

# DLR / magazine

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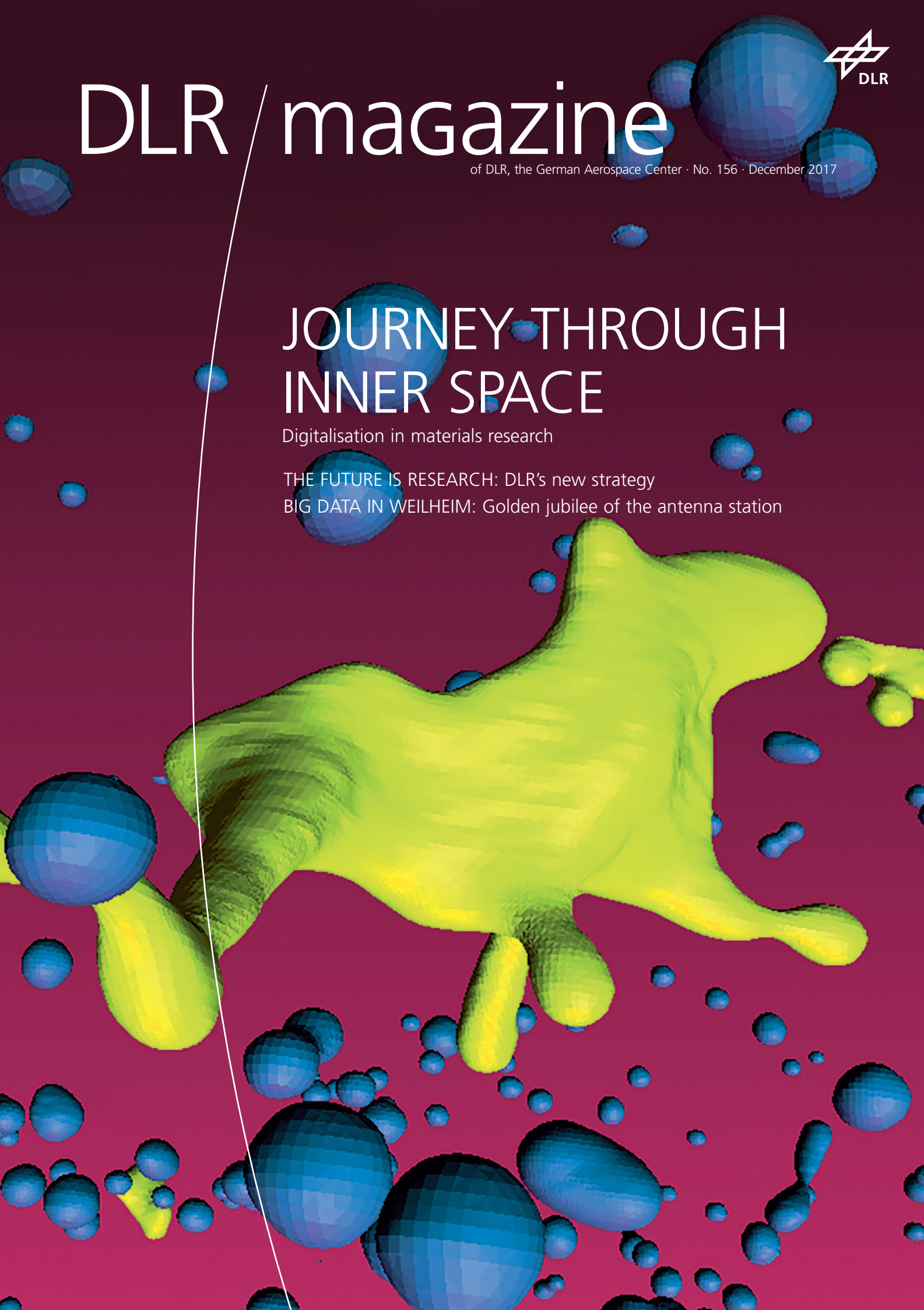


## JOURNEY THROUGH INNER SPACE

Digitalisation in materials research

THE FUTURE IS RESEARCH: DLR's new strategy

BIG DATA IN WEILHEIM: Golden jubilee of the antenna station





Dear readers,

Inner qualities are not always visible at first glance. Sometimes, potential needs to be discovered first. Only after it has come to light can it be exploited to the full. This is also the case in science. For instance, with digitalisation fundamentally changing our lives, DLR is also challenged to realign itself. It has done exactly that, and in 2017 has devised a new strategy, which we present in the last DLRmagazine of the year.

Inner qualities are also quite literally a subject of this magazine: Materials researcher Marion Bartsch and her team went on a journey through the inner space of materials, using numerical methods to reveal the secrets beneath the surface. Thanks to digitalisation, both the potential and the limitations of material innovations in this area are made visible, which is crucial to many applications – whether for aircraft construction, the aerospace industry or other technical facilities.

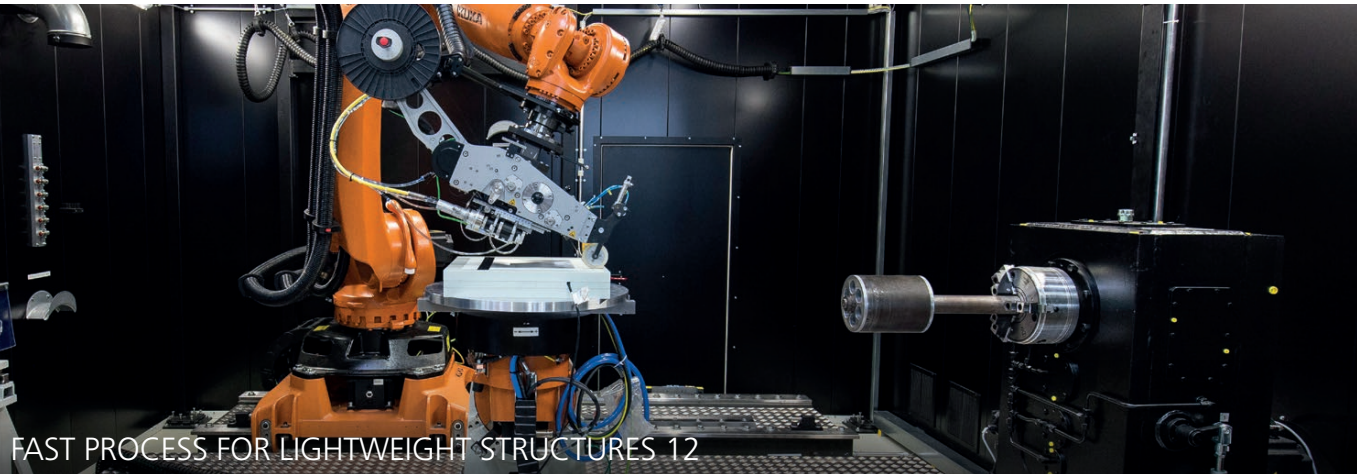
The story of DLR’s Weilheim antenna station began deliberately ‘in the dark’. In 1967, the search was on for a location with low radio interference. Big Data was not yet a concept some 50 years ago. Looking back, the data reception from the first German satellite AZUR in the placid Bavarian town marked the beginning of some remarkable developments. Contemporary witnesses bring this moment to life for readers of the DLRmagazine, including the younger readership. To this day, it has led to the European Data Relay System (EDRS), which provides enormous volumes of data – up to 50 terabytes per day – available for further processing in near-real time.

The DLRmagazine editorial team was also impressed by an unusual-looking aircraft with a single engine attached at the rear between the tailplanes, designed by students who won a design competition run by NASA and DLR. What other interesting topics are there to report on as 2017 comes to an end? A mobile laboratory to detect space debris was set up in Stuttgart, and a new generation of rotor blades for wind turbines was created. The DLRmagazine is always at the forefront. We wish you a great end to the year!

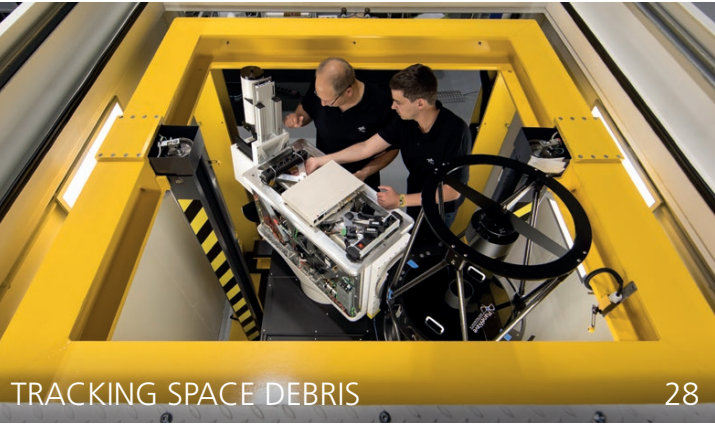
Your magazine editorial team



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# THE FUTURE IS RESEARCH

**C**limate change, the future of energy supply, digitalisation and national security – the 21st century presents new challenges that largely affect the world population. DLR, in its continuous drive to conduct cutting-edge research, strengthen its core competencies, use synergy potentials and provide momentum towards innovation, is ever more responsive to these challenges and will increasingly contribute to finding solutions. The DLR Strategy for 2030 shows the way forward in this respect, and supports society and government in setting the right course.

With its Strategy 2030, DLR is setting the course for dealing with key issues relating to social progress, while strengthening its core competencies and exploiting the potential for synergies.

DLR's pioneering work focuses on aeronautics, space, energy and transport, as well as the cross-sectoral fields of security and digitalisation. In addition to its role as a publicly funded research institution, DLR is also a space agency and project management agency. In all of its roles and functions, DLR's work is aligned with economic demands and societal needs. "We want to strengthen DLR's core competencies and exploit internal synergy potential in a more targeted way, in order to further strengthen DLR's leading position in research for the benefit of society and the economy," explains Pascale Ehrenfreund, Chair of the DLR Executive Board, about the overall line of approach. These ambitions are reflected in the strategic objectives of its research, 10 new cross-sectoral projects and the new cross-sectoral field of digitalisation.

DLR's research is based on the following three guidelines:

- **Excellent science**
- **Contributing to addressing societal challenges**
- **Being an economic partner**

DLR has 40 institutes and research facilities at 20 locations across Germany, including seven new institutes that expand the DLR research portfolio. The DLR Space Administration – in its role as a space agency – conceives the German space programme on behalf of the Federal Government, implements it and integrates all German space activities at the national and European level. In its role as a project management agency, DLR promotes and manages projects and programmes on behalf of several federal ministries and other funding agencies. The DLR Project Management Agency and the Project Management Agency for Aeronautics Research and Technology provide science, innovation and education management for all research areas and along the entire value chain.

## Solutions under one roof

The traditional strength of DLR lies in its unique system capability in Europe for aeronautics and aerospace research, which is maintained and continuously being developed. In the fields of energy and transport research, DLR demonstrates its profound understanding of systems while dealing with key issues that are important for the Energy Transition and future transport policy. DLR will continue to expand the cross-sectoral area of security research in order to be able to offer practical solutions for future threat scenarios. A new cross-sectoral digitalisation field has been established to give due consideration to the current technological and social transformation brought about by the digital revolution.



Environmentally-friendly flight: Joint DLR / NASA research flights have shown that adding biofuel to kerosene reduces aircraft soot particle emissions by more than 50 percent compared to conventional fuel. Scientists on board the DLR Falcon measured the composition of the exhaust gas from a DC-8 that is flying in front of them.

As a research centre, project management agency and space agency, DLR has a unique, bundled spectrum of competencies that provides models and courses of action for important societal issues such as climate change. In this respect, satellite remote sensing data is pivotal for climate research and, at the same time, remote sensing is essential for immediate response of relief services in the event of natural disasters.

The central research areas and cross-sectoral fields have the following strategic objectives:

DLR's aeronautics research addresses all essential aspects of the air transport system – from the basics through to their application – in accordance with the aeronautics strategy of the German Federal Government. This entails the operation of aircraft using intelligent traffic management control systems and communications, as well as the assessment of the effects of air transport as a whole. "The aircraft of tomorrow should be safe, economically viable, environmentally friendly and quiet. The development of such an aircraft is a big challenge. The key to this lies in digitalisation or virtualisation. To this end, we are working on the representation of flying craft, taking into account all characteristics and behaviour, in a virtual atmosphere over the entire product life cycle," outlines Rolf Henke, DLR Executive Board Member responsible for Aeronautics Research. This combines cross-disciplinary research approaches to design, lightweight construction, virtual vehicles, assistance systems and new processes (3D printing) for digitalised production in the virtual product, as well as wind tunnel tests and research flights.

"Satellites enable global communication and navigation services. By further developing these – for example through optical, quantum cryptographic systems – DLR's space research is making an important contribution to digitalisation and the mobility of the future," says



Research for the Energy Transition: High-temperature heat storage materials are key for controllable, renewable electricity. At the DLR test facility TESIS, companies can test components to be used in molten salt storage.

Hansjörg Dittus, DLR Executive Board Member for Space Research and Technology. Satellites are becoming more durable and cost-effective thanks to advances made in robotics. New sensors, mission concepts and high-performance ground infrastructures enable a permanent availability of Earth observation and exploration data for services and science in order to generate new information and knowledge. Environment-friendly launchers and fuels are also analysed and tested to ensure the sustainability of the entire system.

DLR's energy research is making a vital contribution to the Energy Transition and to the decarbonised energy system of the future. It deals with topics that have realistic applications and can make a quantitative difference, especially in the provision of on-demand, environment-friendly electricity. This includes efficient energy storage systems (thermal, electrical and chemical), wind and solar power plants, fuel cells and environmentally friendly gas turbines. Energy systems analysis completes this research with technology ratings and economic deployment scenarios. "The Energy Transition is one of the greatest challenges we face today. It can only succeed if, in addition to power, the areas of heat and mobility are considered. Thanks to its competencies in the areas of energy and transport, DLR is making important contributions towards this topic," emphasises Karsten Lemmer, DLR Executive Board Member for Energy and Transport.

"Transport research at DLR addresses the key challenges of future mobility on the ground: maximum efficiency, minimal emissions and the highest levels of safety. In particular, digitalisation possibilities are used to devise solutions that allow for increased automation, the targeted development and utilisation of new data sources, the intensive networking of different modes of transport, as well as the consideration of the relationships between these different modes of transport," highlights Lemmer.

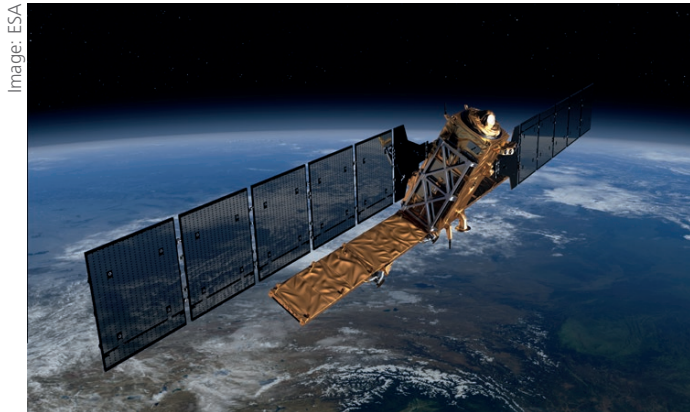


Image: ESA

The launch of the Sentinel-1A satellite on 3 April 2014 marked the birth of the European Earth observation programme Copernicus. Based on satellite observations of Earth, this programme makes information on the state of our environment available and supports diverse applications, ranging from land and forestry management to disaster relief.

DLR's security research covers a broad range of topics, since most societal challenges such as digitalisation, cyber security, mobility and protection of critical infrastructures are closely linked to security. For this purpose, innovative organisational concepts and technologies, as well as the corresponding action strategies, are being developed in close coordination with essential users from industry, government and civil society.

In the new cross-sectoral area of digitalisation, DLR is building on the core competencies of its research interests and areas. With its digital agenda, the German Federal Government has set itself the goal of shaping the digital transformation of the economy and society. DLR is aware of the importance of digitalisation and is therefore expanding its portfolio. The focus is on multidisciplinary and interdisciplinary projects that connect DLR's research areas with each other.

