at the edge of the test field records the speed, position and direction of travel of passing cars and lorries and transmits this information to other vehicles. This simulates the communication between vehicles.

Additional key components of the test field include high-precision digital maps and simulations. Automated and networked driving systems must undergo intensive testing before they can be brought to market. But carrying out all of these tests on real roads would prove far too complex and costly. Virtual test facilities make it possible to test the driving functions much more efficiently. This combination of real and virtual facility makes the Test Field in Lower Saxony unique. The digital maps are crucial for an array of different applications, including operating automated vehicles in public spaces, deriving test scenarios and for comparability purposes. In addition, the accuracy of models and developments in simulation-based environments and test sites can be checked. For this purpose, routes are entered into databases alongside vehicle data and contain topographical and topological information about the respective roads, traffic infrastructure, buildings and even vegetation.

More than just DLR

A successful research and development platform can be used for a wide range of different purposes and be continuously further developed. The test field should encourage scientific discussion and, together with its users, help to shape the future of automated and networked mobility. With its diverse infrastructure and technology, the platform will prove extremely useful for companies and scientific institutions working in the field of mobility research.

DLR also relied on the expertise of its partners and drew up a close network already during the planning phase. The German Automobile Club of Lower Saxony/Saxony-Anhalt, the company Continental, the engineering firm IAV and the companies NordSys, Oecon, Siemens, Volkswagen and Wolfsburg AG were all important partners and consultants in the development of the test field. This large-scale project received funding from the Ministry for Economic Affairs, Labour, Transport and Digitalisation of Lower Saxony and the Ministry for Science and Culture of Lower Saxony. The Federal State of Lower Saxony also financed the project via the European Regional Development Fund (ERDF). The network of partners will be expanded and, following extensive test measurements, initial projects in cooperation with these companies will begin.

WHY? WHO IS IT FOR? WHAT NOW?

Three questions for Katharina Seifert, Director of the Institute of Transportation Systems, and Frank Köster, Head of Business Development at the Institute of Transportation Systems and responsible for test field activities.

Why are test fields needed for the development of automated vehicles?

Seifert: An automated vehicle must be able to cope with a large number of road users and different situations. These situations must be extensively tested in order to develop such vehicles safely. In addition, the sensor technology developed for these vehicles must be tested in a clearly defined area to ensure that it correctly perceives reality.

Köster: This requires the combination of simulation-based test environments with mixed-reality approaches and real test sites, as well as testing in public spaces. The Test Field in Lower Saxony offers all this.

For whom are the services offered by the test field particularly interesting?

Köster: Some examples are companies and scientific institutions that conduct research in the field of automated and networked mobility, that develop sensors, driving systems and innovative technological components for vehicles and the transport infrastructure. But they are also of interest to policymakers and organisations that are looking to learn more about automated and networked driving. We want to create a strong network with these stakeholders.

How do you see future transport?

Seifert: In my work, I am driven by the idea of shaping a future in which safe driving is a given and driving comfort goes well beyond restful seats. Traffic will flow better and generate less emissions.

Köster: We now have the opportunity to design a safer, more efficient and more comfortable mobility. To achieve this, we want to fully exploit the potential of networked and automated vehicle fleets.

Eva-Maria Dobriloff is responsible for public relations at the Institute of Transportation Systems.

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Katharina Seifert and Frank Köster



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TEST FIELD IN LOWER SAXONY – TECHNICAL INFRASTRUCTURE

The Test Field is accessible to companies and scientific institutions, either individually or in associations.



Monitoring technology: High-resolution stereo camera systems installed over 7.5 kilometres of the A39 motorway offer high-precision tracking of vehicles and other objects within the traffic area.



Communications technology: Road-side units (RSUs) on the A39 enable V2X communication between vehicles and infrastructure, allowing messages to be received on the stretch of motorway.



High-precision maps: Topographical and topological information about the road, traffic signs and infrastructure provide the foundations for creating realistic virtual traffic environments and can also be used as highly accurate geo-reference landmarks.



Scenarios & models: These enable simulation-based analyses of vehicles or vehicle components within a virtual environment. The virtual test field section is approximately 84 kilometres long.



Interfaces: Current and historic data from a variety of sources (including the traffic management centre Lower Saxony in Hanover) are imported via standardised data interfaces. Among other things, this makes up-to-date signalling and information from traffic infrastructure accessible to cars.



Mobile platforms: These can be used on campaign-specific sections of the test field that are not equipped with stationary infrastructure and in special areas, such as the testing site, car parks and industrial estates.



Land registry information: The registry contains information that is relevant for the test field, such as road and guardrail condition, as well as weather data that can be used to explain unusual vehicle behaviour.



Background systems: An information and communications technology platform for data management and central information processing and supply serves as an important system component for linking different test field services together.



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BEST OF BOTH WORLDS

Shaping new ideas together
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 second in the series, addresses sustainable business.

A sustainable economic system requires innovative ideas that transgress national borders. This precise approach led to the creation of the Eurostars subsidy programme, which provides funding and support to small and medium-sized enterprises (SMEs) in 36 countries. The projects range from sustainable leather tanning via the by-products of olive tree cultivation, to laser-based measuring systems that determine the maintenance requirements of buildings using drone fly-bys, and imaging processes that visualise a heartbeat in real time during an MRI. Over the last 13 years, the programme has awarded funding to 1880 projects. The DLR Project Management Agency has been responsible for the German programme from the very outset.

Stefanie Bartels-Schmies and Joachim Burbiel

Stefanie Bartels-Schmies has been a research assistant for Eurostars since 2010 and the national Eurostars Project Coordinator since October 2018. Joachim Burbiel heads the International Market-Related Research and Innovation Department and is standing in as the group leader for International SME Funding. He has also served as Germany’s EUREKA Project Coordinator for almost four years. Both work on European and international cooperation at the DLR Project Management Agency.



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What makes an all-encompassing programme like Eurostars stand out?

Bartels-Schmies: The idea behind Eurostars is to combine research and development and international business by bringing together the best of both worlds. In other words, this programme is instrumental in enabling small and medium-sized enterprises to develop innovative ready-to-market solutions together with international research partners.

Burbiel: EU laws on state aid limit funding to the prototype stage. One of the requirements of the programme is that the outcomes of the Eurostars process should be on the market within two years following completion of the project. Our statistics prove that this is possible. On average, it takes less than five years to get from the application submission to the finished product. That is not long at all if you consider the complex nature of the ideas that we support.

Who is the funding initiative aimed at, and what role does the Project Management Agency play?

Bartels-Schmies: It is aimed primarily at small and medium-sized enterprises that invest at least 10 percent of their turnover in R&D activities or dedicate at least 10 percent of its full-time equivalents to those activities. However, the financial support is not available to individual companies, but is awarded exclusively to research consortia. In addition to the leading company, these must include at least one project partner from another Eurostars country. These partners can be research institutes or large companies. Eurostars is rooted in the vision of promoting sustainable business.

Burbiel: The task of project managing such a complex structure is far from easy. In Germany, the Eurostars funding is provided by the Federal Ministry of Education and Research (BMBF), on whose behalf we are responsible for programme management. One of our core

tasks is to support the German institutions involved in the funded projects throughout the entire period. We also draft the funding announcements in collaboration with all 36 funding agencies in the participating countries. Furthermore, we provide the applicants with advice, evaluate all the applications with German involvement, regulate the flow of funds and monitor the progress of individual projects. Advising the BMBF is also very important for us. When the second funding phase of the programme concludes at the end of 2020, it will be time for Eurostars-3 – a third phase of funding – which is also politically desired.

You have been involved in Eurostars for many years. What makes it special?

Burbiel: In my opinion, the really exciting thing about Eurostars is the incredible variety of topics. Also interesting are the clear economic trends seen in the ideas submitted. For example, in recent years we have observed a shift towards biotechnology and information and communications technology.

Bartels-Schmies: Bringing people from different cultures together is always a good idea. It encourages out-of-the-box thinking, expands people’s horizons and allows them to learn from one another. This leads to innovation.

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

The future of mobility lies in autonomous driving. “In 20 years, we will no longer use cars for our daily journeys,” says Peter Wüstnienhaus, Department Head at the DLR Project Management Agency. More in the next issue of the DLRmagazine.

EUROSTARS PROJECTS

GreenSkin

The joint German-Austrian GreenSkin project focuses on planted facades. ‘Greened’ facades have a cooling effect on the surrounding microclimate, offer a habitat for insects and other animals, and help to regulate the temperature inside the building, while absorbing pollutants. The problem is that they are expensive to install retroactively. Against this backdrop, the GreenSkin Eurostars project is developing facade modules that comprise facade-bound greenery and the necessary infrastructure, such as irrigation.

TaniXing

Leather is a ubiquitous product. The manufacture of leather footwear is increasingly becoming subject to scrutiny due to the high level of toxic chromium and other allergens used. In the very first Eurostars project, which kicked off the funding programme, German companies worked with Spanish partners to develop the patented wet-green® tanning process. This completely avoids tanning chemicals that are damaging to the environment and human health, instead using tanning agents based on a by-product of olive oil production. Thanks to Eurostars funding, ‘olive leather’ was ready for the market after only five years. Today, BMW, Hugo Boss and Porsche are among its customers.

HIGH-TECH TRAVELLERS FLY TO THE MOON

The MARE experiment will provide insights into radiation exposure in deep space

By Manuela Braun

The only people to have left Earth's protective magnetic field are the 24 Apollo astronauts who flew to the Moon, leaving the Van Allen Belts behind. Earth's outermost radiation belt reaches up to approximately 58,000 kilometres above the surface, after which our planet's magnetic field falls to zero. From that point onwards, there is nothing to protect the human body against cosmic radiation and the charged particles continuously streaming from the Sun. Since the Apollo programme, which ended in 1975, only unmanned spacecraft have ventured into these deadly regions. NASA's Artemis mission is set to change all that; the US space agency is planning to send the first woman and the next man to the Moon on board the Orion spacecraft. To this end, the Matroshka AstroRad Radiation Experiment (MARE) will investigate the radiation to which this crew will be exposed. DLR medical experts are preparing MARE for its test flight – with Helga and Zohar, the first 'female astronauts' to travel to the Moon.

Helga is 95 centimetres tall, weighs 36 kilograms and is made up of 38 slices. Her organs and bones are made of plastic material. Helga is clearly not your ordinary astronaut. But together with her sister, Zohar, she will make a decisive contribution to space exploration. The two female phantoms will sit in the passenger seats of the Orion capsule and be subjected to the exact kind of radiation that a human body is exposed to during a flight to the Moon and back.