The DLR Space Administration – in its role as a space agency – conceives the German space programme on behalf of the Federal Government. Gerd Gruppe, DLR Executive Board Member responsible for the Space Administration emphasises: “The national space strategy of the German Federal Government is based on excellent science, technological competence and a clear market orientation. The DLR strategy is closely aligned with this. Thanks to its projects and participation in programmes such as Copernicus or Galileo, DLR can be considered a heavyweight in this respect.”

The DLR Project Management Agency will continue to strengthen its position in the market as a system-relevant, internationally-oriented project sponsor with a broad range of topics.

Under the new strategy, DLR will use its strengths to significantly develop technology transfer in the economy and act as a driver of innovation in that respect – not only in its relevant research areas, but in all sectors of the economy.



Mobility of the future: This research intersection in the Braunschweig inner city ring is equipped with sensors that assess local traffic conditions with the aim of better understanding the behaviour of road users.

#### Synergy potential in research – the DLR cross-sectoral initiatives

Synergy potential arises at the interfaces between various research interests and cross-sectoral areas. In the future, these synergies will be systematically identified and consistently implemented. To this end, DLR is launching new cross-sectoral initiatives: 10 new interdisciplinary cross-sectoral projects that will allow DLR to create unique technological and societal added value for Germany that extends beyond the existing focus areas.

The new cross-sectoral area of digitalisation currently comprises eight projects:

- **Digitalisation in the economy**
  - Global connectivity – global broadband access via satellite and high-altitude platforms using laser-based optical data transmission
  - Factory of the future – intelligent robotics in digitalised production processes
  - Simulation-based certification – simulation processes as a basis for technical certification.
- **Big and Smart Data / data science**
  - Big data platform – systematic analysis of large data sets from multiple sources
  - Condition monitoring for safety relevant structures – novel diagnostics for the secure operation of complex structures
- **Cyber security**
  - Cyber security for autonomous and networked systems – in the areas of aeronautics and space as well as ground transport
- **Intelligent mobility**
  - Transport 5.0 – automated and networked transport systems
  - Digital atlas – geodatabase for the transport area of the future



Digitalisation in maritime traffic: Measurement campaign on the coast of Heligoland aimed at transferring larger data sets when seas are rough will contribute to maritime security.

In addition, two projects on **energy storage / energy efficiency** are also being launched:

- Future fuels – fuels of the future, high-capacity chemical storage
- GigaStore – low-cost power and heat storage for the energy and transport system of the future

#### New institutes

Seven new institutes have expanded the DLR research portfolio since November 2016. The new institutes are incorporated and integrated into DLR's research portfolio in such a way that the new competencies will benefit DLR's central and cross-sectoral areas and will strengthen DLR's system capability for research. In the future, the following topics will be investigated in Augsburg, Bremerhaven, Dresden, Hamburg, Jena and Oldenburg:

- Digitalisation in aeronautics research with increased commitment to maintenance and modification, system architectures, software methods, virtual engines and the virtual product
- System technologies to address the Energy Transition
- Solutions for the protection of critical maritime infrastructures
- Big and Smart Data /data science

The new institutes are thus important building blocks for the new DLR strategy.

#### Innovation and technology transfer

In order to increase the potential for innovation and to strengthen the transfer of technology, DLR will be heavily and purposefully investing in innovation projects across all economic sectors over the coming years. These projects will be carried out with partners in industry – small and medium-sized enterprises in particular – as well as other research institutions. In addition, DLR will strengthen support



Digital product development: DLR has set up the Systems & Control Innovation Lab (SCIL) in Oberpfaffenhofen to make modern design technologies and software for mechatronic systems available. It is especially tailored to small- and medium-sized enterprises.

for business start-ups and expand on the possibilities of entrepreneurial participation in its spin-offs. Moreover, it is reinforcing cooperation with industry within the framework of existing and new strategic partnerships for innovation.

#### Research policy framework

DLR offers the economy, society and government its problem-solving competence in the face of upcoming challenges. DLR is particularly guided by the civil and military aviation strategy, as well as the national space strategy, the digital agenda and High-Tech Strategy (HTS), for which the German Federal Government has outlined its key strategic objectives and the priorities of state research funding. The European funding programme Horizon 2020; the coming ninth EU research programme Flightpath 2050; the Strategic Research and Innovation Agenda (SRIA) of the European technology platform ACARE (Advisory Council for Aviation Research and Innovation in Europe); and the energy- and transport-policy objectives of the German government play an essential role in the future and global competitiveness of Europe from the perspective of innovation policy. They also represent important framework conditions for DLR's activities. Another important framework condition is membership of the Helmholtz Association of German Research Centres and participation in the process of programme-orientated funding. Through its interdependent research and development work in aeronautics, space, energy, transport, security and digitalisation, DLR also contributes towards a number of United Nations Sustainable Development Goals (SDGs).

Everyday, people must deal with the effects of global changes in terms of national security, digitalisation, energy supply or climate processes. The dynamics involved are continually increasing. Knowledge-based solutions that can keep pace with the speed of these changes are in demand. The Strategy 2030 aims to further develop DLR's leading position in the field of research for the benefit of society and the economy.



# THE SEVEN NEW INSTITUTES

DLR renews focus on the energy system and digitalisation

## Safe at sea

The maritime industry is becoming more and more complex: the increase in transport by sea, more efficient ports and stronger interconnectivity require both science and technology. Against this background, the security of maritime facilities and systems, such as ships, port facilities, oil platforms and off-shore wind farms must be ensured at all times. This is the focus of the new DLR institute in Bremerhaven. Here, experts are developing analysis methods to determine the risks and hazards for maritime systems. Furthermore, they are developing technologies and security concepts. In this way, they are increasing the resilience of infrastructures to external or internal disruptions.

**Institute for the Protection of Maritime Infrastructures  
Bremerhaven**

**Founding Director**  
Dennis Göge

**Departments**

- Resilience of Maritime Systems
- Maritime Security Technologies

**Planned number of employees**  
50

**Website**  
[DLR.de/mi/en](http://DLR.de/mi/en)



## The new energy system at a glance

Since 29 June 2017, the Institute of Networked Energy Systems has expanded energy research at DLR. The former Oldenburg research centre NEXT ENERGY has been integrated into DLR and realigned. It has since been devoted to researching the structures and challenges of the decentralised energy world. Its scientists are focusing on the development of system-oriented technologies and concepts for sustainable energy supply.

**Institute of Networked Energy Systems  
Oldenburg**

**Institute Director**  
Carsten Agert

**Departments**

- Urban and Residential Technologies
- Energy Systems Analysis
- Energy Systems Technology

**Current number of employees**  
150

**Website**  
[DLR.de/ve/en](http://DLR.de/ve/en)



## Work on the engine of the future

The focus of the new DLR institute in Augsburg is on the quieter and more environmentally-friendly aircraft engines of tomorrow. For this, numerical and experimental procedures are being combined, and the digital platform 'Virtual Engine' is being built. Alongside all engine components, this also includes all physical aspects as well as their interactions. In an innovative test rig, the scientists are investigating the effects of mechanical, thermal and chemical loads on the new materials and components.

**Institute of Test and Simulation for Gas Turbines  
Augsburg**

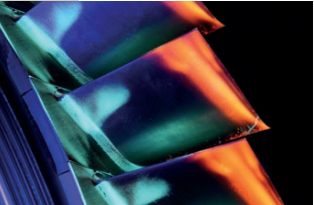
**Founding Director**  
Stefan Reh

**Departments**

- Virtual Engine and Numerical Methods
- Testing and Measurement Techniques
- Information Technology
- Administration and Operational Management

**Planned number of employees**  
45

**Website**  
[DLR.de/sg/en](http://DLR.de/sg/en)



## Aeronautics research and Industry 4.0

The aeronautical system comprises many areas that must be perfectly aligned with one another. Starting from the air transport system as a whole, to the aircraft, and right up to production of its individual components, the different levels can still be separated out. In Hamburg, the new DLR institute is researching the interactions between the various system levels. The focus is on coupling virtual product designs with digital production in the framework of Industry 4.0. The experts are also working on new solutions for the fuselage and cabin.

**Institute of System Architectures in Aeronautics  
Hamburg**


**Founding Director**  
Björn Nagel

**Departments**

- Aircraft Design and System Integration
- Automation
- Energy and Security
- Cabin and Payload Systems

**Planned number of employees**  
80

**Website:**  
[DLR.de/si/en](http://DLR.de/si/en)



## Aircraft maintenance on the computer

The regular maintenance of aircraft is an indispensable part of their lifecycle, but also means they cannot be in operation continuously. The DLR institute in Hamburg is, for the first time, covering the complete maintenance process with its research. The 'digital twin' is at the centre of the real aircraft, a model that changes with it and therefore supports the efficient and predictive operation of the aircraft. The researchers are also investigating the use of new technologies for data integration and visualisation, as well as for linking individual process steps such as monitoring and repair measures.

**Institute of Maintenance, Repair and Overhaul  
Hamburg**

**Founding Director**  
Hans-Peter Monner

**Departments**

- Maintenance and Repair Technologies
- Process Optimisation and Digitalisation
- Product Lifecycle Management

**Planned number of employees**  
80

**Website**  
[DLR.de/mo/en](http://DLR.de/mo/en)



## Managing data intelligently

The volume of data collected for scientific research is no longer growing linearly, but rather exponentially due to increasing digitalisation. In order for researchers to be able to use the data optimally, it must be stored, consolidated and analysed in an expedient way. In Jena, scientists at the new Institute of Data Science are working on the question of how the scientific information from all DLR research areas can be organised and processed. Their research focuses on the areas of IT security, preparation and analysis of data, Industry 4.0, Citizen Science and the Internet of Things.

**Institute of Data Science  
Jena**

**Founding Director**  
Robert Axmann

**Departments**

- Data Management and Analysis
- Smart Systems
- IT Security
- Citizen Science

**Planned number of employees**  
65

**Website:**  
[DLR.de/dw/en](http://DLR.de/dw/en)



## Ensuring the take-off of digital aircraft

In Dresden, work is currently under way on the software foundation for virtual aircraft. It should behave in the same way as the real aircraft under all circumstances. In close collaboration with engineers from specialised institutes, the scientists are developing multidisciplinary software platforms on high-performance computers with which the virtual product can be comprehensively analysed and optimised. They are also investigating new approaches and methods to analyse and manage large volumes of data as well as for simulation-based certification. In this way, they are reducing cost-intensive development work and lengthy testing procedures that are generally needed for certification of the aircraft.

**Institute of Software Methods for Product Virtualization  
Dresden**

**Founding Director**  
Norbert Kroll

**Departments**

- High Performance Computing
- Platform Research
- Software Development

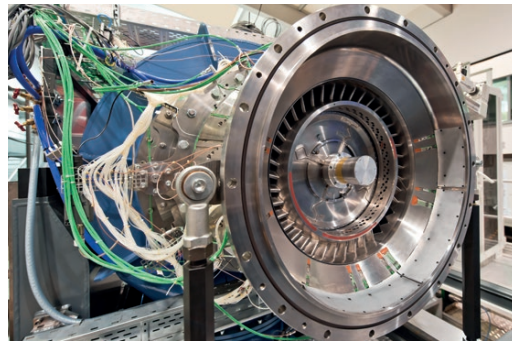
**Planned number of employees**  
70

**Website**  
[DLR.de/sp/en](http://DLR.de/sp/en)





# NEW TURBINE FOR ENVIRONMENT-FRIENDLY AIRCRAFT



View into the new turbine test rig at the DLR site in Göttingen

DLR researchers from Göttingen have examined the interaction between the combustion chamber and aircraft turbine in a new test rig. The interface between the two represents significant challenges for engine manufacturers in their quest to produce more environmentally-friendly aircraft – in addition to the very hot gases, there are also extremely turbulent air flows. Until now, it has only been possible to examine these two components under realistic conditions separately rather than as a whole. Now thanks to the new 'Next-Generation Turbine' (NG-Turb) system, the combustion chamber and turbine can be examined together.

What makes this project special is the use of a combustor simulator in the inflow of the turbine combined with various pneumatic and optical measurement techniques using laser and infrared light. The objective of the

FACTOR (Full Aerothermal Combustor-Turbine interactiOns Research) project is to investigate and better understand, in particular, the effect of combustion chamber outflow, which can reach up to 1700 degrees Celsius, on turbine function. Researchers use highly accurate measuring methods that are not suitable for use under real engine conditions. This should not only reduce fuel consumption and pollutant emissions, but also improve the service life and optimise the maintenance costs of the turbine components.

The NG-Turb test rig is among the most powerful international test facilities for aircraft turbines. It is capable of analysing the turbines of modern aircraft in detail – from business aircraft to the A380.

# SOLAR PANELS ON THE ROOF – ALSO A MATTER OF PSYCHOLOGY



Photovoltaic power plant in Oberstdorf

Perhaps to the surprise of most homeowners, quite a bit of behavioural psychology is involved in the decision to purchase solar panels. A DLR study shows that a boom in solar panel sales right before a reduction in the feed-in tariff cannot be explained using economic models alone. When additional models based on behavioural economics and cognitive psychology are taken into account, researchers can very accurately predict this type of investment behaviour. Over one million solar panels have been installed on the roofs of German homes over the last few years, funded by the German Renewable Energies Act (EEG). In order to explain the reasons for German residents' investment in solar panels, researchers calculated how much would have been earned with a solar panel and set this profitability against the actual installation. It became clear that whenever legislators reduced the subsidy, there was a boom

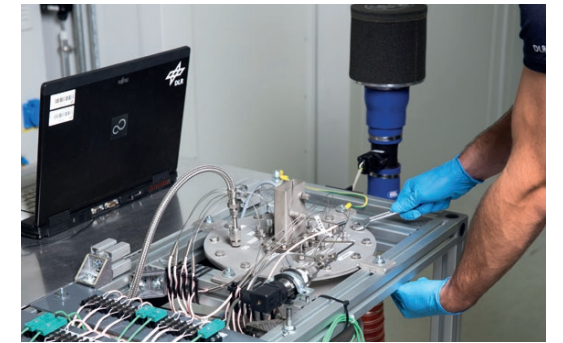
in investment. Residents clearly wanted to profit from a comparatively higher feed-in tariff even if the ultimate profit forecast was not that high at the time.

The investment boom is best explained by 'cognitive bias', that is the systematic deviation from what would have been expected from a rational point of view. According to this, a particular incentive to buy comes from the fear of not having taken advantage of a benefit that will no longer be available in the future.

# INCREASING ELECTRIC VEHICLE RANGE IN THE WINTER

During the winter months, vehicles with electric drives experience a reduction in range. With DuoTherm, DLR scientists have developed a concept in which an efficient heat accumulator takes over the heating capacity in the electric vehicle. Using metal-based latent heat accumulators makes it possible to design an energy storage system able to store heat at a very high energy level. In this way, the storage system can be used to heat the vehicle interior, thereby relieving the drive battery of this task. Latent heat accumulators using metals, such as an aluminium-silicon alloy, not only provide a high specific energy density, but also high thermal conductivity. These storage systems absorb latent heat during a phase change, such as from solid to liquid, and can release this heat again. They store more energy than other forms of thermal storage systems at a small volume and with a low mass, and are therefore well-suited for space-saving installation in electric vehicles.

The project goes one step further – not only would the heat exchangers improve range and comfort, they are also set to maximise the overall efficiency of vehicles by absorbing braking energy, offsetting charge losses and cooling the battery. In order to increase the range and efficiency as a whole, the use of high-temperature storage systems alone is not enough. For this purpose, DuoTherm combines a high-temperature storage system with a low-temperature storage system. The latter can store heat from heat losses that often occur only at low temperatures. This enables higher overall efficiency without additional charging times for the thermal storage system. The system is also more cost-effective for the producer and end consumer than a solution involving a second battery, for example.



Test bench for the investigation of a latent heat storage system

# STUDENTS RESEARCH THE STRATOSPHERE

In October 2017, international student teams launched microgravity research experiments into the stratosphere with the BEXUS 24 and 25 research balloons from the Esrange Space Center near Kiruna in northern Sweden. Each of the two research balloons from the joint DLR and Swedish National Space Board (SNSB) mission carried four scientific experiments by students from Spain, Italy, Sweden, Great Britain and Germany. The experiments included detecting elementary particles (muons), which travel at almost the speed of light, as well as the impact of cosmic radiation on electronic storage systems. Other experiments included testing the stability of a spring-based reflector antenna in the stratosphere and examining infrasound in the stratosphere and troposphere.

The objective of the 'HAMBURG' student team was the automated collection of iron-nickel-containing meteorites smaller than 100 micrometres, which are carried by winds in the atmosphere. The team from Dresden tested solar cells under space conditions. The experiments also focused on the relationship between Earth's incident and reflected solar radiation, as well as a particularly stable telescope.

The German-Swedish BEXUS programme (Balloon Experiments for University Students) allows students to gain practical experience in the preparation and implementation of space projects.

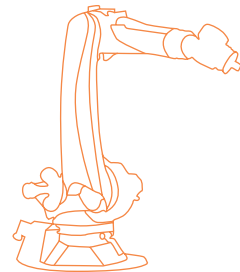


BEXUS 24 on 18 October 2017



# LIGHTNING-FAST PROCESS FOR LIGHTWEIGHT STRUCTURES

The right material in the right place – but which one should be used where? This is a key issue in lightweight construction, regardless of whether it involves a car, aircraft or space rocket. And it is not just a matter of how light and strong the material is, but also whether it is easy to manufacture. Scientists at the Institute of Structures and Design at the DLR sites in Augsburg and Stuttgart are investigating how lightweight constructions can be efficiently produced in high volumes and with a consistent level of quality. Special attention here is being paid to carbon-fibre-reinforced thermoplastics, which are increasingly gaining in importance due to their special properties, particularly in the aviation industry. Although at present their production is time- and energy-intensive, they offer great potential for automation.

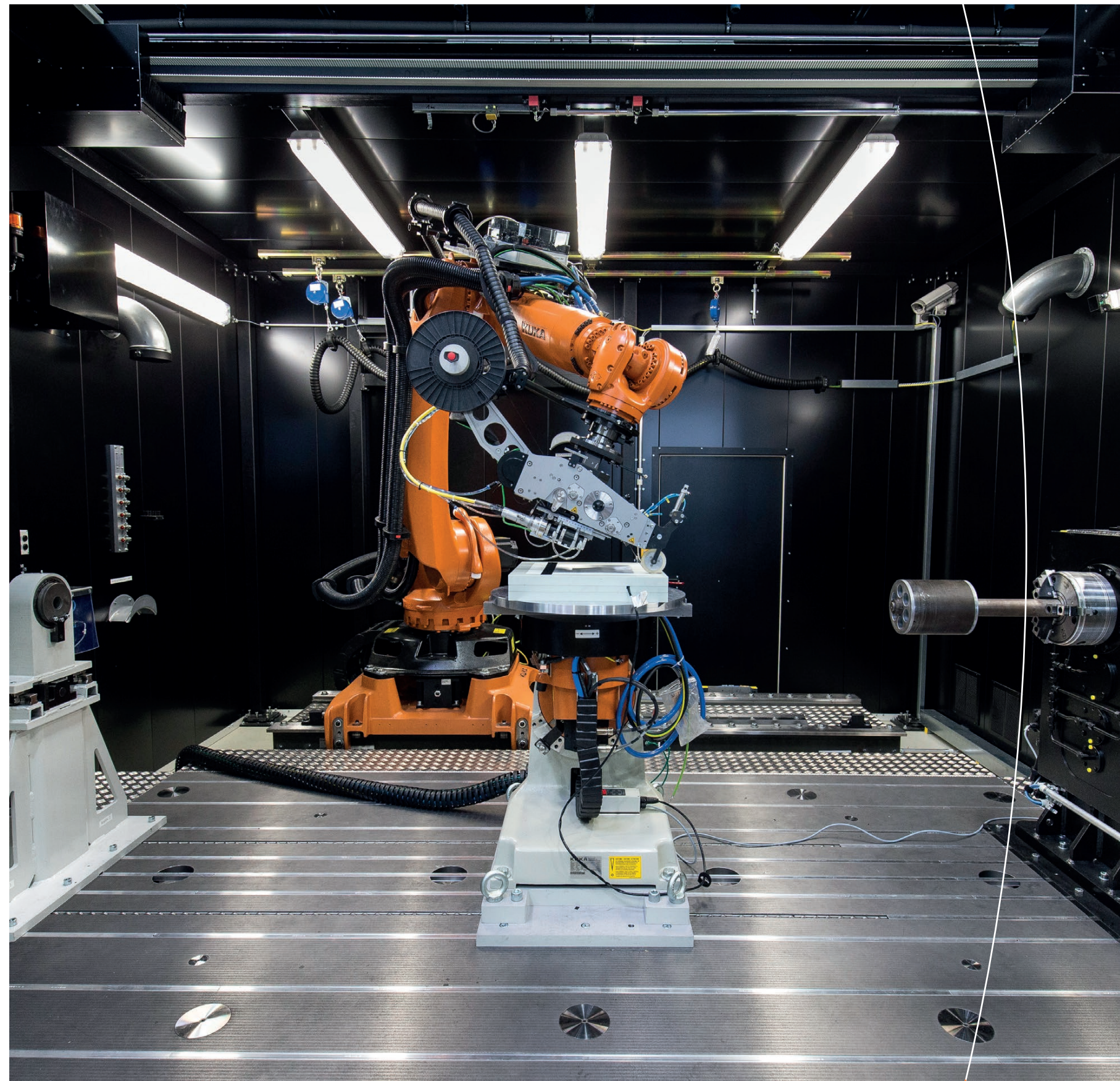


Thermoplastics exhibit appealing advantages. DLR researchers in Stuttgart and Augsburg are preparing them for application.

By Nicole Waibel

Upon entering the technology hall at the DLR Center for Lightweight-Production-Technology (Zentrum für Leichtbauproduktionstechnologie; ZLP) in Augsburg, one is struck by the state-of-the-art robotic equipment – and today, even some very impressive soundscape. The almost eight-metre-tall hot press is already operational and making quite some noise.

Matthias Beyrle, head of the Processes and Automation Group, explains what it is about high-performance thermoplastics that has lightweight materials engineers talking about them: “There are basically two types of carbon-fibre-reinforced plastics (CFRPs) that are distinguished by the matrix – thermosets, which are currently used most often in aeronautics, and thermoplastics. Once cured, for instance by heating in a furnace, thermosets retain their shape permanently. Thermoplastics, on the other hand, can be repeatedly remoulded within a specific temperature range.” But the reason for the growing popularity of thermoplastics for CFRPs is not just their formability – the possibility of shortening process times, lowering costs and increasing production rates makes them particularly appealing. Researchers are working on eliminating the need for expensive autoclaves in the production of components, and instead constructing them in layers while consolidating them. This thermoplastic tape-laying – which is also suitable for larger structures – will make costly vacuum assemblies and furnace runs a thing of the past.



Tape layer machine at the Institute of Structures and Design in Stuttgart. It builds the material (tape) layer by layer in exactly the right shape so that there is minimal material loss and puts it in the right place for further processing.



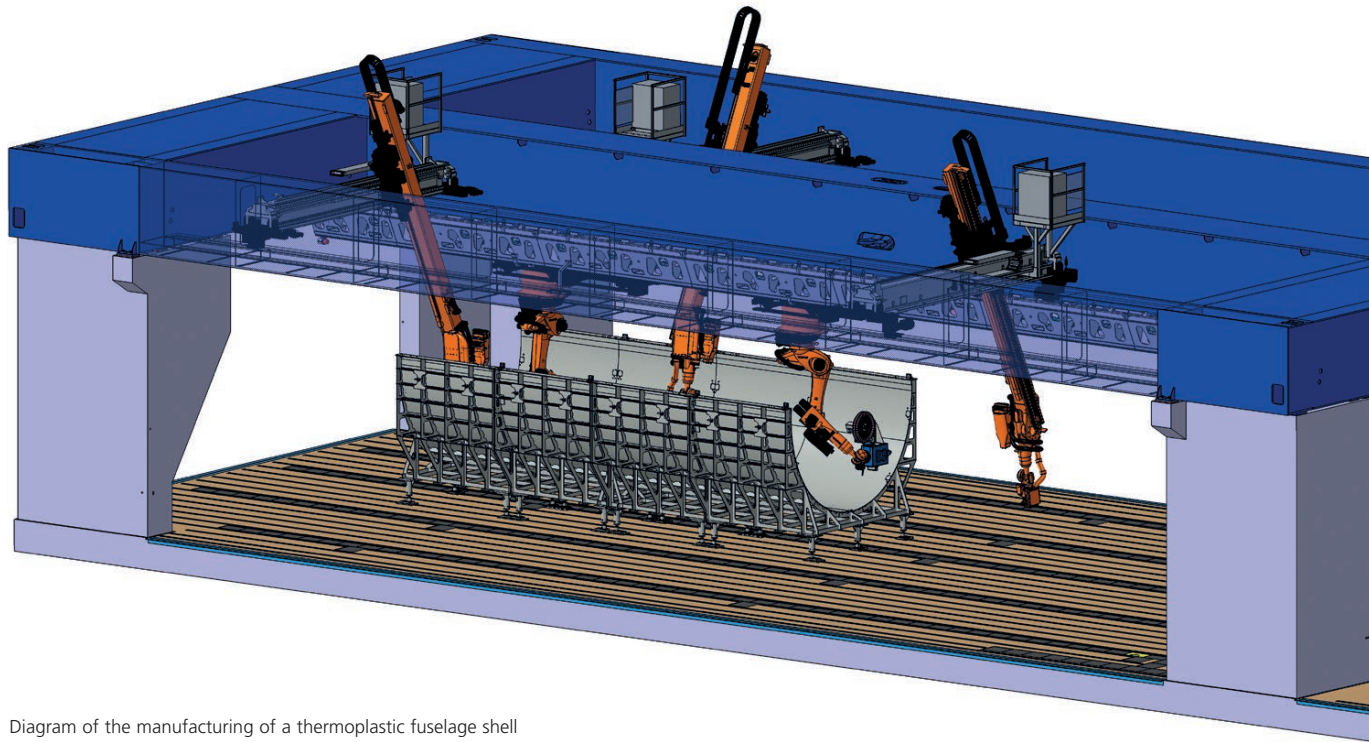


Diagram of the manufacturing of a thermoplastic fuselage shell

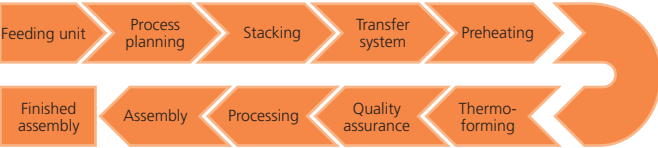
DLR scientists are developing solutions for the automated production of high-performance thermoplastic structures in order to exploit the good material properties, as well as the benefits in moulding and welding. To do so, they require a seamless process chain – from the supplied roll of materials to component manufacturing and the welded assembly. "We have already set up a continuous process chain to manufacture thermoplastic components at the prototype production line of the ZLP," says Frederic Fischer, lead expert in thermoplastic production technology at the ZLP. In the so-called patch preforming process, many tailor-made individual cuts are stacked on top of one another. Using curved moulds, it is possible to manufacture panels for aircraft fuselage and door structures. The resulting preform of layers is then consolidated in a furnace under vacuum conditions or by using a hot press. Fischer elaborates: "Through our research, we are aiming to provide the right material and suitable production technology for each specific application."

### In good shape – thanks to pressure and heat

Thermoplastics are manufactured under high pressure and temperature – approximately 400 degrees Celsius are needed to manufacture high-performance materials, such as polyetheretherketone (PEEK). "Our hot press gives the materials the right shape at a temperature of up to 450 degrees and a press force of 4400 kilonewtons," explains Beyrle, pointing to the large installation whose infrared heating panel is currently lit up in an orange-red glow. Using the hot press, mainly small to medium sized components can be produced. "To validate our production and assembly processes, we have manufactured and welded a demonstrator assembly," Beyrle says. The selected one – a sine wave beam assembly – consists of seven separate components and can be used as a crash absorber in a helicopter subfloor structure, for example.

"It all starts with the design of the component," says Sebastian Nowotny, head of the Design and Production Technologies Department at the Institute of Structures and Design in Stuttgart. "We determine the behaviour of the material during shaping and cooling

in a production simulation. This gives us the design of the mould." The next step is the automatic production of the component at the ZLP in Augsburg. Beyrle adds: "First, we make plies with the cutter. Then, a mobile drawer cabinet docks with the robot cell and transfers the plies to the processing area. These are picked up, precisely laid down, and attached using a camera system on the robot that was developed at the ZLP by Alfons Schuster and his team. The layer stack is then pre-consolidated in the furnace, placed in a tenting frame by the robot, and transported to the press preheating area with the aid of a specially-developed transfer gripper. There, the component is heated up to the required manufacturing temperature by an infrared



heater. It is then moved into the hot press, where the component is shaped into its final geometry. This is followed by the quality inspection, processing and assembly.

### Beacon of hope – thermoplastic tape laying

The scientists also see great potential in in-situ consolidation using tape-laying technology. "To date, this has yet to be successfully demonstrated to a sufficient extent. But if this were to become feasible in the near future, the vacuum consolidation in a furnace could be done away with, leading to enormous savings," says Nowotny.

The Institute has a tape-laying machine. Components with a length of up to 3.6 metres, a diameter of 1.8 metres, and a weight of up to 2000 kilograms can be manufactured and processed here. The unit consists of a robot with a special head that lays a strip of material made of carbon-fibre-reinforced plastic directly onto a mould, thus

building the desired component – layer by layer. This tape, which is between six and 25 millimetres wide, is heated with infrared lamps – or with laser beams, as is the case in the Stuttgart facility – prior to laying, and then fixed with a pressure roller. Nowotny describes the advantages of the technology: "If the forces acting on a component require a reinforcing layer on certain parts of the structure, we can put such a layer precisely where it is needed. This means significantly less off-cutting compared to other fibre-composite technologies."

The scientists are collaborating with their colleagues at the Institute of Materials Research in Cologne to pool their knowledge of materials, and with colleagues from ZLP Augsburg on issues involving robotics. There, the researchers are currently working on a thermoplastic fuselage shell demonstrator that uses patch preforming technology. The aim is to combine both production technologies to the benefit of the final part.

### Saving weight by welding

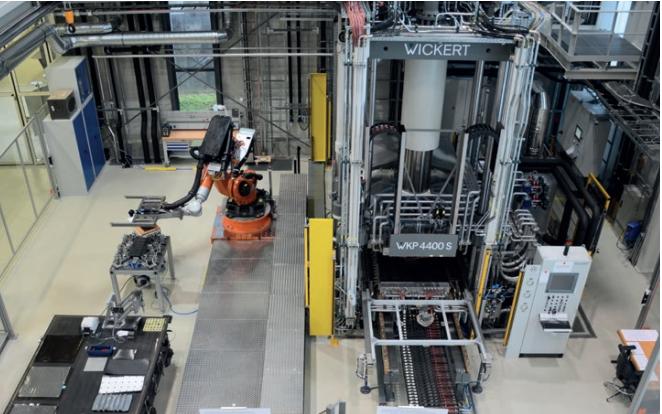
In order to bond structures made of CFRP, they are increasingly being glued together. However, for the most part, they are still attached to one another mechanically, using bolts or 'chicken rivets'. "Holes are bored every couple of centimetres, and cutting through load-bearing fibres weakens the structure. Furthermore, such connecting elements add to the overall weight," explains Lars Larsen, Head of the Assembly and Joining Processes group at ZLP in Augsburg. "An aircraft fuselage consists of the outer skin and – as with a half-timbered house – reinforcing elements, such as longitudinal stringers and vertical frames. Clips are needed to attach these to the aircraft skin. These have previously been attached using bolts. There are thousands of clips in an Airbus A350 XWB, for example."