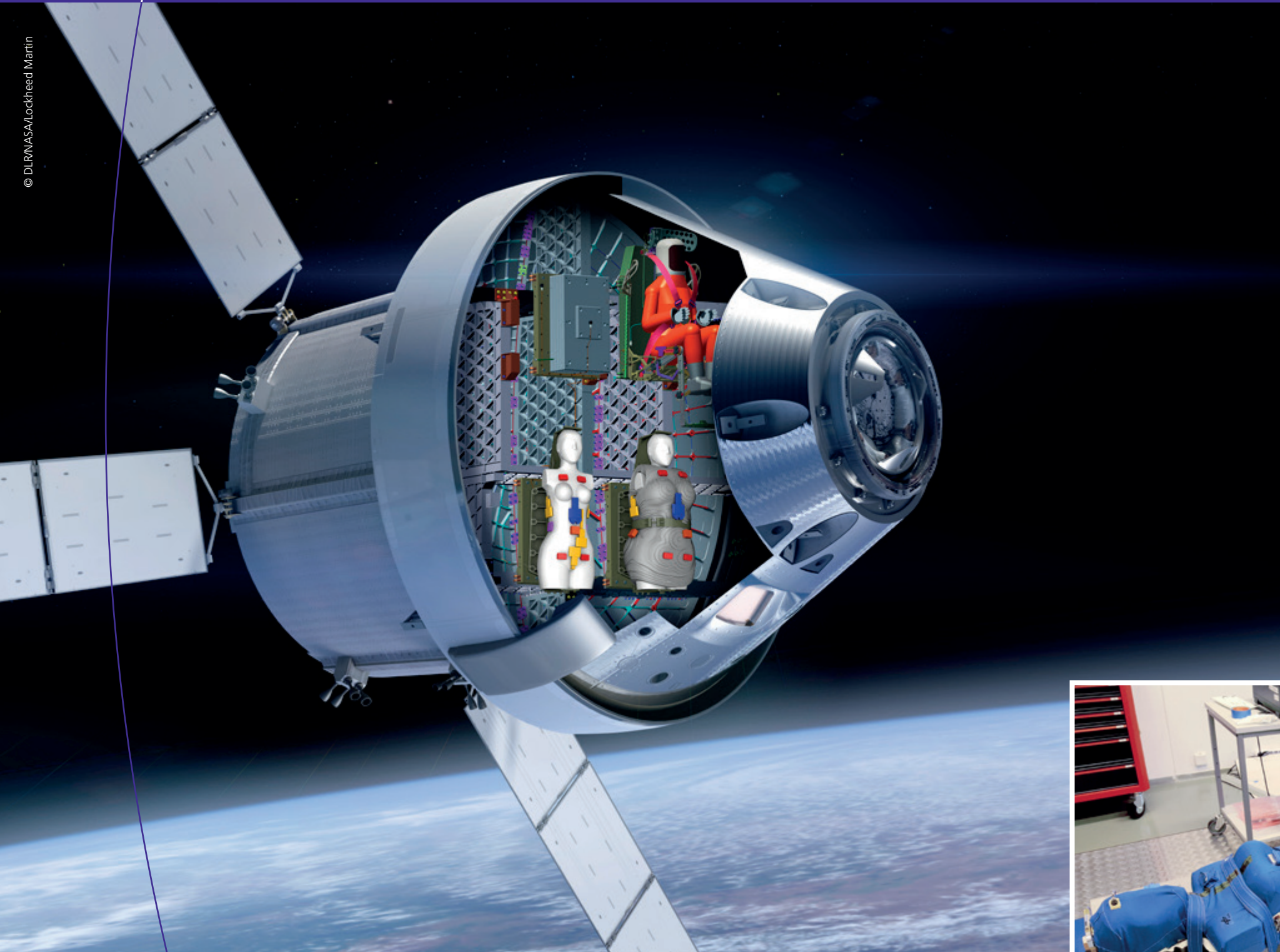
"Several factors pose a risk to humans in space," says Thomas Berger, a radiation biologist at the DLR Institute of Aerospace Medicine. "Microgravity affects bones and muscles, among other things, while the isolation and sheer distance from Earth have a psychological impact. And the exposure to radiation can cause both short-term and long-term damage." For instance, cosmic radiation increases the risk of cancer and impaired eyesight. Solar particle events can lead to radiation sickness, with symptoms such as nausea and fatigue.

On average, people on Earth are exposed to radiation of less than three millisieverts per year – a value that includes medical examinations such as X-rays or computed tomography scans. A team of scientists including DLR experts measured the radiation exposure during a flight to Mars using the Radiation Assessment Detector (RAD) on board the Mars rover Curiosity. In this case, the dose was around two to three millisieverts per day! Conducting research into radiation exposure and developing and implementing possible protective countermeasures is vital to ensure that astronauts can embark on future missions to the Moon and Mars without damaging their health.

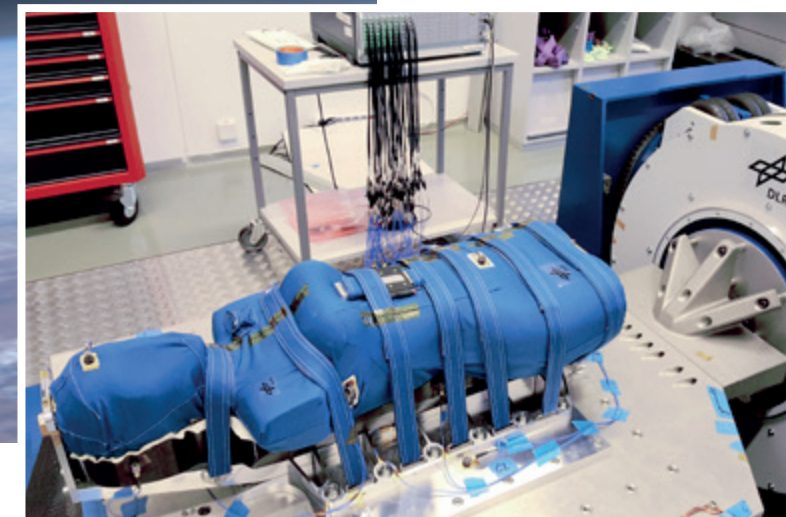
"MARE will enable us to precisely record the radiation exposure of the crew for the first time on such a mission," explains Berger.

Back to the Moon

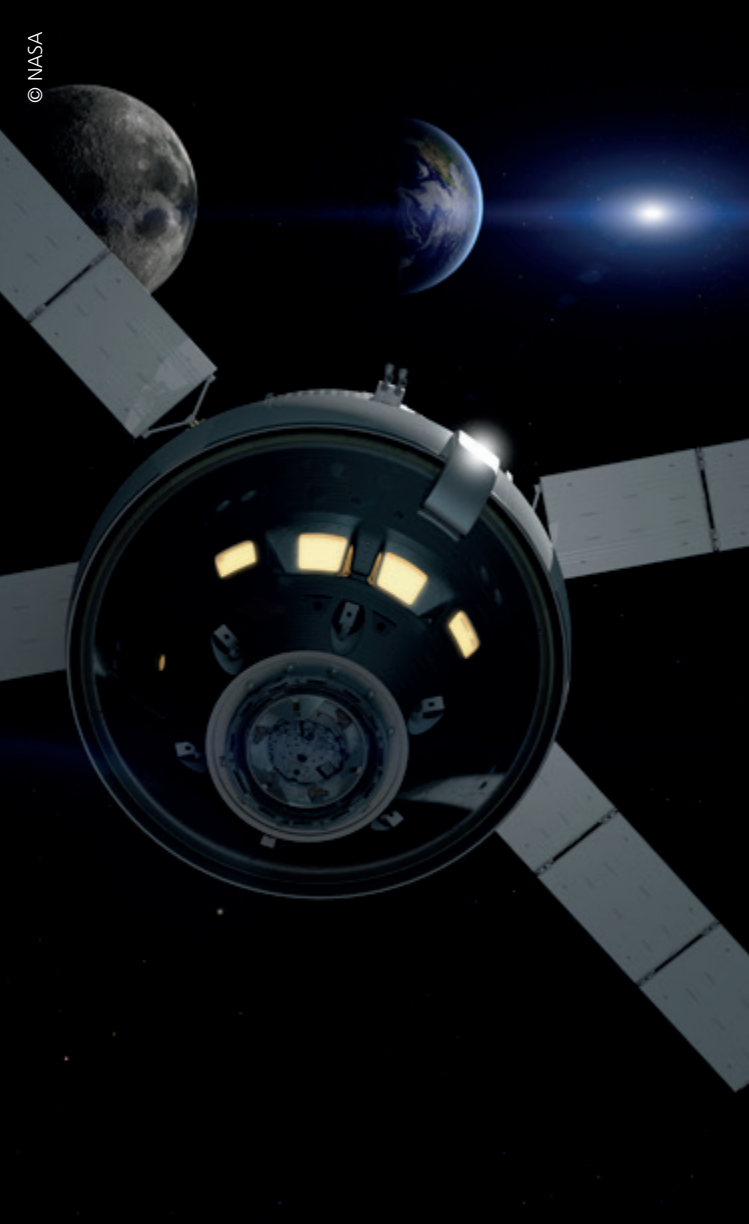
By 'such a mission', Berger is referring to NASA's plan to send people to Earth's satellite again, 50 years after the first Moon landing. While the spaceflights back in the 1960s were named after the Greek god Apollo, the next flights will be made under the name of Apollo's twin sister, Artemis. The name says it all. During the Apollo missions, only men travelled through space, whereas at least one woman will be on board the Artemis mission. Helga and Zohar will fly to the Moon as her representatives in the first flight of the Orion spacecraft from Kennedy Space Center. Zohar, which has been provided by the Israeli Space Agency, will wear a radiation protection vest developed by the Israeli company StemRad. The German Helga will embark on the journey to the Moon



Two female phantoms will occupy the passenger seats during Orion's first flight to the Moon



The sensor-equipped phantom Helga ready for the vibration test at the DLR site in Bremen. Helga will measure the radiation exposure during the flight to the Moon.



The Artemis I mission with Helga and Zohar to the Moon and back to Earth will last a maximum of 42 days

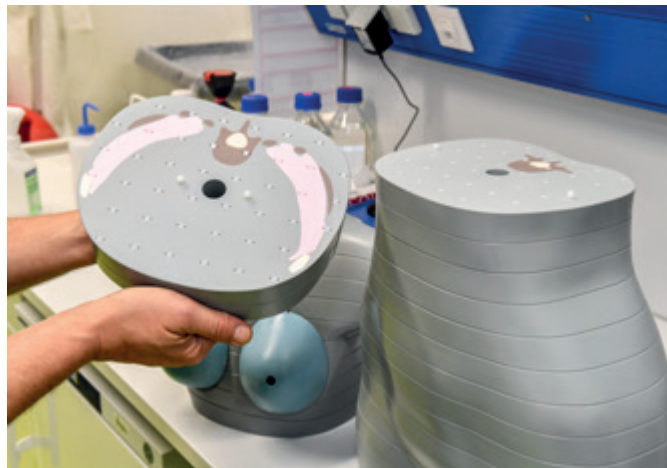
without any protection. Both will be equipped with passive and active radiation detectors, which will allow the scientists to assess not only the radiation, but also the effectiveness of the protective vest.