Saving weight – and thus fuel, emissions and costs – is a key issue in aircraft construction. Bonding technologies such as welding, which can be done without rivets or bolts, are therefore on the rise. Carbon-fibre-reinforced thermoplastics offer this option for rivet- and bolt-free assembly; one of the outstanding features of this material is particularly its suitability for welding. "Welding enables very solid, flat and tight connections and offers considerable potential for saving both weight and costs," Larsen says.

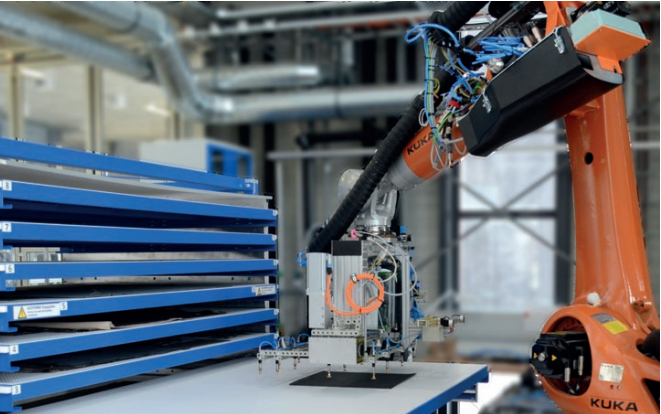
### Dust-free assembly – an option for aircraft construction?

In a live demonstration at this year's JEC World in Paris, the researchers showcased a lightweight construction robot that attaches carbon-fibre-reinforced corners to a composite material panel. The implant resistance welding process was used for this. "To do this, a conductive welding element made of special stainless steel and glass-fibre fabric is placed between the two parts to be joined. Electrical power is used to heat these to several hundred degrees Celsius, melting the entire assembly directly in the connecting zone, while the elements to be joined are pressed together under pressure," says Larsen, explaining the process. This all happens fully automatically, using a compact gripper developed at ZLP Augsburg. "Since the welding process can easily be automated, this is very promising for series production," Larsen adds. And welding has other advantages: "As no bore holes are required, not only do the load-bearing fibres remain intact, but no dust is generated during joining." This opens up new possibilities for the final assembly of future aircraft. For example, pre-assembled cabin components and systems in the cabin can be installed quickly and easily. Aircraft would not only become lighter, but their manufacturing process would also be shorter.

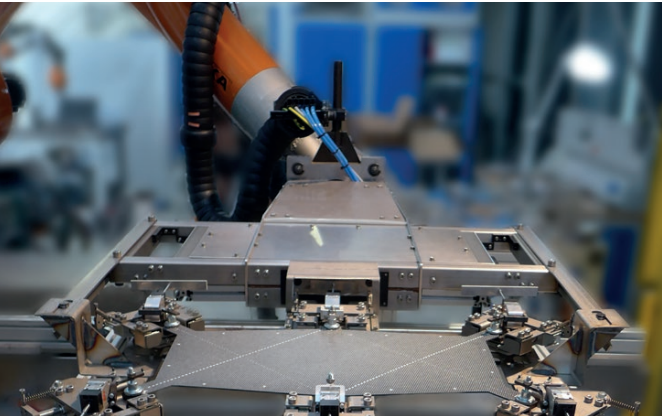
**Nicole Waibel** is responsible for public relations and other areas at the Institute of Structures and Design in Stuttgart and Augsburg.



Thermoplastics area at ZLP Augsburg with a robot (left) and hot press (right)



Plies are provided using a mobile drawer storage unit. Thanks to a camera system, the robot's gripper automatically detects the plies and places them.



Component in the tenting frame before thermoforming (hot pressing)



Component in tenting frame after thermoforming (hot pressing)



# SMART ROTOR BLADES

This 20-metre long wind turbine rotor blade was lifted out of the mould at the DLR Center for Lightweight-Production-Technology (Zentrum für Leichtbauproduktionstechnologie; ZLP) in Stade on 29 September 2017. A team of technicians and engineers spent many months manufacturing the masterpiece – which is made from various fibre composite materials – as part of Project SmartBlades2. Thanks to bending torsion coupling, the rotor blade is expected to be capable of adapting to variable wind conditions. In the preceding SmartBlades1 project, partners in the Research Alliance for Wind Energy (Forschungsverbund Windenergie; FVWE) jointly investigated technologies for manufacturing and assembling rotor blades up to 80 metres in length. These technologies are now being used for the first time. On this scale, a blade must remain light enough so that it can still be easily transported and assembled. In addition, it must be able to withstand strong gust loads and provide an even greater energy yield. Researchers plan to advance the new technology to the point where the blades can be cost-effectively produced by industry.

[www.smartblades.info/English.html](http://www.smartblades.info/English.html)



After the two halves are put together to see how they fit and adjusted precisely, they are welded and cured.



The first SmartBlade fresh from the mould



# JOURNEY THROUGH INNER SPACE

**A** component is only as good as the materials it is made of. And the quality of those materials depends on their composition and microstructure. Scientists at the DLR Institute of Materials Research use modern imaging techniques to get a picture – in the truest sense of the word – of the three-dimensional microstructure. Using X-ray tomography and focused ion beam serial sectional techniques, the researchers obtain very high-resolution three-dimensional images of the microstructure. From these, they can generate three-dimensional digital models. With relatively little experimental effort, and in a very short time, they can draw conclusions regarding the effect of the microstructure on the properties of a material, which is advantageous for materials developers and component designers.

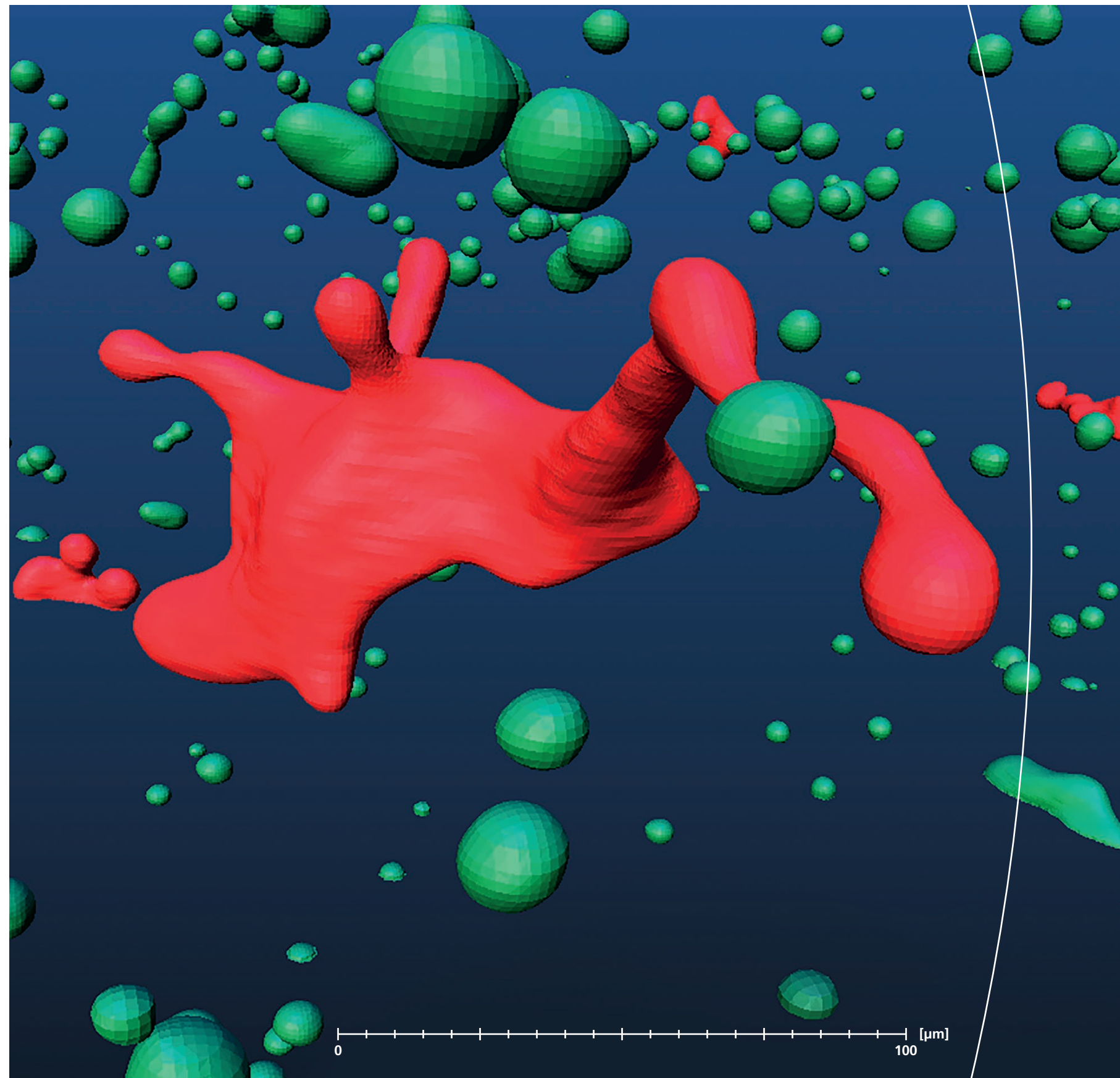


## Digitalisation in materials research

By Marion Bartsch and Klemens Kelm

When a new material is developed, it is expected to have better properties than its predecessor. An important starting point for the development of new materials is their internal structure. What appears to be a uniform block of material from the outside often looks quite heterogeneous when viewed from up close. Metals, for instance, mostly consist of many small crystals that have a different chemical composition and crystal structure. In fibre-composites, the fibres are aligned more or less regularly, and there are often pores or cracks. For some applications, these imperfections are disruptive and can cause a component to malfunction. In other cases, pore and crack networks ensure that a component endures and can suffer damage without malfunctioning. Small defects make ceramic fibre-composite materials, for example, damage-tolerant. It is therefore important to understand the relationship between the microstructure of the material and its properties, especially if its behaviour in a component needs to be calculated under operating loads. The first step in this direction involves obtaining an accurate image of its microscopic structure.

Modern methods make such a deep insight possible. Three-dimensional digital representations can be generated from microscopic images of sequential slices through the material, or from series of X-ray images on a computer. Digitalisation enables some properties that describe the structure to be numerically determined. The digital images can then be converted into a computer model from which the mechanical or other physical properties of the material can be derived. With the results of these calculations, a decision can be made



Three-dimensional digital image of pores in a nickel-based super-alloy for highly-stressed components in aircraft turbine engines. The red irregular shapes are pores that are formed during the solidification process. The smaller, green, round-shaped pores are generated to a large extent during the heat-treatment after solidification. The size and shape of each pore, as well as the number of such pores can be easily obtained from the digital images. This information is important as, during operation, fine cracks may form in the component where pores are present.



as to whether a new material is promising and whether determining its properties more precisely in time- and cost-intensive tests is worth it. The calculation models also help to understand precisely why a material has certain properties and what happens to it when it is under a mechanical load or is exposed to high temperatures.

### Generating digital 3D images

How can a digital three-dimensional image and then a calculation model be derived from an actual piece of material? One option is to thinly slice the material sample, take a picture of each slice, and thus generate a three-dimensional image from the individual pictures. As the dimensions of the internal structure are generally very small – often less than a micrometre – these cuts are not made with a saw or an angle grinder, but with a very fine ion beam, generated by a so-called focused ion beam (FIB) device.

The FIB device generates an ultra-fine focused beam of electrically charged gallium atoms in a vacuum chamber. When this ion beam encounters the surface of a material, the ions knock atoms off the surface at that spot. If the ion current is high enough, the ion beam can cut fine trenches into the surface of the sample.

If the ion optics is built into a scanning electron microscope, this is called a dual beam focused ion beam (FIB) system. In this case, the ion optics and electron optics are arranged in such a way that their axes intersect at an angle of 52 degrees to one another, and both the ion and electron beam can be focused on the point of intersection. In this arrangement, a thin slice of the material under investigation is removed with the ion beam. The electron optics is then used to capture an image of the exposed surface, just like in a normal scanning electron microscope. This process of removing a layer from the surface and subsequently taking an image of it is repeated until the required volume of sample to be investigated has been processed.

The researchers then combine the individual images on a computer. The result is a digital three-dimensional image-like dataset that is divided into small virtual volumes, called voxels. Each voxel is allocated a grey value between black and white. How small the details are that can still be detected in the image of the material microstructure under investigation depends on the cutting width of the ion beam, on the pixel size of the images taken with the scanning electron

microscope and on the number of grey levels. With this process, scientists achieve an image resolution of less than 100 nanometres (0.0001 millimetres).

Another technique for obtaining three-dimensional images is X-ray tomography. In this method, the object under investigation is gradually rotated on an axis, and an X-ray image is taken after each of the often several hundred steps. The X-ray imaging proceeds much like how X-rays of broken bones are taken in a hospital, whereby the object in question is radiographed with X-rays, and the projection is displayed on a screen. The structure of the object can then be calculated or reconstructed from the numerous X-ray images. In order to capture details that are arranged behind one another in a certain viewing direction and make them visible in the overall model, many X-ray images are needed. This process is called back projection and has become easy to carry out thanks to powerful computers.

X-ray tomography with laboratory devices does not achieve the same high image resolution quality as the focused ion beam cutting technique – the threshold is normally a few hundred nanometres. But by using certain X-ray sources and special imaging techniques, details that are less than 100 nanometres in size can be displayed. The major advantage of X-ray tomography is that it is a non-destructive technique, so the material sample does not have to be cut. This is particularly important if you want to know whether the interior of the material has incurred any kind of damage during manufacturing or use. Cutting the material for examination can cause additional damage, thereby distorting the results of the investigation.

### Analysis of the images

Three-dimensional imaging of a material's microstructure not only provides far more comprehensive information on the details of the material's interior than is possible with individual two-dimensional sectional images; much more can be done with the 3D digital information, as for each voxel the position and brightness/grey tone are known. With this information, the sample can be further analysed. In a first step, the various voxels are allocated to the relevant materials that make up the sample according to their brightness. This is easy if materials that are next to each other in the microstructure are very different. An empty pore or air pocket, for example, differs very clearly from the dense material surrounding it. If there are only slight

differences in brightness between adjacent areas, additional information is needed to be able to determine whether the material is the same or different. The criteria for this can be the shape, size and arrangement of the area in question with respect to other structures. After determining the allocation criteria, all voxels are automatically allocated to their respective material using computer image analysis programs. This process is called segmentation, and the result is a data set that represents the spatial distribution of the various material components in the sample under investigation.

With skilful segmentation, it is even possible to characterise spongy structures that are hard to describe, such as aerogel materials. Aerogels are a relatively new class of materials with very low density and excellent thermal insulation properties. They have enormous potential for use in thermal protection systems for aircraft turbine engines or space vehicles, for example. On a digital structure model of such a spongy aerogel generated by X-ray tomography, the larger cavities can, for example, be separated out, so they can be analysed automatically like closed pores.

If a material exhibits different classes of pores with varied shapes or sizes, statistical data can be gathered to describe the total amount of pores, such as the distribution of the various pore sizes or their aspect ratio. Where groups of pores can be put together in a class, they can also be represented in different colours. The images that arise from this are special, not only because they help to understand the structure of the material and even its behaviour under operational loads, but also in terms of aesthetics.

### Computational models

In a further step, it is possible to generate a simulation model from the segmented digital illustration of a sample volume with which the mechanical or other physical properties of the material can be calculated. To do so, the virtual volume of material or the components of the microstructure with the same material can be divided into small areas known as finite elements. Thanks to their small size and simple geometry, their behaviour under a load can be quickly calculated. The finite elements of the model are coupled together using mathematical equations so that an acting force can be transferred from one element to its neighbouring element. This enables the behaviour of the entire model to be calculated.

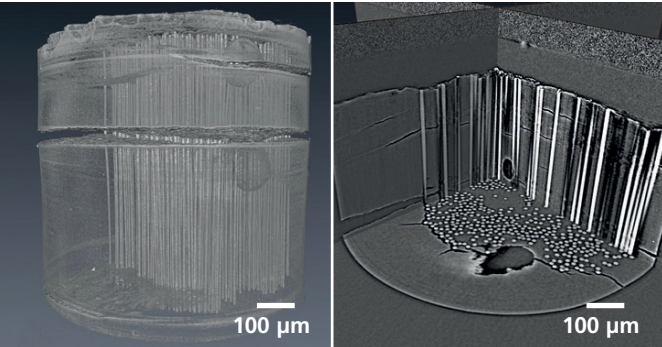
Mechanical analyses require the mechanical properties of the materials found in the microstructure in addition to the geometric microstructure model. If such a model is virtually stressed using a computer program, the calculated result reveals the deformation of the entire model and the local deformation in the microstructure. This can be very irregular.

Microstructure models that are generated through X-ray tomography or using the focused ion beam sectioning technique have a small disadvantage. Since they are very small in relation to the component, they cannot be regarded as representative. Statistical data describing the material components is used to draw reliable conclusions about the quantitative effect of the microstructural makeup on the material properties. For example, in a porous material, if the pore size distribution, the aspect ratio of the pores, and their spatial orientation are known, it is possible to use this data to generate multiple microstructure models that are all slightly different but have the same geometric characteristics. Using the calculated properties of numerous such microstructure models and the distribution of the results, it is possible to draw conclusions on the relationship between the microstructure and the properties. Through systematic variation of the microstructural parameters, it is even possible to predict properties of materials that do not yet exist.

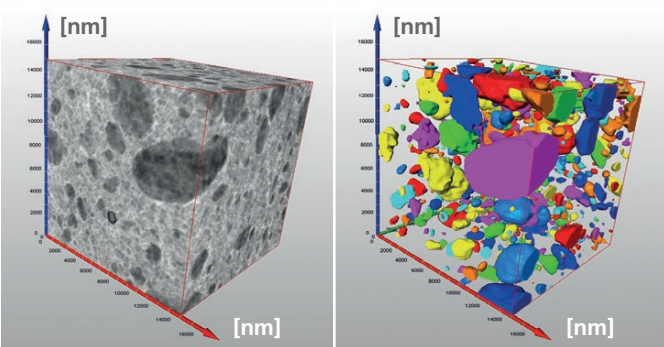
The simulation of materials – this virtual journey into a material's innermost regions – gives the developers of new, more efficient materials valuable information on what is happening in the concealed areas. Thanks to digitalisation, the limitations and potential of materials innovation become apparent, which is fundamental for a myriad of applications.

**Marion Bartsch** is Head of the Department of Experimental and Numerical Methods at the DLR Institute of Materials Research in Cologne. She is also professor of aerospace materials at the Ruhr University Bochum.

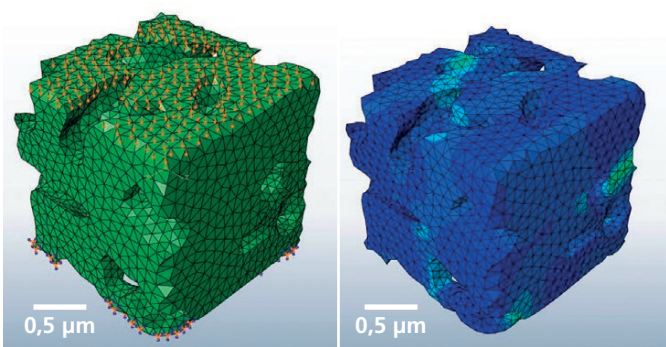
**Klemens Kelm** heads the Central Analytical Research and Metallography service group at the DLR Institute of Materials Research and is a lecturer at the Hochschule Bonn-Rhein-Sieg, University of Applied Sciences.



The images show a ceramic fibre bundle embedded in a ceramic matrix. During the fabrication process, small cracks have emerged at the surface of the fibre bundle that are diverted or stop at the fibres. The data for the images was collected from several X-ray images taken from different directions. For this technique, the sample does not need to be sliced. From this data, virtual cuts in any direction can be calculated.



The grey image shows the porous network in an aerogel material. The image was taken using a special X-ray technique called holotomography, which makes extremely small structures visible. The coloured image shows the same aerogel sample. The cavities in the sponge-like structure are separated and sorted by size and artificially coloured accordingly. By separating the structure into groups of pores it is possible to quantitatively describe the structure of the material.



A simple calculation model has been developed from the digital structural data of a porous ceramic material. The structure was divided into finite elements, tetrahedron-shaped areas in this case. It is easy to calculate these individual tetrahedrons, and the results are combined using mathematical equations. A virtual compression test was carried out by computer here, represented in the left image by the arrows on the top side of the structure whereby the fixation of the bottom is also indicated. Right image: the model under compression. The colours show how much each area is being deformed. The entire model is slightly deformed but, due to the porous structure, the deformation is not uniform.

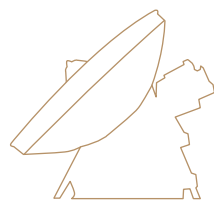


Philipp Watermeyer (left) and Mario Eggeler with the dual beam focused ion beam system. Material samples can be cut into very thin slices using this system. An image of the surface of each of the slices is made using an electron microscope. A digital 3D image-like dataset of the material is then calculated from the individual slices with a computer.



# GOLDEN JUBILEE OF BIG DATA IN WEILHEIM

**F**ifty years ago, the term Big Data was not yet widely known. And yet, in the small town of Weilheim, Big Data was the order of the day – a ground station was set up there to receive data from space. In mid-October 1966, the then German Federal Ministry of Scientific Research (Bundesministerium für wissenschaftliche Forschung; BMWF) mandated the German research institute for aviation (Deutsche Versuchsanstalt für Luftfahrt; DVL) to design, build and operate a central station for the German ground station system (Zentralstation des deutschen Bodenstations-systems; Z-DBS). The Institute for Aircraft Radio and Microwaves at the time – today the DLR Microwaves and Radar Institute – took on the mammoth task. The approaching launch of the first German satellite, AZUR, gave momentum to the construction of the ground station in Weilheim in October 1966. This momentum would accompany the placid town of Weilheim from that moment onwards.



The DLR ground station in the Bavarian town of Weilheim has been the reliable link between satellites and Earth for half a century

By Miriam Poetter



AZUR – the first German research satellite

With the launch of the research satellite AZUR on 8 November 1969 at 02:52 CET, the Federal Republic of Germany joined the group of nations with satellites in space. AZUR weighed 72 kilograms and was launched from Vandenberg, California, on board a Scout rocket. On 15 November 1969, operation of the satellite was handed over to the control centre in Oberpfaffenhofen, which was set up especially for the task. The control centre was run by the German research institute for aviation and spaceflight (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt; DFVLR) – the precursor to DLR. The data was received by antennas at the ground station in Weilheim.

The research satellite was used to investigate cosmic radiation and its interaction with the magnetosphere, especially the inner Van Allen Belt. Earth's aurorae and time-dependent changes in the solar wind during solar flares were also on the agenda. "There was already a great deal of scientific interest in such information at the time," says Martin Häusler, Head of the Weilheim Ground Station. "More than 100 experiments were proposed, of which seven were selected for the actual mission. In addition, the German-US cooperation was intended to expand the technological capabilities of German industry and give Germany the necessary expertise in the complex management of space missions." But five weeks after the launch, the



The landmark of the Weilheim ground station: the 30-metre antenna. It was built to send commands to the HELIOS 1 and 2 spacecraft, which were launched in 1974 and 1976 respectively.





1967 Construction site



1967 Foundation



1968 Antenna construction



1968 Interior construction of the operating room



1971 VHF interferometer for measuring satellite orbits



1972 Construction work on the HELIOS command station



2016 EDRS antennas

magnetic tape storage device malfunctioned – this meant that, from that moment onwards, measurement values and control data could only be received in real time. As a result, the data stream was reduced to 80 percent of the desired volume. “Although the satellite did not reach its expected lifespan of at least one year (contact with AZUR was lost on 29 June 1970 for causes still unknown), the mission was a great success for research and industry,” Häusler adds. “The first German long-term undertaking in space gave us a wealth of valuable knowledge and provided a great deal of momentum for subsequent missions.”

### European Data Relay System delivers enormous volumes of data

One such follow-on mission is EDRS, the European Data Relay System. Europe’s data highway in space is the latest Weilheim mission to produce huge volumes of data. With EDRS, the participating countries have set themselves the goal of improving contact with research satellites in orbit in future. On 11 September 2013, two heavyweight reflectors worth several million euro were placed on the antenna bases. The two parabolic mirrors, each with a six-metre diameter, are made of aluminium and ground with a precision down to a tenth of a millimetre. The foundations penetrate three metres into Weilheim’s clay soil. Two antennas have also been set up in the United Kingdom and Belgium. All of the antennas are operated from the ground station in Weilheim.

EDRS is a new space- and ground-based infrastructure that uses cutting-edge laser technology to deliver large volumes of data – up to 50 terabytes per day – in near-real time. “EDRS will dramatically improve access to time-critical data. This will, for example, shorten the response times of emergency services. Satellite connections cannot always be readily made available. Missions often have special requirements in terms of data capacity, signal processing and frequency ranges; and some satellite connections are only possible under certain circumstances,” Häusler explains. To be able to meet individual mission requirements, the transmitting and receiving antennas must be adjusted. In some cases, new antennas are even designed for specific missions, for instance EDRS.

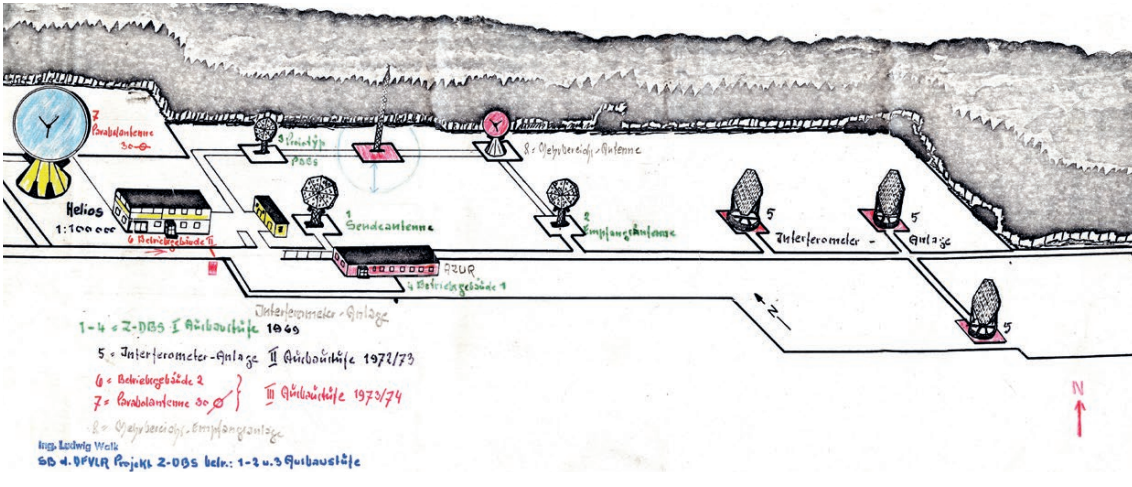
### The Weilheim ground station – a big undertaking

The Weilheim satellite ground station has participated in more than 165 satellite launches, supporting DLR’s own satellites, along with those of other space agencies such as NASA (USA), CNES (France) and JAXA (Japan) in addition to a few space missions to distant planets or asteroids. Commercial satellite operators such as Telesat, Intelsat, Eutelsat and SES Astra also use the Weilheim ground station to position their communications satellites and for emergency situations in satellite operation. In the last 50 years, Germany’s space industry has developed a high level of competency – both for extra-terrestrial and Earth observation missions. The Weilheim ground station is operated 24 hours, seven days a week. A total of 27 staff members are employed there.

In addition to its role as a data link with space, the Weilheim ground station has a new task these days: testing satellites in orbit. In-orbit tests (IOTs) provide a satellite operator with evidence that a satellite is functioning flawlessly. Much like a certification body, the ground station tests the performance parameters of the satellite.



Aerial view of the Weilheim antenna station (2016)



Planned expansion stages of the ground station in Weilheim in a historical sketch by Ludwig Walk, special representative of the DVL administration for land acquisition and basic development of the station of the German ground station system.

## OF FEEDS AND MASERS

### Interview with Klaus Wiedemann, Deputy Head of the Ground Station

#### Mr Wiedemann, you are currently installing a combi-feed in the 30-metre antenna. What is that?

■ The feed is the key element in an antenna. It determines the frequency range of the antenna. The antenna is currently being used by scientists for the Galileo navigation satellites and for the Japanese Hayabusa2 mission, which carries DLR’s MASCOT lander on board.

#### What is special about your current project?

■ Since the antenna is being used for two missions, we have to repeatedly install and remove the respective feeds. The Galileo mission requires a feed for the L-band, and Hayabusa2 requires a feed for the X-band. This is very time consuming. At the moment, it is still quite manageable, as the Japanese space agency JAXA has only booked a few contact times for the Hayabusa2 spacecraft. But that will change in 2018 and we will need the combi-feed, which can receive both signals.

#### What was your first project in Weilheim?

■ I was one of the contractors that worked for DLR in the 1970s. In 1975, I was employed by General Electric. The HELIOS mission was underway. My workstation was a container in the Eifel in Effelsberg. We used the 100-metre antenna – a radio telescope of the Max Planck Society – to receive data from the HELIOS mission. Our 30-metre antenna in Weilheim was still just a transmitting antenna at the time. When it was repurposed into a dual-purpose (transmitter and receiver) antenna in 1976, we were able to use the site in Weilheim for the HELIOS mission.

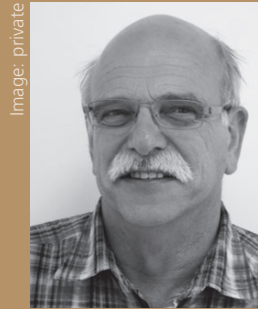
#### The HELIOS mission came to an end in 1986. What followed?

■ After I became a permanent DLR staff member in 1990, I was responsible for the maintenance of the masers – the preamplifiers

that provide low-noise reception. The masers needed to be cooled to minus 270 degrees Celsius, which significantly reduced signal noise. We achieved these low temperatures using a cooling circuit based on liquid helium. It was a very laborious process. After the HELIOS mission, which used an S-band maser, an X-band maser was installed that was used until the antenna was decommissioned in 2009. When the 30-metre antenna resumed operations in 2011, but was no longer being used for receiving signals from deep space, we removed the maser. The Max Planck Society has recently asked to use our maser. We are of course delighted to make it available to them.

#### Which result was most special to you?

■ Spitzbergen. We carried out a compatibility test for the SAR-Lupe mission there in 2005. Before a satellite launch, you need to test whether the satellite and the ground station are compatible. Since the military satellite SAR-Lupe flies in a polar orbit, its visibility in the far north is greater than elsewhere. So, Spitzbergen is home to a polar station. All the roads were snowed in. The launch time was approaching, and we could not wait for the weather to improve. So we set off for the ground station on touring skis. That was quite an adventure.



**Klaus Wiedemann** born in 1953 in Wiesbaden, has two children and lives in Peissenberg. After his apprenticeship at the Telecommunications Office, he studied communications engineering at the University of Applied Sciences in Wiesbaden. Today, he is Deputy Head of the Weilheim ground station.



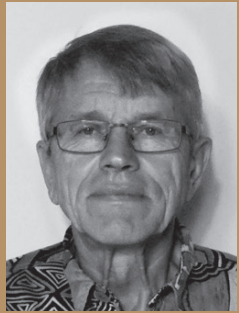


Image: private

#### Winfried Pötzsch

born in Leipzig in 1944, is married, has one daughter, and lives in Gilching. He joined the Institute of Aircraft Radio and Microwaves at the then German research institute for aviation (DVL) – today DLR – as an apprentice in September 1961. He subsequently went to Munich Polytechnic, came back to the institute as an engineer and became responsible for special developments in the field of computer technology.

## NEW TERRITORY ON THE ROAD TO HIGH TECHNOLOGY

### A conversation with eyewitnesses

Miriam Poetter, responsible for communications at the DLR sites in Oberpfaffenhofen, Augsburg and Weilheim, spoke with two veteran employees – David Hounam and Winfried Poetzsch – about the first days of the Weilheim antenna station.