At present, both phantoms are still at the DLR Radiation Biology Laboratory in Cologne, where they are being prepared for their journey. Slightly hidden away in a little-visited corner of the lab is the Matroshka phantom, their male colleague, not currently in use. This phantom has been on board the International Space Station (ISS) since 2004 and was exposed to radiation not only in various research laboratories inside the ISS but also on the exterior. Its final mission came to an end in 2011, with Matroshka having spent 310 days in the Japanese Kibo module.

Helga will be one of the first two artificial female astronauts to fly to space. “We could have chosen to use a male phantom again, but the number of female astronauts is increasing, so we need to bring our scientific research into line with this,” says Berger. The first woman in space was the Russian cosmonaut Valentina Tereshkova, who flew in 1963. Since then, women have been involved in US Space Shuttle missions, worked on the ISS and conducted extravehicular activities (EVAs).

Thousands of detectors

Helga and Zohar simulate the female body, with its reproductive organs and breasts. Preparing the two phantoms for their mission



Helga and Zohar each consist of 38 slices. DLR scientists have equipped them with thousands of radiation detectors.



DLR radiation biologist Thomas Berger with the phantoms in the Orion capsule

requires painstaking, meticulous work. Each of the 38 slices harbours multiple sensor locations, in which the DLR scientists will place tiny crystals. These are able to store ionising radiation in their crystal matrix. Some 1400 sensor locations have to be filled, and a total of 5600 crystals have to be carefully placed one by one in the right place using tweezers and their locations documented. Every single one of these passive detectors will continuously absorb the radiation from the start of the mission until the return to Earth. Analysis of the crystals will yield a three-dimensional representation of the dose distribution inside the human body. This will show the levels of radiation exposure to bones and organs in different parts of the body during a flight to the Moon. These will be supplemented by 16 active radiation detectors. Instead of capturing the total radiation over the entire mission, they will measure the current radiation exposure at specific times. This will give scientists an insight into the phases of the mission and the conditions under which radiation exposure affects parts of the body. The measuring devices are installed in the most sensitive organs in both phantoms – the lungs, stomach, uterus and among other places, the spinal cord.

Test run for the flight to the Moon

These detectors are powered by batteries, which must not become discharged before the mission is complete. After all, the radiation biologists will have no way communicating with their measuring devices from the ground. Accelerometers within the devices ensure that the detectors switch on during the launch. The scientists have already carried out successful tests under realistic conditions on the last

two MAPHEUS flights, a DLR research programme using high-altitude research rockets. The researchers also tested the radiation-measuring detectors during a flight on a NASA balloon campaign over the South Pole.

The phantoms will be handed over to NASA 12 days before the launch date. After that, the scientists will only regain access to their experiments once the Orion capsule has descended through the atmosphere on parachutes, safely landed in the Pacific Ocean and been recovered. “Depending on the launch date and orbit, the mission may last between 25 and 42 days – and that is how long our batteries will have to keep powering the active detectors, keeping them running and ensuring that the data is stored.”

Helga and Zohar’s journey will take them farther from Earth than any astronaut has ever gone before. As it flies past the Moon, the Orion spacecraft will gather momentum and only start its return once it is 70,000 kilometres beyond the Moon. At that point, the two phantoms will be almost half a million kilometres from Earth. NASA accomplished its first successful unmanned test flight with the Orion spacecraft in December 2014. On that occasion, the capsule orbited Earth twice before landing in the Pacific Ocean almost five hours later. The launch abort system for Orion capsules was successfully tested in July 2019.

The Artemis programme – a new chapter

The Artemis I mission, which is planned for the last quarter of this year, will conduct its first flight around the Moon with MARE on board. Whether this launch date is met or delayed depends primarily on the progress made in the development of the Space Launch System (SLS) – the heavy-lift rocket that NASA is currently developing and testing for missions to the Moon. It is intended to be even more powerful than the Saturn V rocket that launched the Apollo astronauts towards the Moon. Orion’s first manned flight to Earth’s natural satellite is scheduled to take place in 2022 – but on this occasion, the passenger seats will not be occupied by phantoms like Helga and Zohar, but by a four-person crew. They will orbit the Moon as part of the Artemis II mission. With Artemis III, NASA is currently planning the next Moon landing, which will include a mixed crew and take place in 2024. Subsequent Artemis missions are aimed at setting up the Lunar Gateway, a permanent space station in lunar orbit, by 2026.

But first it will be Zohar and Helga’s turn. Their mission has already achieved its first milestones – the testing of the seating in the Orion capsule went without a hiccup, and the structure upon which the two phantoms are secured and transported withstood the challenging conditions of a rocket launch during a vibration test at the DLR facility in Bremen. Since 2019, the ISS crew has been testing the Israeli radiation protection vest – after all, it must be both functional and practical. Thomas Berger’s team has been working with the Israeli partner company at the laboratory in Cologne to ensure that the vest fits Zohar perfectly. “You can only go so far with drawings and designs; the reality is something else.” Although Helga and Zohar are made of nothing but slices and plastic, their mission must run flawlessly – just like it would for astronauts of flesh and blood.

Manuela Braun is responsible for strategic communications on subjects relating to space research and technology.

EUROPE’S CONTRIBUTION TO THE ORION SPACECRAFT

The ESA European Service Module (ESM) provides propulsion to NASA’s Orion capsule. The composite spacecraft is powered by four solar arrays. In addition, the ESM stores the propellants, and oxygen and water supplies for the crew. Only at the end of the mission does the ESM separate from the Orion capsule and burn up in Earth’s atmosphere.

Germany is financing approximately 40 percent of the ESM and is thus the largest European partner. The German contribution is managed by DLR’s Space Administration in Bonn.



Orion’s first crewed flight to the Moon is planned for 2022

OUR OTHERWORLDLY 'SISTER'

Today, we know Mars quite well, but what about Venus?

By Jörn Helbert and Ulrich Köhler

What makes Venus so different to Earth? It is hard to know for sure due to the thick clouds that hide its surface. But there are plans for new missions that could help solve the mystery.

It has been observed through telescopes for 400 years and explored by interplanetary spacecraft for 60 years. Yet our planetary neighbour Venus, located barely 40 million kilometres from Earth at its closest approach, remains a mystery. Named after the Roman goddess of love, and the only planet named after a female, Venus is often referred to as Earth's sister planet. And, as with many siblings, it can be difficult to understand why two members of the same family have developed so differently.

Then there is Mars. Thanks to numerous interplanetary missions, we know a whole lot more about our outer neighbour than we do about Venus, our immediate fellow planet towards the Sun. With a diameter approximately half of Earth's and just one tenth of its mass, Mars has a thin atmosphere but is thought to have been at least temporarily home to a water cycle similar to Earth's. Whether this water once harboured simple living organisms is the subject of much research. And it remains possible, despite the freezing cold that prevails on Mars today.

Although Venus is considered to be inhospitable to life, people thought differently during the Age of Enlightenment, right up until the beginning of the space age. After the Moon, Venus is the brightest object in the night sky and can easily be observed with ground-based telescopes. Yet the planet's surface itself is obscured by the thick clouds in its extremely dense atmosphere. This provided much fuel for the imagination in the 18th century, even among the most respected scholars. Could this cloud cover be concealing Earth-like oceans and continents at life-friendly temperatures?

The first spacecraft to visit Venus, such as those of the US-American Mariner and Pioneer programmes or the highly successful Soviet Venera and Vega missions, revealed a different reality. Venus' atmosphere consists almost entirely of carbon dioxide (as was the case on Earth up to approximately 2.5 billion years ago, and is still the case on Mars), but the entire gaseous envelope is almost 100 times as massive as Earth's atmosphere. This means that, although the heat

Venus is permanently enveloped by cloud cover that obscures the view of the planetary surface and shows few contours in visible light. In the ultraviolet wavelengths, however, an unidentified gas molecule absorbs some of the sunlight and reveals dynamic structures in the planet's clouds. Japan's Akatsuki orbiter observes the weather during its 10-day orbit.

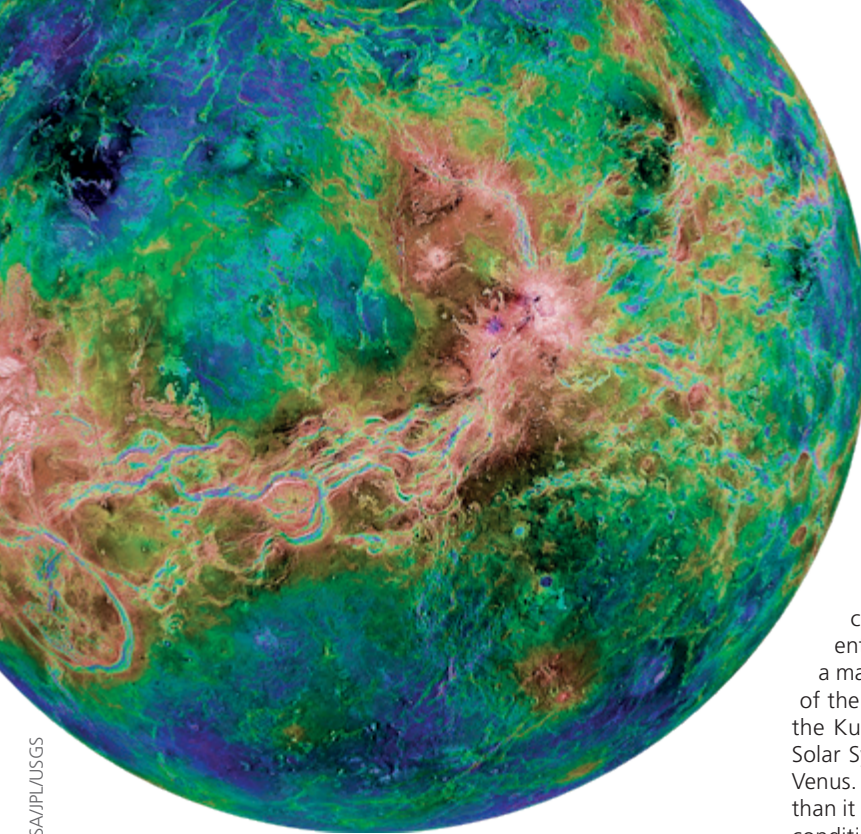
radiation cast onto the planet by the Sun does initially penetrate the atmosphere, much of it is then unable to escape. As the radiation interacts with gas molecules and the surface of Venus, its wavelength increases, rendering it unable to escape into space and trapping the heat in the atmosphere. The temperature within the atmosphere rises and rises. We see this on Earth to a much milder extent – we know it as the greenhouse effect. On Venus, it leads to temperatures of up to 470 degrees Celsius, high enough to melt even lead.

We only 'see' the last half a billion years of Venusian history

But was Venus always like this? We know that Earth has undergone dramatic changes since its formation 4.5 billion years ago. First, a vast magma ocean 1000 kilometres deep had to cool down enough to form a crust. Tens of thousands of years of continuous rainfall gave rise to the oceans. Eventually, the process of plate tectonics began, which, like a thermostat, regulated Earth's system from the inside out and played a major role in the emergence of life. Shifting crustal plates, forming at active continental margins and recycling at passive ones, and the replenishment of the atmosphere with volcanic gases were key factors in the development of life.

Although many of the necessary conditions for these processes also existed on Venus, we do not see any continents, plate tectonics, oceans or active volcanoes feeding water and other volatile substances into its atmosphere. What we see instead is quite astonishing. NASA's Magellan orbiter (1990–1994) gave us the first, and to this day only, high-resolution glimpse of the planet's surface. Radar instruments capable of observing through the atmosphere revealed a terrain shaped by global volcanic activity, but which had remained unchanged for around half a billion years. There are only a few isolated instances of plate tectonics, and they appear never to have developed beyond their early stages. Instead, Venus is littered with more than 10,000 ancient volcanoes. Are some of them still active? It is possible! The European Venus Express spacecraft conducted long-term observations of Venus' atmosphere and sent data back to Earth indicating areas in which temperatures exceeded 480 degrees Celsius. Based on theoretical models that use this data, volcanic activity is certainly possible.

However, as far as geophysicists are concerned, a lack of plate tectonics means that Venus simply consists of one crustal plate. This rests on the hot mantle like a heavy gravestone, preventing the heat generated within the planet from escaping through junctions, as it does at plate boundaries on Earth. Instead, it simply builds up, the pressure rising like a pressure cooker. Eventually, the lid flies off – volcanic activity bursts to the surface with incredible force, flooding the entire planet with lava. The result of what occurred half a billion years ago is what we see today. But what happened during the formation of the planet between 4.5 and 1 billion years ago?



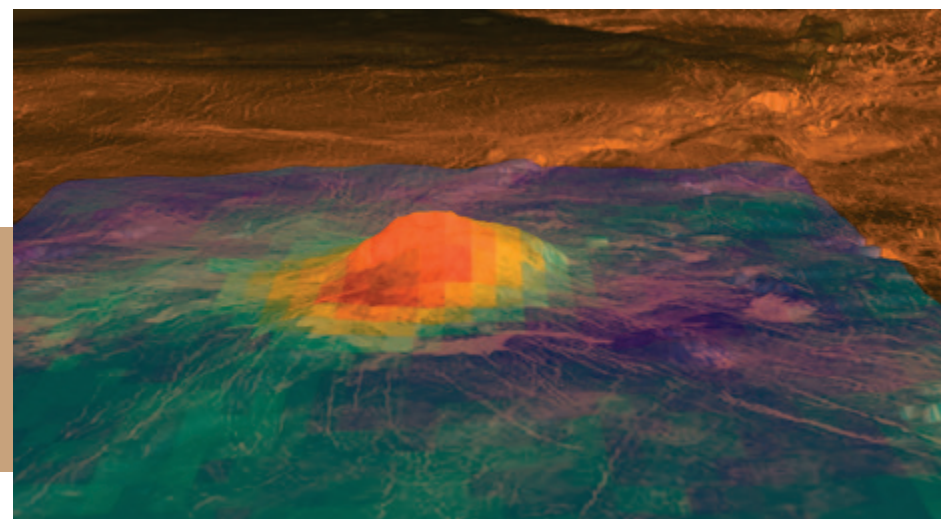
NASA's Magellan orbiter revealed topographical details in high resolution for the first time. Continental plateaus (beige) tower several thousand metres above the volcanic lowlands (blue and green) and their tens of thousands of extinct volcanoes and other mysterious tectonic structures.

This could be one of the reasons for Venus' lack of water. However, it is highly likely that Earth's water did not only come from the protoplanetary disc containing the 'ingredients' for the planets. A considerable proportion, perhaps even a majority, probably came from ice-rich bodies in the outer edges of the Main Asteroid Belt, from comets and from larger objects in the Kuiper Belt beyond Neptune's orbit. In the early days of the Solar System, these celestial bodies brought ice to both Earth and Venus. During this period, the Sun was also up to a third dimmer than it is today. It is thus possible that the pressure and temperature conditions on Venus were suitable for water to exist in its liquid state. So were there oceans on Venus for many hundreds of millions of years, or perhaps even one or two billion years? Did water act as a lubricant for active plate tectonics? Although not impossible, it would then raise the question of whether Venus was capable of supporting the development of life, as Earth did around 3.6 billion years ago.

Were the two planets similar in their infancy only to become strikingly different as they developed, as is often the case with siblings? Is this why we see two completely different 'adult' planets today? The mountain of unanswered questions has only grown in recent years. In light of this, Venus researchers from all over the world are acting as consultants for the NASA Venus Exploration Analysis Group (VEXAG) are proposing the exploration of Venus from up close via new space missions. Today, orbiters can be equipped with a much more modern and powerful array of instruments. This would make it possible to take gas samples from the dynamic atmosphere, study the surface using high-resolution radar and imaging spectrometers, and even land modules on the surface, which would be able to conduct experiments, this time for more than two hours.

Was Venus once a 'blue planet'?

When we compare the two planets, we see that Venus and Earth are almost the same size and mass, have an almost identical inventory of chemical elements, and a comparable mineralogical composition. Even though Venus is 'only' 50 million kilometres closer to the Sun, this could account for some of the differences between the dissimilar siblings. When it comes to planetary formation, the general rule is that the further a planet is from the Sun, the lower its proportion of heavy elements such as iron, nickel, magnesium and silicon, and the higher the proportion of volatile substances such as hydrogen and carbon. Hence, heavy, Earth-like planets with solid surfaces formed in the inner Solar System, while the gas giants formed at distances of approximately one billion kilometres from the Sun and beyond. Could the slight difference between the orbits of Venus and Earth, at 100 and 150 million kilometres from the Sun respectively, be the crucial distinction and the reason why Venus received little or no water from the circumsolar disc of dust and gas from which the planets formed?



Measurements with the VIRTIS spectrometer on ESA's Venus Express spacecraft showed that some volcanoes, such as the 2500-metre-high Idunn Mons, have a higher temperature than their surroundings and could still be active.

© VR2 Planets



EnVision is a candidate for an ESA Venus orbiter that will use radar to analyse areas above and below the surface and detect active volcanoes

© NASA/JPL-Caltech



VERITAS is a finalist for one of two new missions in the NASA Discovery programme. The orbiter would map the surface of Venus.

A DECADE OF VENUS RESEARCH

International interest in missions to Venus is currently on the rise, to the extent that some scientists already predict an upcoming decade of research into the planet. The technology for the following missions either already exists or is being developed.

DAVINCI+ (Deep Atmosphere of Venus Investigation of Noble gases, Chemistry & Imaging, Plus): A probe falls through the atmosphere of Venus on a parachute, taking precise measurements of the atmospheric composition, particularly isotope ratios, during its descent. This would allow scientists to draw conclusions about the period of time over which Venus lost its water.

VERITAS (Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy mission): A high-resolution radar system combined with a near-infrared spectrometer developed by DLR would provide the first global mineralogical map of Venus and represent a step towards a future landing mission.

EnVision: One of the three finalists for ESA's fifth medium class mission. The mission is intended to determine the current state of geological activity on Venus and its relationship with the atmosphere. A second radar system would provide a first glimpse of Venus' subsurface. The payload would be supplemented by three spectrometers from France, Belgium and Germany, with DLR playing a leading role.

Shukrayaan-1: The Indian Space Research Organisation (ISRO) is currently evaluating the requirements for the Shukrayaan-1 mission. It would combine a radar instrument with a range of spectrometers and plasma instruments.

Venera-D: This mission has been the subject of study by Russian researchers for many years. In addition to an orbiter, a landing module based on the successful Venera landers would be sent to Venus. The possibility of the lander carrying balloons or other flight equipment is also being considered.

Implications for exoplanet research

Rapid improvements in high-temperature electronics have allowed for the design of landers capable of surviving on the surface of Venus for days or even months rather than hours. NASA's Glenn Research Center is working on a concept for a miniaturised lander designed to survive for at least 60 days on the Venusian surface. This would allow long-term measurements of the planet's seismic activity to be conducted in a comparable way to those made on Mars by NASA's InSight mission. Venusquakes could also be recorded by balloons in the atmosphere. Due to its high density, the atmosphere transmits the waves from the planet's surface very effectively, making it possible for them to be measured with geophones mounted beneath a balloon. Similar measurements are carried out in Earth's oceans.

If we look beyond the Solar System, we find that there are many Venus-like planets among the over 4000 exoplanets that have been discovered so far. The planned missions to Venus will allow us to

study this class of exoplanet right on our doorstep, and gain some insight into the likelihood of their ability to harbour life.

Jörn Helbert is a planetary physicist and heads the Planetary Spectroscopy Laboratory group at the DLR Institute of Planetary Research. He is particularly fascinated by planets and moons with hot surfaces and recreates their 'hellish' conditions in the laboratory.

Ulrich Köhler is a planetary geologist at the same institute and has spent the last 30 years striving to understand why the five terrestrial planetary bodies of the inner Solar System developed so differently from one another. He communicates his findings to the public in a variety of ways.



ROLLING OUT THE RED CARPET

Introducing ISTAR, the latest member of DLR's aircraft fleet.

By Falk Dambowsky

It is a fresh January day at the beginning of a new decade, and the Falcon 2000LX ISTAR is making its way from the Dassault plant in Bordeaux-Mérignac to its new home at the DLR site in Braunschweig. ISTAR stands for In-flight Systems & Technology Airborne Research. As an in-flight simulator, it will expand DLR's fleet of research aircraft and help both to increase knowledge about automated and uncrewed flight and to implement more advanced pilot assistance systems. The DLRmagazine introduces the newcomer.



Traces of the last handprints and a sudden rain shower are removed so that ISTAR is spotless for the handover



With the key, the ISTAR is handed over, from Dassault Aviation to DLR.

For almost two years, the Dassault Falcon 2000 – one of the first models in its series – was prepared for its second 'life' as a research aircraft in France, and the appropriate equipment was installed. On this January morning, the aircraft is being meticulously polished by numerous diligent workers. A brief rain shower surprises those involved as the aircraft taxis to the hangar where the ceremonial handover will take place. It is given a quick once-over before the big moment, when the key is handed over, opening up a new chapter in DLR aeronautics research.

Prepped for change

Let's go back to when it all began. In April 2018, DLR signed the purchase contract for ISTAR with Dassault at the ILA Berlin Air Show. At the headquarters of the French aircraft manufacturer in Bordeaux, the twinjet was fitted with sensors, brackets and new cable fittings and underwent other modifications to bring it in line with DLR specifications – all preparations for the installation of the basic measurement system. In future, this central unit in the ISTAR cabin will record key aerodynamic parameters for the aircraft, while also recording signals from the experimental sensors and antennas. It includes a workstation with two positions for flight test engineers, who will control the experiments and monitor the data during the flights. DLR engineers will integrate the basic measurement system in Braunschweig by summer 2020. With it, ISTAR will initially be used as a flight test aircraft investigating aerodynamics, aeroelasticity, structures and propulsion.