**In the beginning, two locations were considered for the antenna station – Weilheim in Upper Bavaria and Buchheim in Baden-Württemberg. Weilheim was the one chosen. What tipped the scales?**

**: David Hounam** A ground station requires a location with limited radio interference. The fields on which the Weilheim station was finally built are nestled entirely within a basin. That is ideal. With long wavelengths, which we initially used, even the slightest interference was noticeable. At the time we were overcautious, as we had no experience in building such stations. For example, driving a car directly into the premises was forbidden. In general, the subject of space was treated with great respect.

**: Winfried Poetzsch** The site consisted of many small plots of land that were purchased from farmers in 1966. Ludwig Walk, our colleague looking after the procurement, wandered from farmer to farmer and probably also had to have more than one beer with them. One of the farmers even forced him to take his ox, as he had no grazing land left for it. So we bought the animal. The ox later found a home at another farm.

#### Construction of the station began in 1967. What were your duties?

**: Winfried Poetzsch** They were varied. From 1968, I was part of the team developing the programme control unit for the transmitting and receiving station for the AZUR satellite. Later, I built the synchroniser for the high-speed data line (HSDL) for the link to the HELIOS spacecraft. That was something very special as HELIOS was the first US-German interplanetary mission. After the launches in 1974 and 1976, the two HELIOS spacecraft – built in Germany by MBB – approached the Sun, getting closer to it than the innermost planet, Mercury, and closer than any previous space probe. The probes used complementary measurements to investigate the interaction between the Sun and Earth. The HELIOS Deep Space Antenna is still the biggest antenna on the site today; the 30-metre mirror is visible from a distance.

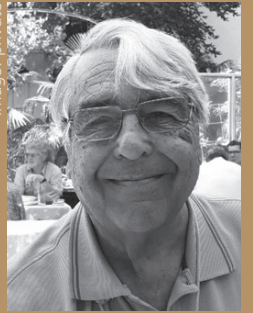
Another project was the VHF interferometer, which David and I both worked on. VHF stands for Very High Frequency. In fact, it involved positioning three movable, diamond-shaped antennas. By tracking a transmitted signal, you can measure the orbit of a satellite from a single location with extreme accuracy. The interferometer was primarily set up for determining the orbits of the Franco-German SYMPHONIE satellites. These experimental, geostationary communications satellites were launched in the mid-1970s. The interferometer fulfilled all expectations and only became obsolete when the VHF band was dropped. These were demanding projects, but a great time.

**: David Hounam** I was also in the interferometer group. I was responsible for both the high-precision reception equipment and for calibrating the interferometer. In the late 1970s, the Institute of Aircraft Radio and Microwaves switched to remote sensing, and contact with the ground station in Lichtenau died off. Apart from a five-year spell with the European Space Agency in The Netherlands (ESTEC) in the 1980s, I stayed at DLR until my retirement.

#### What memories do you have of that early period?

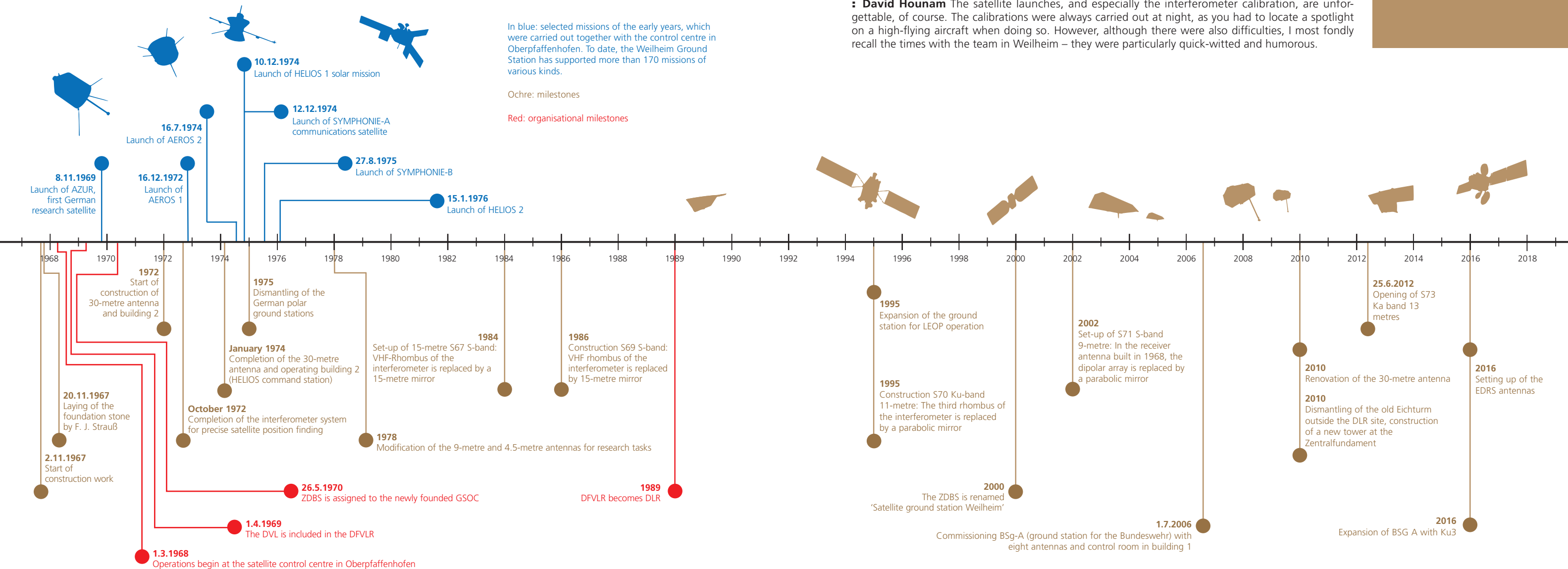
**: Winfried Poetzsch** For many years, we commuted between Oberpfaffenhofen and Weilheim, often using just a rusty Ford Transit. All those years, it took us – quite often with a bucket of food – on the 45-kilometre stretch from the institute in Oberpfaffenhofen to Weilheim. We brought along all the tools and materials we would need on site every time.

**: David Hounam** The satellite launches, and especially the interferometer calibration, are unforgettable, of course. The calibrations were always carried out at night, as you had to locate a spotlight on a high-flying aircraft when doing so. However, although there were also difficulties, I most fondly recall the times with the team in Weilheim – they were particularly quick-witted and humorous.



#### David Hounam

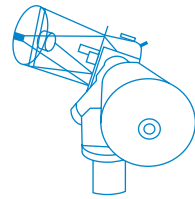
born in Darlington (England) in 1944, is married and lives in Oberpfaffenhofen. He studied physics in England. Then he and his wife moved abroad. Interesting job offers came from Germany, where there was a lack of specialised personnel in the 1960s. In 1968, the family moved to Bavaria, and Hounam began to work for the company Rohde & Schwarz in Munich. In 1971, he applied to the then DFVLR, where he soon became Head of the Microwave Systems Department.





# HITTING THE BULLSEYE 700 KILOMETRES AWAY

No modern society can do without satellites. Be it communication, navigation or Earth observation – none of this is possible without some help from space. When the space age was born 60 years ago with the launch of Sputnik 1, the numerous practical applications of space technology were inconceivable. As were their consequences – a collection of hundreds of thousands of leftover human-made objects in Earth orbit. Today, space debris is a threat to the technology that we have been dependent on for some time now. Space debris has become a controversial topic that is highly relevant for the economy, society and security. Tackling this issue is precisely why a new observatory has been established on the hills of Stuttgart. DLR researchers are working on determining the trajectories of small pieces of space debris.



Developing technologies for laser-based high-precision detection of small space debris objects

By Denise Nüssle

Leif Humbert is sweating bullets, and not just because of the high summer temperatures in the vineyards overlooking the Stuttgart deep valley. As if spellbound, the DLR researcher gazes up at a white shipping container dangling from the hook of a special crane that is swaying gently in the breeze. As if floating, the container slowly makes its way to its destination – a meadow on the 300-metre-high Schnarrenberg mountain, which offers a panoramic view of the Neckar valley and the northern districts of Stuttgart, the state capital of Baden-Württemberg. From here, the Stuttgart office of the German Meteorological Service measures the climatic fluctuations of the Swabian metropole on a daily basis. Since mid-June 2017, it is also home to the latest acquisition of scientists at the DLR Institute of Technical Physics. The crane operator slowly sets down the valuable cargo. Inside the container is a mobile observatory that represents a major milestone for researchers on their way to achieving their goal: to determine the trajectory of small pieces of space debris as precisely as possible by means of a laser-based detection system.

## Space debris – a threat to space infrastructure

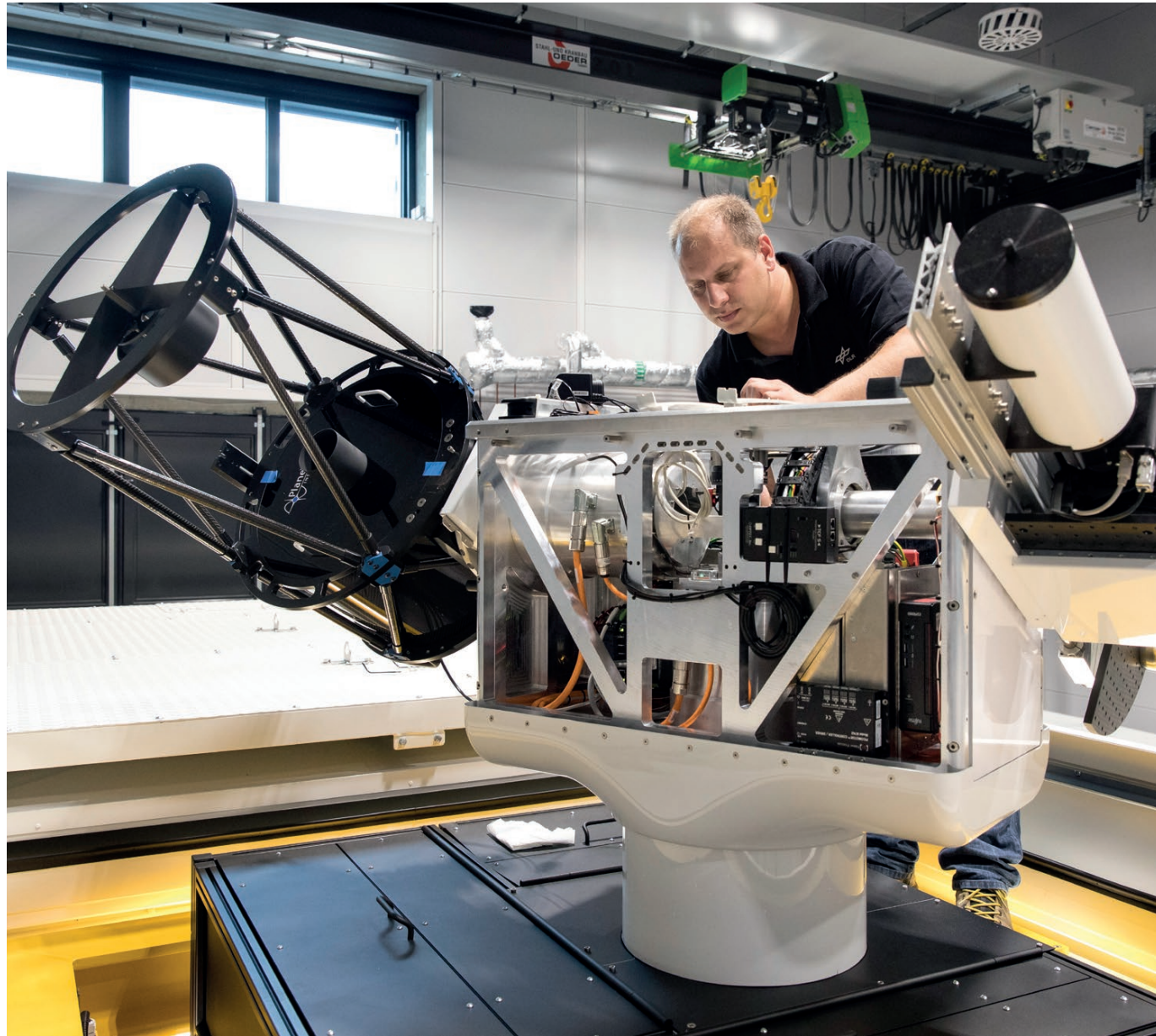
“Today, approximately three quarters of a million unused objects larger than one centimetre in diameter orbit the Earth. Travelling at high speeds of up to eight kilometres per second, they are capable of disabling a satellite in the event of a collision or endangering the International Space Station (ISS) and its crew,” says Wolfgang Riede, department head at the Institute of Technical Physics. “So it is important to know the trajectories of these objects as



Image: DLR/Frank Eppler

The mobile space debris observatory on the Stuttgart Schnarrenberg mountain. Leif Humbert and his colleague Thomas Hasenohr check the tilt/swivel mount of the telescope.





Leif Humbert during the final work on the container before it sets off on its first journey

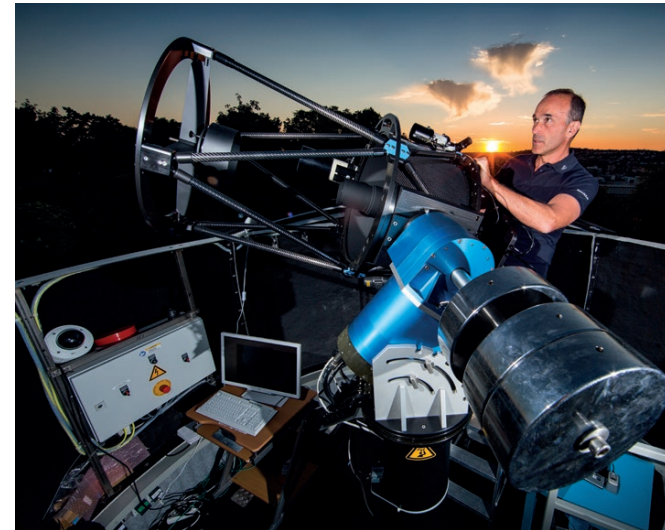
precisely as possible. Satellite operators then have the possibility to conduct specific avoidance manoeuvres, or the ISS can be placed into a different orbit if need be. It is therefore a matter of actively protecting the space infrastructure that has become indispensable to our modern industrial society.”

For the last eight years, Riede’s 10-member team has been working on developing and testing the laser-based system needed for this. Compared with previous methods, it is more accurate, more flexible, substantially more cost-effective, and can be deployed in a modular way. To date, there are two conventional methods for determining the trajectories of objects orbiting Earth: radar systems can detect objects larger than one centimetre at a distance of up to 2000 kilometres. Optical telescopes are used for objects 20 centimetres across or larger that are in a geostationary orbit – that is, at a distance of some 36,000 kilometres. From Earth, such objects appear to be

stationary because they orbit at the same angular speed as Earth rotates. Many television and communications satellites are found in geostationary orbit.

#### A complex observation method

Some 400,000 observations are made and recorded in a catalogue every day through the Space Surveillance Network – a network of 30 globally distributed radar and optical telescopes operated by the U.S. Army, Navy and Air Force. “Because these observations include orbital data on military satellites, only part of the catalogue is publicly accessible. But since there is no comparable database, satellite operators and scientists alike are dependent on what is published there,” Riede says. In addition, the radar technology employed has several disadvantages: “From large radar dishes and a very costly and extensive infrastructure through to data preparation, the process is rather time consuming.”



Wolfgang Riede during measurements at the Uhlandshöhe Research Observatory

#### Twilight ‘zone’

In contrast, the Stuttgart scientists are working on a substantially more compact, mobile technology. The functional principle is as follows: on the basis of existing rough orbital data, first, the researchers use an optical telescope to determine the exact position of an object in the sky. They do so in twilight orbit – when the Earth is in local night and debris is sunlit – and use the star background to determine the accurate angular position information. The next step is determining the distance to the object. To do so, a special laser is used in a process known as ‘laser ranging’, in which the time difference between the pulse emission from the laser and the detection of the returning pulse from the object is measured. “The challenge here is to hit the object, which is maybe just a few centimetres across, from a distance of several hundred kilometres. In football terms, this would be like scoring a goal from a distance of 700,000 kilometres,” says Riede. “Determining the distance to said object is only possible if enough light is scattered back. From the roughly 3000 laser pulses that the laser emits every second, only about 100 to 500 photons are received back.” After many more subsequent measurements, scientists can then calculate the object’s orbital path from its position in the sky and its distance.

But the laser ranging method is not new. Laser-based methods have been used since the 1960s to, for example, precisely measure the distance of a satellite from a ground station. However, only a few laser ranging stations in the world use this method to study space debris. “This approach holds promising potential. Nevertheless, plenty of research is still required to advance from the experimental stage to technology development and implementation,” says Thomas Dekorsy, Head of the DLR Institute of Technical Physics. As a first milestone, in 2012, scientists at the Institute demonstrated, in cooperation with the Graz laser station of the Space Research Institute of the Austrian Academy of Sciences, that the laser-based detection method is in principle feasible. Laser outputs of 10 to well over 100 watts are required for observing very small pieces of space debris, in order that the number of photons which return to Earth are enough to be able to carry out the distance calculations. Therefore, the focus is on developing and testing suitable laser systems for this particular application and on practical implementation of the concept in initial test stations.

## UNWELCOME LEFTOVERS FROM 60 YEARS OF SPACEFLIGHT

With the successful launch of Sputnik 1 in autumn 1957, humankind began to exploit space and use it for its own purposes. Since then, more than 5000 rockets have been launched and 7500 satellites placed in orbit. Only about 1200 of these are currently operational and can be actively controlled. In addition to obsolete and defunct satellites, sections of launcher upper stages in orbit and an incalculable number of small, but very dangerous, particles of debris also populate these orbits. These arise, for example, when residual fuel in satellites no longer being used causes them to explode, or when pieces of space debris collide with one another, creating even smaller fragments. At the frequently used altitudes of 800 kilometres and 1500 kilometres, the density of debris objects is particularly high today. In the foreseeable future, there is a risk that these orbits can no longer be used, which would have far-reaching consequences for the infrastructure there.

## INSTITUTE OF TECHNICAL PHYSICS

The approximately 70 employees at the Institute of Technical Physics study and develop laser systems for applications in the aerospace industry as well as the security and defence sectors at the DLR sites in Stuttgart and Lampoldshausen. Their work is interdisciplinary and focuses on topics such as the detection and elimination of space debris; laser-based standoff detection of harmful and hazardous substances; laser-based sensors for flight instruments; and high-performance lasers. One of the oldest DLR institutes, it was established in Stuttgart in 1977 and has been involved in the development of laser technology since its very inception.





The special feature of the mobile space debris observatory is the lifting platform for the telescope. It is extended upwards through a sunroof.

## 'UFO' over Stuttgart

Uhlandshöhe, situated above the 'Stuttgart deep valley', has already borne witness to a few things. Surrounded by a large park, the first Waldorf school was founded here 100 years ago. For almost as long, amateur astronomers of the Stuttgart Observatory (operated by the association Schwäbische Sternwarte) have been observing the night sky from here. Since 2012, it is even home to the 'UFO' – the Uhlandshöhe Forschungsobservatorium (Uhlandshöhe Research Observatory). The observatory is one of the first outposts from which DLR researchers will implement and test the laser-based detection of space debris under real conditions. Together with trainees from the Institute's systems electronics department and members of the Schwäbische Sternwarte association, Riede's team has built a functioning demonstrator in a dome.

"With the help of UFO, we are investigating the possibilities and limitations of our concept and, above all, are constantly developing the control software," explains Daniel Hampf, who manages the

activities at Uhlandshöhe. "We have written the entire control software ourselves. It is one of the biggest challenges of the project because it must bring together all the components into a functioning whole," Hampf adds. DLR researchers carried out the first measurements with the optical telescope back in 2013. Since the end of 2015, the laser has also been used for determining distances. Researchers first survey cooperative objects with orbits that are already roughly known and that are equipped with a reflector that will return the laser's light signal particularly well. In addition to satellites, objects such as larger space debris could also be previously identified. To determine how precise the laser-based distance measurement is – and hence to calibrate the system's elapsed-time electronics – DLR scientists have occupied another 'high point' in Stuttgart. At the burial chapel on the Württemberg, which King Wilhelm I built as a token of love for his wife Katharina, scientists set up a small reflector. By means of this reflector, they were able to measure the distance between the 'UFO' and the burial chapel, compare the result with the distance on the map, and thus calibrate their system.



Grappling science – the container arrives on the Schnarrenberg.

## Working in a box for science

As a further step towards a flexible, modular solution for determining the trajectories of space debris objects, DLR researchers rely on a good old shipping container. A backbone of global trade, these are normally used for simple, fast transportation of goods across the world's seas. "Our idea was to install a complete laser ranging station in the container, set it up nearby and then test whether everything was working as we had imagined and calculated," explains Leif Humbert, who is responsible for this part of the project. "The container can be transported to different locations relatively easily. The station is completely independent from the power grid as it runs on an external generator. It therefore needs no additional infrastructure – unlike other stations that are set up in buildings."

Furthermore, Humbert and his research colleagues calculate that a completely developed mobile container station would cost less than one million euro, making it a relatively inexpensive solution compared to stationary alternatives. One year of preparatory work was needed before the mobile observatory prototype was able to undertake its first journey. The team implemented the laser, the emitting and receiving telescope, including the necessary mounts, and programmed the system for this new setup. Then, of course, they stowed everything carefully in the container, so it could be transported safely. DLR scientists want to start taking the first measurements on the Schnarrenberg in 2018.

The container will remain at its first location on the Schnarrenberg until all functions have been adequately tested. These also include joint measurements with the stationary research observatory in Uhlandshöhe. Afterwards, it is a matter of going out into the big wide world. In the medium term, the system is due to be examined in various test sites with different climatic conditions and then further developed for fully automated operation. First considerations on where the container and researchers should go are currently taking place, as Wolfgang Riede explains: "The next location should, of course, offer good observation conditions. We need plenty of clear skies, limited light pollution and as much twilight as possible, like the one found at high geographic latitudes near the polar caps. There are also plenty of objects in low polar orbits." Presumably, the message to the team will be 'dress warmly'.

From cooperative objects with orbits that are roughly known, DLR scientists plan to gradually move towards detecting non-cooperative targets. In the long term, the plan is to develop a small network of



At the finish line – the transport is complete and construction of the mobile observatory can begin.

stations for shared observations, combining and processing all the discoveries made. Within this network, a station discovers a new object, roughly determines its trajectory and forwards it to the next station for more accurate measurements. In this way, it is possible to observe a relatively large section of the orbit and determine the orbital data very accurately. "Our experiments so far have confirmed the high expectations on the precision of the laser-based measurement process for this particular application," says Dekorsy. "This technology could form the basis for independently issuing collision warnings in Europe and generating a directory of observed objects with their orbital paths." It is conceivable that the Stuttgart researchers might also combine their laser-based approach with existing radar technology. In this case, the radar station would roughly detect objects, and a laser-based system – in a container next to the stationary radar facility, for example – would then measure them precisely.

But until then, a few challenges remain. Stronger lasers and larger receiving telescopes are needed for target objects smaller than 10 centimetres. To optimise the target precision and beam quality, short-pulse lasers are a primary focus of current research.

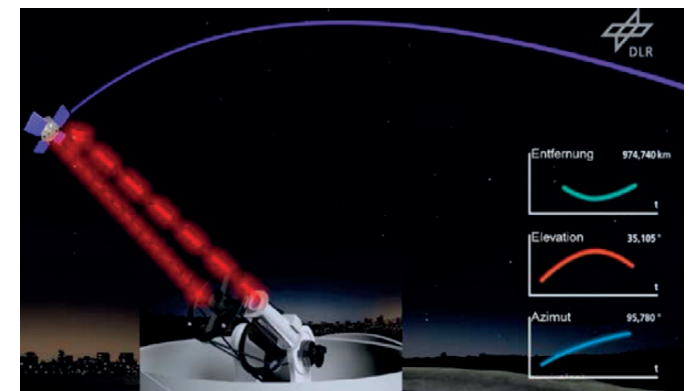
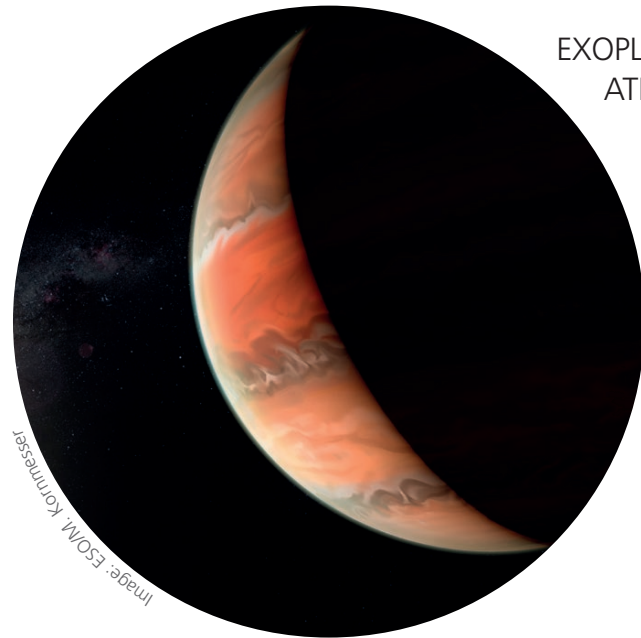


Diagram of the laser ranging method for determining the trajectory of objects in space





## EXOPLANET AMAZES WITH TITANIUM OXIDE IN THE ATMOSPHERE

Young DLR scientist Elyar Sedaghati has identified a heavy element – namely titanium oxide – in the atmosphere of the extrasolar planet WASP-19b, which can be described as a hot Jupiter. This discovery was published in the scientific journal 'Nature'. If present in large enough quantities, these molecules prevent heat from entering or escaping through the atmosphere, leading to a thermal inversion – the temperature is higher in the upper atmosphere and lower further down, the opposite of the normal situation. The young researcher carried out his investigation together with a team of nine other astronomers using the European Southern Observatory (ESO) Very Large Telescope (VLT) in Chile. To determine the chemical composition of the atmosphere, millions of individual spectra were collected across the entire optical spectral range, and special algorithms were applied that also take into account different temperatures and the varying properties of clouds and haze layers.

## SAFE OPERATION OF LOW-FLYING DRONES

The importance of drones is on the rise, not only for private individuals but also for the economy. There are still no Europe-wide harmonised regulations on the safe and efficient integration of this new class of aircraft in the lower airspace. Solutions are being developed in the European research project CORUS (Concept of Operation for European UTM Systems) with the involvement of DLR. Led by the 'European Organisation for the Safety of Air Navigation' (EUROCONTROL), CORUS is bringing together experts to develop a comprehensive concept as to how unmanned aviation systems should be operated and controlled in the future at Europe's lowest altitudes. The DLR Institute of Flight Guidance will devise a safety and risk assessment of flight scenarios as part of the project. Here, the characteristics of the flight area, such as the density of the population and air traffic, but also technical and meteorological influences, are also covered. Additional safety requirements for unmanned aircraft in the lower airspace will be derived from the risk assessment. To better understand possible incidents and be able to feed this information back, the researchers are also developing guidelines and message procedures.



## Aerospace collaboration

At the International Astronautical Congress IAC at the end of September 2017 in Adelaide, Australia, DLR signed agreements for closer collaboration with various partners. In addition to two Australian universities and the International Space University ISU, with headquarters in France, these include the Sierra Nevada Corporation and the South African National Space Agency (SANSA). Areas for collaboration include actuators for aerospace systems, components for optical detectors in the hyperspectral and infrared range, optical communications, satellite control and the tracking of space debris, as well as the use of the 'Dream Chaser' and technologies for the period beyond the International Space Station (ISS).



## FOR SMOOTH AIR TRAFFIC

Robust network and flight planning are crucial to ensure that passengers are satisfied and traveling on time, as well as for efficient, cost-effective flight operation. DLR is now using software from Lufthansa Systems to carry out research that is as application-oriented as

possible. Both partners are involved in a research project called 'Robust Flight Plan'. Direct access to the planning software in use at over 70 airlines also enables 'What If' scenarios. The NetLine/Plan and NetLine/Sched software simulates new connections, creates forecasts for passenger flows based on market data and calculates the impact on costs and revenues. In this way, DLR researchers can also ascertain which modifications better shield flight planning operations against disruptions, and how innovations impact the development of the flight plan.

## HEALTHY ARRIVAL ON THE RED PLANET

For a flight to Mars, space agencies Roskosmos and ESA worked together to simulate a flight to our neighbouring planet in the Mars 500 study that ran from June 2010 to November 2011. Scientists from Germany, Austria and Great Britain investigated the development of microorganisms in the space station under the leadership of DLR. During their 520-day mission, the six study participants lived isolated from the outside world in a 'spaceship', constructed at the Institute for Biomedical Problems IBMP near Moscow. Alongside technical and social aspects, microorganisms were also investigated in the enclosed habitat. At 18 previously defined points in time, the 'marsonauts' took microbial samples from the air and from the surfaces of the different spaceship sections. It became clear that the diversity of microorganisms reduced throughout the duration of isolation, in part due to the cleaning agents used. A microbially complex environment is, however, good for health. Countermeasures shall therefore be taken in the future to maintain microbial diversity.



## MEET DLR AT ...

### BONN SPACE EVENING 2017

14 December 2017 • Bonn, Germany

The German Aerospace Center (DLR) is responsible for planning and implementation of the German space programme on behalf of the Federal Government. As part of the Bonn Space Evening series of events, the DLR Space Administration invites a select group of guests from government, industry, science and the media to provide information on current programmes and topics. The guests have the opportunity to discuss the latest issues in a relaxed atmosphere afterwards, during the reception.

### JEC WORLD 2018

6 - 8 March 2018 • Paris, France

DLR will present current research projects in the field of fibre-reinforced high-performance plastics at JEC World in Paris, the leading European trade fair for fibre composite construction. This time, the joint presentation of the DLR Institute of Composite Structures and Adaptive Systems and the Center for Lightweight-Production-Technology (ZLP), located in Stade, will focus on innovative technologies for the efficient production of composite fibre components. At the approximately 80-square-metre DLR stand, located in Hall 5a (E66), scientists will explain and demonstrate a wide range of applications, particularly in the field of aerospace. The programme is open to entrepreneurs with an innovative project, a SME or a startup – including academic spin-offs, who want to meet the world leaders in the composites industry to bring them to the next level.

### DLR CONFERENCE ON CLIMATE CHANGE 2018

17 - 19 April 2018 • Cologne, Germany

The aim of the Paris Agreement is to reinforce the global response to the threats arising from climatic change by, for example, imposing a global temperature rise within this century well below two degrees Celsius above pre-industrial levels. The agreement underlines the necessity to study ways of reducing the consequences of climate change. This scientific conference aims to bring international scientists, space agencies and interested parties together with United Nations entities such as UNOOSA, UNSPIDER, UNFCCC, WMO and GCOS and thus provide a discussion forum to elaborate on the substantial challenges faced by atmospheric climate research. By encouraging an open exchange of ideas we hope to facilitate the implementation of suitable measures to support the requirements as outlined in Paris.

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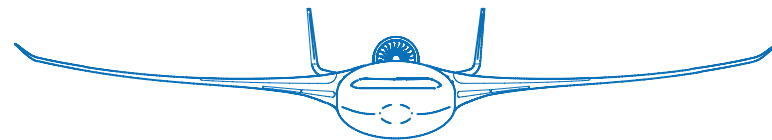
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# FROM LEGEND TO LINER – AN URBAN DESIGN STORY

Aerospace students are constantly coming up with new ideas, hoping to achieve a breakthrough design for the aircraft of the future: new aircraft concepts that will take passenger transport beyond the sound barrier or that are revolutionarily quiet and low emission. DLR and the US space agency NASA organised a joint student competition that posed these two specific challenges to student teams from Germany and the United States. The teams each chose one of two categories to work on: either the renaissance of supersonic flight with much lower environmental impact and sonic boom mitigation; or venturing out to the technical boundaries of subsonic passenger transport in terms of lower emissions, reduced noise and greater efficiency. The winning German team from the TU Munich impressed the jury with its 'Urban Liner'.