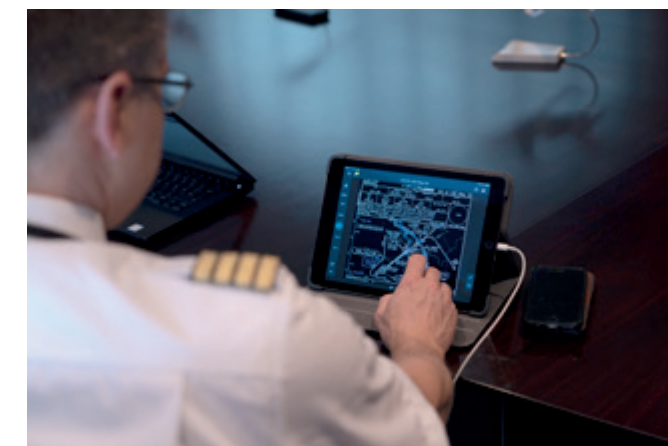
A digital twin as a faithful companion

In Bordeaux-Mérignac, two pairs of scissors elegantly lie on a red velvet cushion and ribbons have been made taut. Rolf Henke, the DLR Executive Board Member responsible for aeronautics research, and Burkard Wigger, Director of DLR Flight Experiments, stand ready and waiting – beaming with pride and joy. "Our latest research aircraft is developing into an all-rounder for optimised aerodynamics, flight guidance and flight control. ISTAR also enables a major leap forward in the digitalisation of aviation. We intend to create a digital twin for ISTAR, which will accompany it throughout its lifetime," says Henke. Following the handover, DLR test pilot Jens Heider and a colleague from Dassault taxi the aircraft onto the runway, taking off at around 14:00. This flight marks the completion of the first conversion phase. The coming week, months and years will see the first research flights and new projects in the name of science.

One of these, which will closely accompany the ISTAR during the first three years is the DLR HighFly (High speed inflight validation) project. It will combine initial training for DLR researchers on the new flight test aircraft with the development of the instrumentation. The first measurement flights are scheduled to begin in mid-2020, during which the researchers will record, among other things, mechanical and dynamic properties during specific flight manoeuvres. These will be followed by a Taxi Vibration Test (TVT) and a Ground Vibration Test (GVT) in autumn 2020. The vibration properties of the aircraft will be



Ready for the big moment. During the official handover of ISTAR from the French aircraft manufacturer Dassault to DLR, a red ribbon is cut as per tradition.



DLR test pilot Jens Heider checks the flight route from Bordeaux-Mérignac to Braunschweig



Roll-out of ISTAR, the first DLR research aircraft with a digital twin.



Striking – the orange winglets.



Jens Heider flew ISTAR to Braunschweig. The last metres on the ground are taken over by the towing vehicle.

measured during these investigations. The aircraft will be stationary during the GVT and mobile for the TVT. In order to record every movement, researchers from the DLR Institute of Aeroelasticity in Göttingen will attach numerous accelerometers to the aircraft's exterior, in addition to the permanently installed acceleration sensors. These will also record how the vibrations excited during the tests are damped.

At the limits of what is possible

From 2021, the HighFly project, which will accompany the development of ISTAR, will enter a second phase. Laser measurement technology, special cameras and microphones will record the turbulent airflow and its acoustics behind a running engine. The Particle Image Velocimetry (PIV) method developed at DLR in Göttingen will be used for this purpose. This technique makes flow patterns visible

using pulsed laser light reflected from the smallest light-scattering particles. In 2022, ISTAR's aerodynamics will be recorded using the latest measurement technology from DLR in Braunschweig. This will take the new research aircraft to the limits of its flight capabilities. The results of these tests will be used to improve computer models for flow simulation and design new aircraft with greater precision while making them lighter and more energy efficient.

The research activities and modifications carried out in the first few years will be important for researchers and pilots to familiarise themselves with the new member of the DLR research aircraft family. With 12 fixed- and rotary-wing aircraft, it is the largest civilian research fleet in Europe. In 2023, ISTAR will return to Dassault in France, where it will be fitted with an experimental electronic flight control system (fly by wire) and an experimental autopilot system.

This will allow automated pilot assistance systems to be tested, including automatic taxiing and take-off. The system will also be used for tests regarding the integration of unmanned aerial vehicles into controlled airspace. The third and final stage of development will take place at Dassault in the mid-2020s. At this point, ISTAR will be used to test the flight characteristics of new aircraft designs – whether real or virtual, crewed or uncrewed – under real operating conditions. Its digital twin will collect all of the data throughout ISTAR's entire lifecycle. It will be used to mirror the present operating phase of the real aircraft, as well as to track and manage modifications, maintenance and repairs, alongside operational aspects.

At around 16:00 on 31 January 2020, the Sun hangs low in the sky as ISTAR approaches Braunschweig research airport. The international aviation community is following its arrival on social media.

The excitement and anticipation generated by this new and versatile research aircraft are almost tangible. Photographers, camera crews and two firefighting vehicles are waiting on the ground to give the aircraft its deserved reception. After touchdown, the newcomer is showered by the two fire engines by way of a welcome. As the Sun sets, ISTAR stands in front of the DLR hangar, its new home. Having witnessed the very first flight, Rolf Henke is now looking to the future: "This is exactly the right aircraft for DLR, for the present time, and for the research that lies ahead."

Falk Dambowsky is a Media Relations editor at DLR.



The newcomer is admired



The aircraft is the star today



Make way. New aircraft configurations will be simulated with the flying research laboratory.

TIMELESS SPACES

Preserving history, telling stories, building bridges – the DLR Central Archive safeguards the past, the present and ideas for the future.

By Peter Zarth



Composed, concentrated, focused and creative: the DLR Central Archive in Göttingen revolves around Jessika Wichner, a director ideally suited to preserving the past for today and tomorrow, and above all keeping it alive.

An ark of life, an archive for Earth

Arche (ἀρχή): The word is both ancient and timeless. In antiquity, philosophers used it to describe the beginning of all things. The Bible refers to the vessel constructed by Noah to provide salvation for animal species as the Ark. Today, derivatives of the word are used to describe repositories for cultural assets: the Voyager Mission, for instance, or the Nebra Ark. The Barbarastollen underground archive in Oberried officially goes by the matter-of-fact title 'Central Storage Site of the Federal Republic of Germany', but it too is often referred to as an ark. Outside of Germany, the Globalt sikkerhetshvelv for frø på Svalbard on Spitzbergen is the world's largest seed bank – an ark of life, an archive for Earth.

A century of knowledge for tomorrow

Sometimes you have to reach 100 years of age before you are interested in your past. For an institution such as DLR that strives to produce 'knowledge for tomorrow', 100 is no age at all. Indeed, 'tomorrow' is the daily mission for research. As two-time Nobel Prize winner Linus Pauling concisely put it, "Science is fallacy updated". In 2007 DLR celebrated its centenary with festivities in Göttingen, its place of origin. On this occasion, initial discussions were held, and plans made for the establishment of the DLR Central Archive in Göttingen, a city with rich scientific history and producer of 45 Nobel Laureates. Two years later, the management position had to be filled.

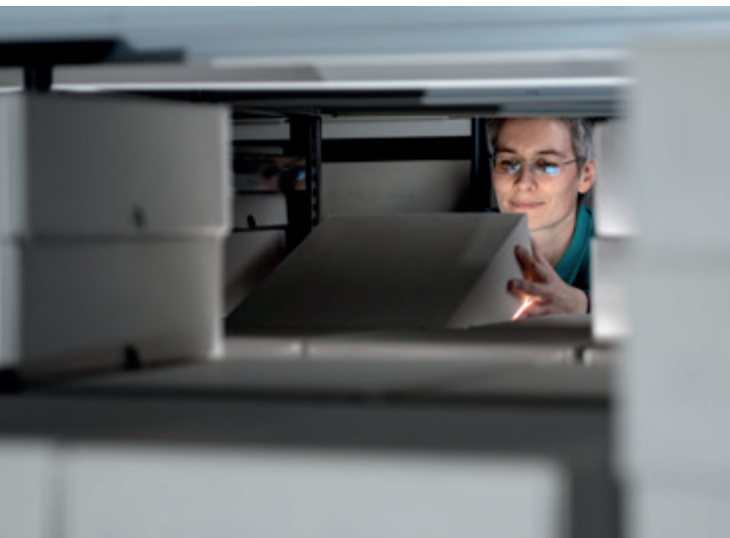
At that time, Jessika Wichner was completing her PhD in History of Science. She had applied for the role and was on her way to Scotland – one of her adopted homes – when she got the call. Wichner was tasked not only with the role of director, but with helping to establish the archive itself. It was like she was meant for the role. The daughter of a flight instructor, she grew up around aircraft and aviation enthusiasts near Göttingen. She acquired a deep-set interest in aerospace at home and was already familiar with DLR. Her doctoral thesis was entitled 'The dream of flight – from antiquity to balloon ascents in Great Britain in the late 18th century'. In an interview with the DLRmagazine, she recalls how surprised she had been at the almost complete lack of prior publications in the field. The interdisciplinary nature of the topic appealed to her: combining aviation, history, English and literary studies.

Composure and creativity

A lot changed for Wichner after that call. "It was fantastic to find out that I would soon be at DLR and working on something like this," she says, and her enthusiasm continues to this day. Wichner's affinity for interdisciplinary work is not the only thing that makes her well suited for the role. As an artistic roller skater, she learned from a young age to concentrate on what is essential. "Competitive sport gave me a certain composure," she says. "Because when you compete and things can come down to a tenth of a second, you can't simply back out." She also attributes her creativity to sport, as "if doing things one way isn't working, you have to find another way quickly."

The fine art of omission

In her office, Wichner describes the core tasks of the DLR Central Archive, its inventory and the procedures through which interested parties from both within DLR and beyond can access its material. The archive contains over 50,000 documents and the ratio of external enquiries to those submitted by DLR employees is roughly two to one. One important period is the years following 1969, the year in which the transitional agreement was signed between the Aerodynamics Research Institute (Aerodynamische Versuchsanstalt; AVA), the German Research Institute for Aviation (Deutsche Forschungsanstalt für Luftfahrt; DFL), the German Aviation Test



© DLR

Institute (DVL) and the German Test and Research Institute for Aviation and Space Flight (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt e.V.; DFVLR). With these agreements, DLR as we know it today came into being. Key documents also include original copies of research papers dating from 1897 by Ludwig Prandtl, considered in a sense to be the founding father of DLR. Today, even the very latest press releases are added to the 'living archive'. Wichner explains that "The criteria we use to determine what requires archiving is decided upon in conjunction with the DLR Executive Board. Of particular importance are documents that contain interesting and meaningful information about the institution." This is where the most difficult questions are discussed. What should be collected? What might be of interest in the future? When it comes to the fine art of omission, it is helpful to establish and follow procedures.

Documents that ensure legal certainty, for instance, such as expired patents from the 1930s and 40s and architectural drawings of the DLR sites, should always be archived. Beyond these, it is a matter of preserving frequently requested material and "archiving to the best of your ability," says Wichner. A distinction is made between the archiving of administrative documents, right down to selected personnel files, in accordance with data protection and personal confidentiality requirements, and research documents. Documents are released according to the regulations of the Federal Archive, which has the longest closing times for documents in Germany. For organisational and historical reasons, documents from the DLR Space Administration and DLR Project Management Agencies are stored in the German Federal Archive rather than DLR's Central Archive.

The over 50,000 records, or 'items', consist of files containing the proceedings of meetings and board resolutions, decisions made by the DLR Senate and the DLR Scientific-Technical Advisory Council, as well as countless other transcripts. The image material includes 15,000 historic photographic glass plates, primarily from Göttingen and Oberpfaffenhofen, images from DLR Photo Media, which handed over 700 files of negatives in 2019, and much more. "A central registry is essential," says Wichner. "After all, we want to take the burden off employees. What people might see as wastepaper is often a real treasure trove. We're working against time, against the loss of knowledge." The latter point also applies to older digital material, where the poorer durability of older storage material can cause significant problems. "The IT sector focuses on different, shorter timeframes and expectations than are necessary for an archive." But various external bodies are able to help, such as the Baden-Württemberg Library Service Centre in Konstanz.

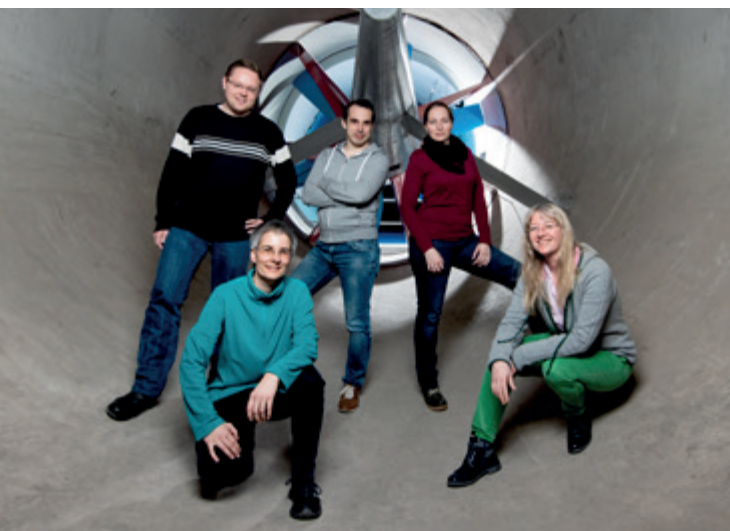
Archiving can give rise to unforeseen problems: "The increasing use of email to replace older, physical forms of correspondence will result in a knowledge gap for archives," she says. Those who lived through the age of circulars and paper memos will know exactly what she means.

House calls, valuable glimpses into the past and considering the future

As a living archive, the profiling and collection of material rely heavily on the involvement of DLR employees. Archiving is voluntary, but an archive is not simply a place to store superfluous material. "We have to work hard," says Wichner, "to ensure that DLR employees are aware of what we do, think of us and draw our attention to what is worth preserving." The identification of something potentially interesting for the archive results in a business trip which she jokingly refers to as 'our house call'. "DLR's site in Oberpfaffenhofen is one of the main ports of call for such business trips. The site is home to the Department of Scientific Information, headed by Jutta Graf who is responsible for the DLR Central Archive, the DLR Library and the DLR research data manager." Oberpfaffenhofen remains the most productive DLR site in terms of submissions to the Central Archive. The four employees of the DLR Archive look over requests and are often called to view garages full of old papers or asked to offer professional advice during relocations.



Paper treasures: Originals from 1897 of student research projects by DLR's founding father Ludwig Prandtl are treated with great care.



© DLR

Without tunnel vision: The Archive team (back row from left to right: Stefan Bondzio, Thore Herzog, Ute Rasche, front row: Jessika Wichner, Sylvia Arendt) is characterised by 'focused foresight': Accuracy, curiosity and perseverance, even in difficult research fields.

Keeping the past from becoming forgotten brings a new dimension to the archiving of scientific and technical work. Wichner shares an anecdote about some documents in the archive that came from helicopter researcher Walter Just, who founded the German Helicopter Study Group (Deutsche Studiengemeinschaft Hubschrauber) in 1953, which was later incorporated into the DFL in Braunschweig in 1964. The documents include theses by students that are of interest to engineers today. They contain all sorts of ideas that were not practicable at that time but which could be realised today using modern materials. "That's just one example," says Wichner, "of how relaying scientific and engineering history can open up potential for the future."

Building bridges for young people

The future belongs to the young. As such, inspiring young people is an important part of archiving work. 'Future Day' (also called 'Girls' Day/Future Day', including boys in Lower Saxony) offers a good opportunity to do just that. "We are building bridges," says Wichner, "by showing children what we are interested in preserving and how we acquire it. Often, the subject that it concerns will be familiar to them from their schoolwork." She fetches one of the archive's treasures, an original copy of a letter written in 1935 by the last German Kaiser, Wilhelm II, long after his abdication and from his exile in Doorn, the Netherlands, to Professor Heinrich Koppe in Braunschweig. In it, Wilhelm expresses his gratitude for the scientific work that the Professor had sent him, of which he found "a lecture on the practical experience of lightning strikes in aircraft" particularly interesting. Most intriguingly of all, from our point of view, he adds his autograph – "as a token of my gratitude and appreciation" – majestically signed in purple ink.

© DLR



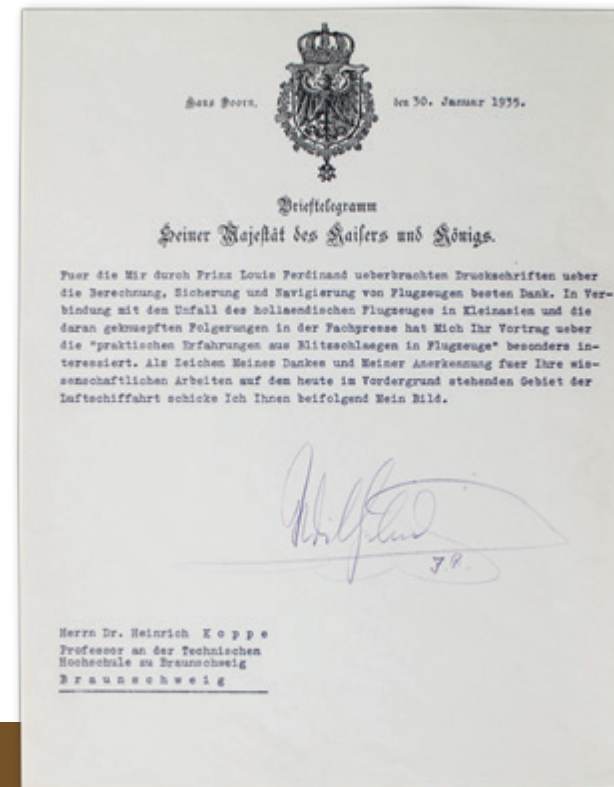
Unrestricted: For a science and research institution such as DLR, openness is an important quality. The doors behind which documents are stored and protected are opened for visitors.

A network of ideas

Jessika Wichner writes simply, with a pencil. When asked about her use of graphite, she says that, while it is a coincidence, ballpoint pen ink does indeed fade much faster. This kind of coincidence (which often don't seem to be coincidences after all) may well be what sets good historians who can run successful archives apart. This archivist still very much enjoys working in timeless spaces where history, stories, people's lives and the future coexist. "I enjoy every day and always learn something new," says Wichner. "People come together at DLR to develop ideas as part of a network."

We are all most welcome to visit the archive and its team of employees. That goes for you, too!

Peter Zarth works in the Public Affairs and Communications department at DLR.



Imperial thank you: A letter (picture above) from the last German Kaiser from his place of exile, Doorn, the Netherlands, to Professor Heinrich Koppe in Braunschweig concerning his work on the 'practical experience of lightning strikes in airplanes'.



Work on the aerodynamics of aircraft wings and engines. A typical example of file contents in the DLR Central Archive in Göttingen.

JOURNEY AROUND A UTOPIAN PLANET

At the Klimahaus Bremerhaven

By Peter Zarth

The Klimahaus Bremerhaven is brilliant in its telling of how man has become alienated from nature and its portrayal of the places where people and nature continue to live in harmony. It is a journey of experiences to places where the world's climate is greatly changing and affecting nature, microclimates and life itself. Follow us as we go along some unusual paths, before discovering the climate worlds located on the mouth of the Weser River for yourself.

In his novel *Raumlicht – Der Fall Evelyn B.*, the late author Ernst Augustin, a former neurologist and psychiatrist at Berlin's Charité hospital, depicts a grand journey. Externally, it takes us all the way to Kandahar, Afghanistan, while internally it delves into the mystery of the 'Raumlicht' (Evelyn's aura) that gives it the title. It is a puzzle, it walks the line between dream and nightmare, reality and delusion, it is bold and truthful, and definitely crazy – and lasts, strictly speaking, just four hours.

Bizarre spaces

In some respects, this setting closely resembles the Klimahaus Bremerhaven (KHB). Augustin's journey to distant places mirrors how visitors to the KHB travel from Bremerhaven. The exhibition takes guests south, around the Earth along a line close to the eighth meridian east, or 8°34'30"E. Like the novel, the 'knowledge experience', as the creators refer to it, appeals to one's curiosity, thirst for knowledge, love of solving puzzles and desire to improve the world. *Raumlicht* tells the tale of two characters in which, by helping to save a younger woman, an older man ends up saving himself. The young woman's journey is precarious. In order to help her, the older man, a psychiatrist, sets up a series of strange and challenging environments through which she must journey, unable to trust her senses.

Almost everything in flux

Visitors to Bremerhaven also experience an adventure as they traverse this vast attraction. The tour leads guests along our 'One_World'. Initially they may be unsure what to make of the building's muddy green architecture, but inside, they will undoubtedly be taken aback by the view. One moment, they will sweat in the hot, dry desert of Kanak, Niger, and another, pass through a door and find themselves 1158 kilometres further south along the meridian, in the wet, humid rain-forest of Ikenge in Cameroon.

Emerging from the hot expanses, they suddenly reach a river with water so clear that can only be noticed when it ripples. Catfish, cichlids, egg-laying toothcarps and characins all swim around. The water pools around mangroves, rapids and rocks. A rope bridge leads them across the river, the rigging and planks allowing a view of the water below. A woman in platform shoes makes her way over it rather unsteadily – unfitting for the intense humidity of the tropics. She steps carefully across, keeping her delicate balance.

Death in paradise

Was this transition from the burning desert a bit too abrupt? Only a moment ago, we were in the desert, lying in the cosy warmth, gazing upwards at a film about the Tuareg people of North Africa. The hot, 35-degree-Celsius air blows around our legs, slowing our minds. Children watch with eyes wide open. In the film, the Tuareg speak of their lives and their previously idyllic world of warm sands, one that the guests are now experiencing for themselves. But it hardly rains there anymore. Climate change has brought death.

And now, we are suddenly whisked away to the tropics, where water is ubiquitous – water below in the river teeming with fish, water falling plentifully as rain from above. The next film shows children dancing to the beat of drums. The waterfalls thunder and Galago monkeys scream. Dwarf crocodiles lurk nearby and the air is humid. The woman on the rope bridge sporting tan plateau shoes has come to a halt – stranger than fiction.

Minus six degrees Celsius – high summer

The vast expanse leaves visitors searching for a point of interest. The sound of birds fills the air. Then, suddenly, the roar of chainsaws breaks the silence. The rainforest is being cleared to make room for palm oil cultivation. Palm oil is produced in vast single-crop plantations. The creation of such plantations destroys the carbon dioxide stores of the rainforest and causes ecosystems to collapse. Today, palm oil can be found in around half of all supermarket products. And there is nothing idyllic about this, nor the palm oil plantations. Visitors then encounter a stiff plastic curtain, reminiscent of the cold storage of a slaughterhouse. The path leads up a few wooden steps and the air grows icy cold. The next location is Queen Maud Land, Antarctica. It is high summer, and minus six degrees Celsius. The climate worlds of the KHB are truly diverse.

The Klimahaus is an immersive experience. A quote from Oskar Maria Graf appears at the entrance to the journey: "Europe is the cradle of culture, but you cannot spend your whole life in the cradle". Those who embark on it will surely end the journey having learned a lot and be brimming with questions. Which of the world's cultures are still close to nature? Are there places where people still live in harmony with nature? Where have they not become alienated from it?

The mixture of muggy air, dust, heat, extreme cold and humidity can be trying at times. Fortunately, located just after the jungles of Cameroon, the restaurant offers a respite. Second turn on the left, then a right, and you will find an aquaculture fish ready for your plate. Or would you rather first visit the penguins, the beaches of Samoa, the clownfish or the hawkfish? How about heading through a 'stargate'? Or for something even more exotic, boarding a platform and setting out across a mud flat? By the end of the tour, which began high in the mountains,

among chamois and marmots, you will want to help save as much as you possibly can in what has become a game of survival.

Simple, spellbinding and successful

Let's look back 20 years. The planet was not in order, and buzzwords like 'narrative' and 'storytelling' were yet to be born. But the current manager of the KHB and a few like-minded individuals wanted to tell a story. They had the idea of transforming a vast gravel car park on waste land beside the Weser River into a tourist attraction for Bremerhaven. The infrastructure problems in the north of Germany at the time would not have instilled much confidence in the project. It was certainly a tall order and it would have been easy to have left this story untold, given the difficulties. But their objective was to leave a lasting impression on as many people as possible and engage them in climate change. At the same time, they wanted to create a building that would speak to the identity of the city, which was suffering from its remoteness and a sense of feeling overlooked.

Making a statement

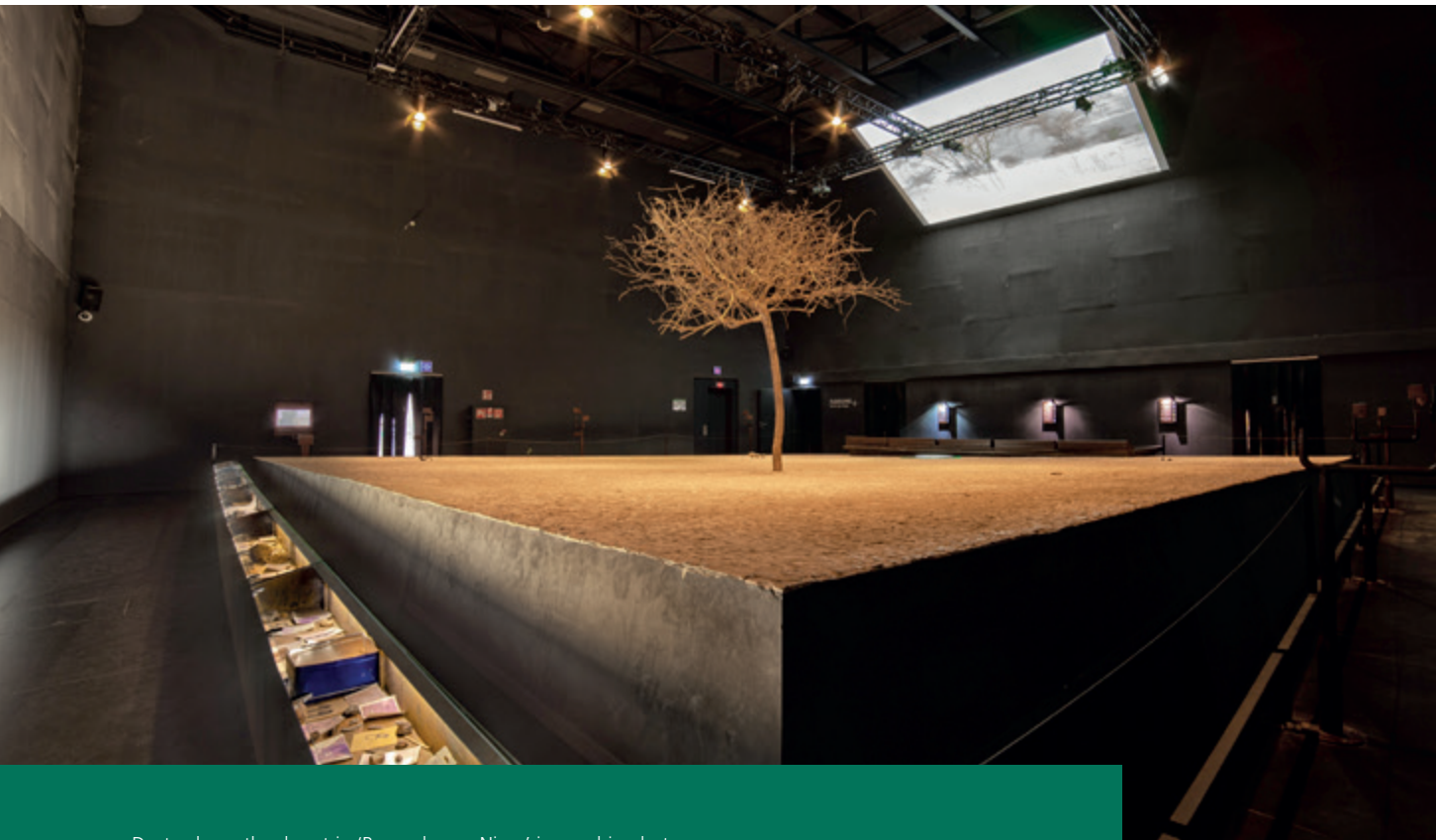
They wanted to create an urban yet shapeless landmark. It may remind the architect of a cloud, others a pillow. From the outside, the design of the KHB is typical of its time, with its exaggerated height providing an impact. Form before function. The trends of architecture have now moved away from this style and both we and the people we spoke with in Bremerhaven are left unsure as to whether the design was entirely successful. Directly beside the KHB, a 'Mediterranean-style' shopping centre now provides a backdrop. Fortunately, just a few steps further on is a building where the architect has really worked to highlight the exhibits inside – the German Maritime Museum, designed by the Bremerhaven native Hans Scharoun.

Lemmings on holiday

The KHB's 'journey' concept and the way in which it has been implemented are very convincing. You quickly forget it is all an illusion, although they could make it easier to spot the emergency exits. Its more than half a million visitors per year, despite the high admission prices, speaks for itself. There is much to celebrate here. UNESCO has



In the Klimahaus Bremerhaven, visitors require courage: a suspended wagon with which people and material are transported through the mudflats to the Hallig Langeneß.



© KHB

Dusty, dry ... the desert in 'Bremerhaven-Niger' is scorching hot.



Exterior view of the Klimahaus Bremerhaven. The facade gives no clue as to the adventurous journey that awaits visitors.

repeatedly deemed the attraction 'a top-quality extracurricular learning venue'. And the KHB is always supplementing and expanding its central 'journey'. Everything also feels very authentic. In the Ikenge river, for example, every fish that can be seen swimming in this section of the KHB is sourced from outside the nature reserves in Cameroon in collaboration with the local authorities. The residents of the Klimahaus are always changing. At the moment, the lemmings are on holiday. We found out that they are on their way to the Arctic tundra, leaving us to continue through the LED 'stargate' instead. The support staff are all very enthusiastic and highly knowledgeable about the exhibits. Fortunately, unlike their wild cousins, we are assured that the lemmings will make it back from their excursions safely.

Taking responsibility

This authenticity extends to the KHB's scientific approach. For example, one member of the team is a geophysicist who focuses on atmospheric physics and climate modelling. She wants visitors to get a real taste of how protecting the Earth can pay off. People cannot survive without nature, and this is especially applicable to places that are more affected by climate change. At the KHB, she says, the target audience is everyone; climate change does not discriminate. But there is particular focus on engaging young people, as they will feel the effects of climate change the most. There is also plenty to interest those keen on science. The Alfred Wegener Institute (AWI), Thünen Institute, Fraunhofer Institute for Wind Energy Systems, Max Planck Institute for Marine Microbiology, and various universities are all frequent guests. The aim is to host likeminded organisations that can help to spread the KHB's message. The true highlight: the tours along 8° in the dark.

Every Friday – utopias for future generations

The quality of the KHB's work with young people will be clear to anyone who attends one of their school sessions. During our visit, the conference room hosted a lesson on 'Utopias for future generations'. The staff member leading the lesson quickly transformed a group of bored school-children into a crowd of interested listeners. One of the pupils even suggested a possible project. Smartphones – dubbed mini-computers here – are allowed, although the teacher noted that they are "only to be used when sensible". In the next room, a meteorologist gave a casual, easily comprehensible talk on 'Weather on Earth', that helped everyone to understand why 2018 was so hot and dry for so long. These talks can be attended by anyone visiting the attraction and questions are positively encouraged. At our talk, we learned a lot, had our interest piqued and discovered places like Cherrapunji in the Khasi Mountains. This area receives 11,430 litres of rainfall per square metre per year. Germany, for comparison, sees an average of 789 litres per square metre. In spite of this, Cherrapunji is experiencing major problems with its water as the rain is failing to seep into the soil.

A sense of change

As we slowly make our way back to our starting point at the KHB, we also look back to the beginning of this article and the novel that is quite parallel to this journey into unfamiliar territory. In the book, there is a dream-like river landscape, exotic animals, green beetles with a metallic sheen that have to be seen to be believed, and the healing power of experience. Some elements delve into the realms of schizophrenia, as sometimes also feels the case with political discussions about climate change. If you ever get your hands on a copy of Raumlicht – Der Fall Evelyn B., make sure to read until the end. It contains surprises right up to the final page.

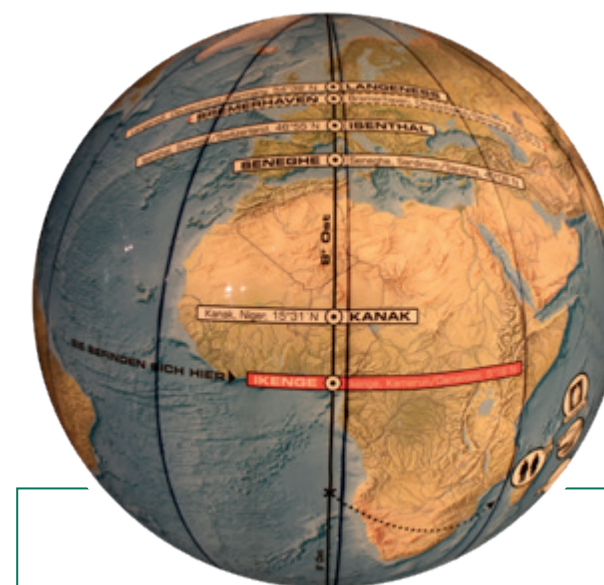
At the KHB, too, the world is extraordinary, beautiful, astounding and endangered. We travel around the globe and learn to make a difference through small acts. It is nice to see that those behind the project put their focus on the work that needs to be done. As far as they are concerned, all visitors are on an equal footing and can make a difference. You experience a sense of change as your journey takes you south along 8° East, from the mouth of the Weser and around an entire utopian planet in just under four hours.

Peter Zarth works at DLR's Public Affairs and Communications Department.

© KHB



The KHB is justifiably praised for its educational offerings. Young people show interest in the journey around the planet along the eight degrees east.



Klimahaus Bremerhaven 8° Ost
Am Längengrad 8
27568 Bremerhaven
Telephone: +49-0471-902030-0

Opening hours

The opening hours vary. Please check:
www.klimahaus-bremerhaven.de/en/discover/general-information/oeffnungszeiten-preise.html

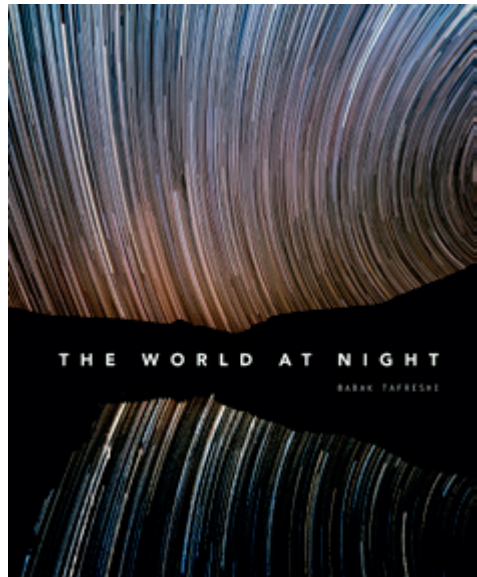
Admission

Adult: 17.50 euro / Child: 13 euro

Additional information:

Various discounts and special ticket offers are available.
Visit: klimahaus-bremerhaven.de

REVIEWS



NIGHTLY REVELATIONS

When picking up the book 'The World at Night', you might be puzzled at first. This pictorial volume does not include images of Earth at night taken from space, but is actually an Earth-bound, nocturnal photographic journey around the world. With this, it brings true ability to inspire.

Thanks to the expeditions of 35 photographers through 20 countries, we are able to see facets of the heavens and Earth that remain mostly hidden from us. Even if we are able to take an 'atmospheric' photograph on a cloudless evening, very few of us will succeed in capturing aurorae, meteor showers or the Milky Way in such an impressive way. Even if, as the adept astrophotographer David Malin explains in the preface, all that is needed is a standard digital camera, some skill, imagination and knowledge of image processing – the images presented here are far from ordinary. They move us with their rare beauty. Sometimes, they were planned for months, like the image of the Moon setting over Tenerife. Sometimes, the photographer waited five hours in the subarctic forest of Finland to capture circular star trails over dark treetops on old-fashioned, photographic film. For an analemma image of the Sun, the photographer had to go to the exact same place twice a month at exactly the same time of the day, photograph the Sun and then combine the images. A figure resembling the number eight can be seen, which is characteristic of such photographs. These are true works of art, created thanks to the great discipline of the parties involved. For example, a long-term shot of violently dancing aurorae reflected in a calm lake, might as well be mistaken for a work of art by van Gogh.

To achieve the effect of this book, the publisher relies on a combination of images and adds texts – no more than 10 lines long – that inform the reader about the location where the image was acquired, as well as the photographic technique used. One or two-page texts introduce each of the six chapters. With a light hand and a focus on the essentials, the author, Babak Tafreshi – born in 1978 – describes the astronomical phenomena and imaging techniques. He founded and leads the international association 'The World at Night' and has compiled this visual indulgence.

He shows us: "Night hides a world but reveals the Universe." This is a book that fascinates, yet also reveals the limitations of printed images. It gets increasingly difficult to be satisfied with the mere photographs. The desire to go out into the night, onto a hill, to witness the allure of the starry sky yourself, to capture its depth, to sense infinity, grows. And yet the path into a dark-enough-night is long ... And so, we are made aware: "We lose something essential; we lose a part of ourselves when we lose access to the night sky."

Cordula Tegen

UBIQUITOUS COSMIC ART



Over the decades, space has become an important part of human culture and has had a strong influence on it – in daily life as well as in thinking. This in turn finds its expression in literature and other forms of art. Dieter Seitz and Markus Kaiser describe how this happens and which historical testimonies can still be found today in their illustrated book **Cosmic Culture: Soviet space aesthetics in everyday life**. Even the first pages cast a strange spell. Space travel as proof of the superiority of a social system is not only found in the rooms of Soviet space facilities. Cinemas bear names like Kosmos, Vostok or Mir, and space adventures can be relived on playgrounds. Not everything is propaganda, much is pride in what has been achieved, for example when the inhabitants of a small Kyrgyz town artfully decorate dreary walls with space mosaics. This volume provides an insight into a bygone era. A bygone era? No. In places like Berlin, evidence of this fascination can still be found today. Be it with power boxes that have been robbed of their dreary grey by space motifs, the world's largest seven-storey Gagarin portrait in Ludwigsfelder Strasse in Berlin-Hellersdorf or the astronaut floating on a huge wall in Kreuzberg.

Andreas Schütz

ABOUT SUSTAINABILITY



Sustainability has become a buzzword. At times, it feels as though it has lost meaning along the way. Seeing sustainability plans on oil companies' websites makes you wonder if the concept is more than just corporate box-ticking. **Sustainability in the Anthropocene**, edited by Róisín Lally, is the opposite – complex and challenging at times, and unafraid of diving into difficult questions.

Readers should not expect to agree with each of the 12 essays that make up the book, but rather to learn from what they disagree with and what they agree with. The essays address a variety of topics, beginning with considerations of what sustainability means, before building to focus on specific issues of design, technology, and ethics in the light of sustainability, ranging from the expected, like renewable power, to the less expected, like reproductive technology and despair. The book is not light reading, but is accessible to readers without a background in environmental philosophy or philosophy in general. Overall, the book is a good inoculation against rapid talk about sustainability, leaving the reader with much to think about.

Sarah Leach

FIELD TRIP TO THE MOON



In the picture book **Field Trip to the Moon** by graphic artist John Hare a school class is allowed to explore this extraordinary destination. While the other children admire the geology of the Moon, one of them dreamily draws Earth shining in the distance, loses sight of the others ... and is finally forgotten and left behind. However, the child does not remain alone with the painting utensils for long. It is easy to get lost in the lovingly drawn pictures. Together with the youngster left behind, one explores the extraordinary inhabitants of Earth's natural satellite. It is almost more beautiful that no text was used at all. Involuntarily, there is a wish to complement the pictures with our own stories. Absolutely enchanting.

Julia Heil

RECOMMENDED LINKS

MARS MULTIMEDIA GALORE

mars.nasa.gov/insight/multimedia/
Mars, the Red Planet and one of our closest planetary neighbours. What do we know about it and what are current missions finding out? The InSight mission is currently on Mars, exploring the surface everyday. On board are various experiments including DLR's 'Mole'. Check out the latest images from Mars, videos, gifs and more in this magnificent multimedia gallery.

TERRAGENESIS – STAR SETTLERS

t1p.de/oq6o

Do you ever find yourself daydreaming about what it would be like to be on a different planet? Are you looking for something to immerse yourself in and keep you occupied at home? Then look no further! This (free!) interplanetary strategy game made using NASA data allows you to inhabit and terraform new planets. Build and sustain your planetary settlements from where you are. This app is available for iOS and Android. What are you waiting for? Time to get terraforming!

PERSONAL AI: REPLIKA

replika.ai

With all the current videochats, calling and texting going on, would you like to know what a conversation with yourself would be like? Try out the personal AI Replika. Through chatting with this AI you can learn about yourself and witness the modern wonders of AI. In the words of the creators: "It's a space where you can safely share your thoughts, feelings, beliefs, experiences, memories, dreams – your 'private perceptual world'."

FLY FROM HOME

www.geo-fs.com

Are you a frequent flyer or are passionate about flying? Staying at home during these complicated times must not be easy. What if we told you that you could actually take to the skies from home? Yes, it's possible with GeoFS, a free flight simulator with a worldwide environment generated from satellite images. The best part is that it runs in your web browser so you don't have to install anything. You can choose from 20 aircraft and fly across the world using a joystick, mouse or keyboard.

STARGAZING

stellarium-web.org

We all look at the night sky from time to time and wonder about all the points of light we see. Is it a star? Is it a planet? Is it a satellite? If you want to know what you are seeing, then Stellarium web is for you. Stellarium, an open source astronomy software used by universities all over the world, now runs in your browser. Head to the page right now to check out what's in the sky above you.

SAVE ENERGY

joulebug.com

Want to make saving energy fun and less of a chore? Then this app is for you. JouleBug helps you build green habits and rewards you when you do good. The more green choices you make, the more badges you earn, and you can share your achievements to encourage others to do the same. You can also interact with the green community on JouleBug, share stories and get inspiration. Available in the App Store and Play Store.

Cover image

When the curtain is drawn back to reveal an aircraft, it has to be something special. This is how ISTAR made its entrance. The new addition to the DLR fleet, now stationed at Braunschweig, is a flying laboratory. Its name stands for 'In-flight Systems and Technology Airborne Research'. ISTAR is being expanded, step-by-step, with highly specialised measurement technologies. It will be able to simulate the flight characteristics of any aircraft – while in the air. Researchers will investigate new technologies for quieter engines and innovative assistance systems, among other things.



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