DLR and NASA Design Challenge – Students design the aircraft of the future

DLR aeronautics editor Falk Dambowsky spoke to the winners Christian Decher, Daniel Metzler and Varga Soma from the Technical University of Munich about their ideas.

**In the third semester of an aerospace master's degree, having attended just one lecture on aircraft design, you find yourself on the winner's podium and the big stage at NASA with an award-winning aircraft design. How does that feel?**

**• Soma Varga** It is every engineer's dream to one day work for NASA or give a presentation there ...

**• Daniel Metzler** ... a dream that gradually became real. When we entered the competition, we never imagined that we would actually travel to NASA as winners.

**How did you find out about the competition, and what specific team strengths helped you to win the DLR/NASA Design Challenge?**

**• Christian Decher** All three of us attended a lecture on aircraft design by Mirko Hornung at TU Munich. He pitched the Design Challenge. There was an initial meeting where the three of us found ourselves naturally forming a team.

**• Daniel Metzler** And then we started working closely together. In any case, being such a small team was an advantage. It enabled us to stay on top of things and it made it easy to keep each other's tasks in mind and help where needed.



Image: TU München

The award-winning Urban Liner aircraft design has a single conventional engine on the rear and additional electric drives integrated into the wing roots



**How did the idea for your aircraft design come about?**

■ **Christian Decher** At first, Daniel and Soma wanted to look at a supersonic configuration, but I managed to convince them to stay in the subsonic range ...

■ **Daniel Metzler**

We started with intensive brainstorming. Did we want to go in the direction of a manta ray-shaped blended wing body? What sort of propulsion system would we use, and how would we integrate it into the aircraft? We moved step by step from a very general idea to all the specifics, until we had the concept of the Urban Liner.

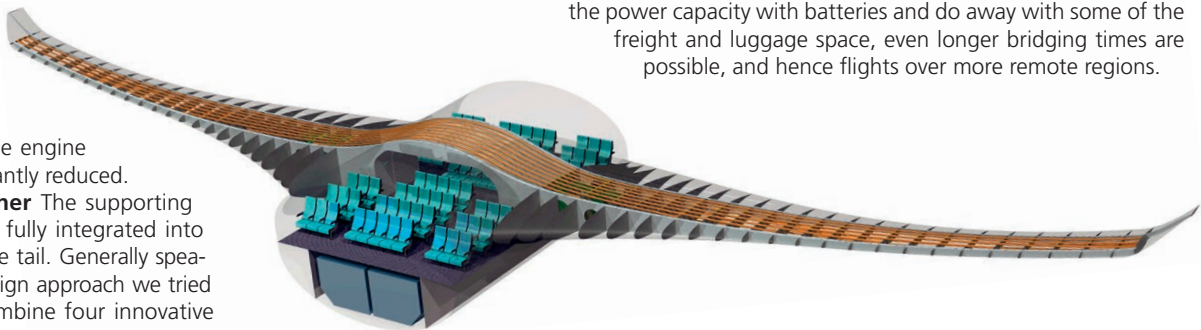
■ **Soma Varga** A particular challenge here was not going into too much detail and keeping our eye on the big picture. In the early design phase, we repeatedly asked ourselves why things are the way they are. Where is the novelty from the design point of view? Which priorities do we need to set? From the outset, we focused on minimising noise pollution; many other decisions were then subordinate to that.

**In addition to the focus on noise reduction, what makes the Urban Liner special?**

■ **Daniel Metzler** First, the single turbofan engine that we piggybacked onto the rear fuselage, which was needed to reduce emissions.

■ **Soma Varga** With the Urban Liner, we are trying to reduce nitrogen oxide and carbon dioxide emissions by up to 80 percent and kerosene consumption by up to 60 percent. The bottom line was that at least one of the large turbofan engines had to go, with full electric flight remaining as the long-term aim. That is why we combined electric propulsion systems with one conventional engine on the tail. At the same time, the engine noise was significantly reduced.

■ **Christian Decher** The supporting electric drives are fully integrated into the wings near the tail. Generally speaking, with our design approach we tried to intelligently combine four innovative technologies.



**Which technologies?**

■ **Soma Varga** For one, there are the integrated electric engines that we mentioned. To integrate these we needed a new, split wing root design at the transition between the wings and the fuselage, and we also used an advanced wing and engine design.

■ **Christian Decher** We did not busy ourselves too much with making small incremental changes to a conventional aircraft design, such as making the landing gear a bit quieter when it is lowered, or using improved engine outlets to reduce jet noise. Rather, we looked at the fundamental design decisions one has to make to create a distinctly more quiet and economical aircraft ...

■ **Daniel Metzler** ... which led us to the issue of the strengths of the individual technologies, their weaknesses and how these could perhaps even cancel each other out.

**So this is about synergies – how are these implemented in the Urban Liner concept?**

■ **Daniel Metzler** To stick with the example of the single turbofan engine: a perfect complement here are the e-fans – the electrofans. They are too weak on their own for extended flight operation, but they are strong enough to support take-off and climbing and, in the event of an emergency, even for taking over the full thrust for a short period.

■ **Soma Varga** Another point is that we constructed our turbofan engine in combination with the variable thrust of the e-fans in such a way that it runs efficiently and economically at full load. The hybrid propulsion system enables the drive to either be on or off and not running under a partial load.

**Are there other synergies in your concept?**

■ **Daniel Metzler** Yes, the integration of the electric engines into the wing roots on the fuselage. The e-fans are primarily needed for additional thrust during the take-off procedure; after this, they need to be out of the way. Hence, it is important that they are integrated into the aircraft. However, they cannot be too small; otherwise their effectiveness is massively compromised.

■ **Soma Varga** We faced the question of how to integrate large e-fans into the aircraft. In the end, we managed to include them by splitting the wing roots – which today run through the cargo area of a commercial airliner – and construct them around, above and below the e-fans. In turn, to be able to split the wing roots and maintain a stable structure, we had to widen the fuselage.

**Using just one large conventional engine on the tail that is supported by e-fans is a fascinating combination. How far would a pilot still be able to fly in the extreme case of a main engine failure?**

■ **Christian Decher** It must first be mentioned that today's engines operate much more reliably than those from a few decades ago. Engine failures have become very rare, which supports the idea of a passenger aircraft with one engine. Of course, if there is an engine failure, there has to be an emergency procedure for such a configuration ...

■ **Daniel Metzler** In this case, the Urban Liner would leave its cruising altitude and would have to descend and change its angle of attack. It could then continue to fly on electric power alone for approximately 90 minutes to reach the nearest airport. If you increase the power capacity with batteries and do away with some of the freight and luggage space, even longer bridging times are possible, and hence flights over more remote regions.

**So what would happen if the aircraft had to make an unscheduled landing at an airport where there were no replacement batteries available?**

■ **Soma Varga** In principle it would not be a problem. As the e-fans are mainly used for the take-off and ascent, and the batteries retain most of their power in case this is needed in an emergency, it would also be possible to take off a second time using the same batteries.

**A major advantage of electric fans is the reduced noise during take-off. In addition, in your design the remaining main engine is placed on the tail so the downwards noise is additionally shielded. So how much quieter would the Urban Liner be compared to the widely used Airbus A320, for example?**

■ **Christian Decher** It is hard to come up with specific numbers on the noise actually occurring on the ground as this depends on a number of factors. But compared to an Airbus A320, we can say that the exit velocity of the gases from the engine of the Urban Liner is only around half that of an A320 engine. This jet noise is a very important factor in the noise output of an aircraft. The Urban Liner would therefore be significantly quieter.

**As winners of the German competition, you were invited to travel in September to NASA's Langley Center, a historic and, to date, an important research location. What did that feel like?**

■ **Soma Varga** It was incredibly exciting. The most interesting part was the tour of the research facilities on the NASA site, such as the large wind tunnel, the aircraft hangar, and a facility for crash-testing aircraft components. We were pleased that the US team was very in-

terested in our work on the Urban Liner and there was a lively discussion on the concepts presented. In fact, we were somewhat in the spotlight as we were the only team from Germany in our category.

**You saw a few aircraft designs presented at the German award ceremony in Braunschweig and some more at the joint symposium with the US winners at NASA. Were there any designs by other teams that impressed you?**

■ **Daniel Metzler** The designs in the supersonic category were fascinating. The winning US team from the Virginia Polytechnic Institute and State University presented the Nimbus concept, a supersonic corporate jet that has an unusual delta wing shape with a distinctive lightweight construction. Thanks to its shape and design, it generates significantly less noise when flying faster than the speed of sound, as well as on approaching the airport. We were also impressed with the HELESA concept presented by the German team from the University of Stuttgart, which earned second place. The HELESA design comprises a long-stretched supersonic aircraft with distinctive variable forward swept wings.

**What advice would you give to other students if they have the chance to take part in such a competition?**

■ **Christian Decher** Do it! And be careful about what is feasible and what is not. At the outset, we went slightly astray with the calculations. We thought we could achieve very accurate results. We ultimately realised what is possible with the design of a concept and where the limits are. Defining early on how far you can and want to go would have saved us a lot of time.

■ **Daniel Metzler** And not being phased by the amount of work. The job may seem huge at the start – designing an entire aircraft ... But in the initial design phase, you can achieve a lot with a bit of diligence, even as a student. The important thing is to go through the whole process once. That is something you do not learn at university. From this aspect alone, the competition was a very valuable experience overall.

■ **Soma Varga** Just try it! You learn so much in a competition like this. Even if you do not win, you see how important the big picture is when designing an aircraft and that you cannot focus on all the tiny details. This will surely be very important in later engineering work.



In September 2017, the three students travelled on behalf of DLR to NASA's Langley Research Center in Virginia to present their award-winning work alongside that of the US competition winners at a symposium with internationally recognised aeronautics researchers.



Rolf Henke, DLR Executive Board Member responsible for Aeronautics research, hailed the work of the Munich trio as a coherent overall concept that intelligently combines highly innovative technologies.

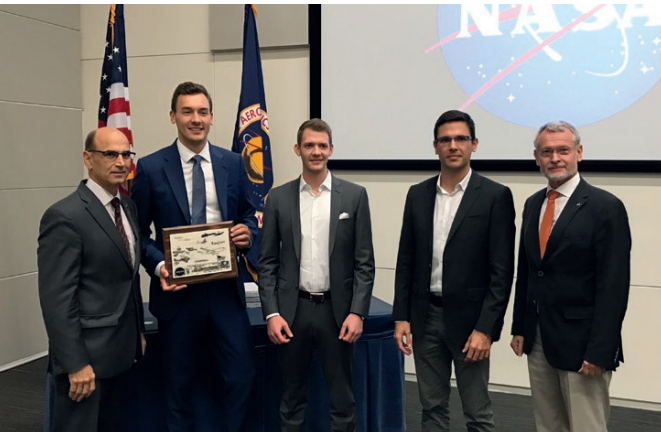
Categories of the DLR/NASA Design Challenge

**Competition category 1: The challenge of supersonic passenger flight**

Concorde is history and, for the time being, so is commercial passenger flight at supersonic speeds. The competition poses the question of whether, by means of new technologies, it is possible to revitalise supersonic transport across long distances without disproportionate environmental pollution. Aerospace researchers around the world are already working on this: The focus lies on increasing energy efficiency and mitigating the supersonic boom to pave the way for the renaissance of supersonic flight.

**Competition category 2: Revolutionary quiet and low-emission flying**

Climate change and society's ever-increasing demand for mobility present major challenges for today's aviation industry. Ambitious goals in Europe and the United States are looking into the technical limits for less emissions, less noise and greater efficiency in passenger air transport. To reconcile long-term continuous growth and environmental compatibility, the technical limits must be exceeded. This calls for new revolutionary ideas.



Acknowledgment of the German winning team of the DLR / NASA Design Challenge (from left to right): George Finelli, Director of Aviation Research at NASA Langley Research Center, Christian Decher, Daniel Metzler, Soma Varga, and Horst Hüners, DLR Aeronautics Programme Director.



# MEASURING, PROJECTING, TAKING ACTION



**T**he 23 UN Climate Change Conference has just taken place in Bonn – another important step for the international community in facing the challenges of global climate change. We need to reduce the anthropogenic impact on the climate system – the disruption caused by humans. Current climate and Earth system research provides unprecedented volumes of data of exceptional quality. Veronika Eyring is Chair of the Coupled Model Intercomparison Project (CMIP) Panel that coordinates global climate model simulations worldwide within the framework of the World Climate Research Programme (WCRP). Bernadette Jung from the DLR Communications Department in Oberpfaffenhofen spoke with her.

Three decades of atmospheric research at DLR

New Earth observation and climate modelling data help to expand our scientific foundation of climate change and to answer questions that are relevant to the action required: How exactly does the climate system work? What are the causes of climate change? What are the implications? At the DLR Institute of Atmospheric Physics in Oberpfaffenhofen, researchers investigate these issues.

Climate data unprecedented in scope and improved models for one of humankind's greatest challenges

## Interview with DLR climate researcher Veronika Eyring

**There is a growing need for scientific information and knowledge about climate change.**

**What role does climate modelling play here?**

■ Numerous influencing factors and interdependencies make the climate a highly complex system. Climate models are numerical tools that simulate these interactions and feedbacks. They are used to understand the past and present-day climate, and for providing projections on future climate. The modelling requirements have increased in line with the need for information. Modern Earth system models are already able to take into account a wide range of factors – from the complete atmospheric chemistry and dynamic land surface processes, including vegetation, through to land and ocean carbon cycles. The horizontal and vertical resolution of the models is also increasing. In my group on Earth System Model Evaluation, we investigate the quality of various models in comparison to observational data. This gives us a better understanding of the processes of the climate system and can guide future development of the models. It is also a vital prerequisite for trustworthy climate projections of the 21st century that are urgently needed by society, government and industry.



The research aircraft HALO (High Altitude and Long Range Research Aircraft) investigates how clouds in clean air above the rainforest differ from those in deforested polluted regions. This image was acquired from the flight deck over the nose boom in front of a thunderstorm over the Amazon.

## How are these research results used?

■ Under the auspices of the World Climate Research Programme (WCRP), hundreds of climate researchers are working in modelling centres around the world, sharing, comparing and analysing the latest results from global climate models. As part of the Coupled Model Intercomparison Project (CMIP), simulations provide important data to the research community for the next five to 10 years. The Intergovernmental Panel on Climate Change (IPCC) uses the CMIP simulations as an important source – for example for its last full 2013 Assessment Report, which provided the scientific basis for the Paris Agreement and led to the adoption of the two-degree climate target. This encourages us in the Earth System Modelling department to make a significant contribution to the Sixth Assessment Report. On the one hand, our climate simulations with the EMAC model (ECHAM/MESSy Atmospheric Chemistry) are contributing to CMIP6 and, on the other, we are further developing the Earth System Model Evaluation Tool (ESMValTool) and applying it to CMIP6 simulations. This enables us to routinely check the models against observational data.

## More complex climate models, more accurate projections – where are the next challenges?

■ One of the main challenges involves the area of Big Data. Thanks to rapid scientific and technological progress, our data stores are reaching entirely new dimensions. This is good news, but it challenges the capacity and creativity of the largest data centres as well as the fastest data networks. For the current CMIP project phase alone, we are expecting a data volume of 20 to 40 petabytes – an increase by a factor of 10 to 20 compared with the CMIP5 model archive from 2013. In the coming years, more than 30 international climate modelling groups will be delivering CMIP6 model data. This data must be archived, documented, distributed and analysed. In addition, Earth observation data from the EU Copernicus satellite programme and other satellite missions, from aircraft measurement campaigns and ground stations have to be processed and provided. In Oberpfaffenhofen, we have been active in this area for a long time and have developed the ESMValTool – a tool for efficiently evaluating the models with observational data. This tool is also routinely applied to CMIP6 simulations at the German Climate Computing Center (Deutsches Klimarechenzentrum; DKRZ).





Preparation for a test flight with the Franco-German climate mission MERLIN (Methane Remote Sensing Lidar Mission) on board HALO. CHARM-F will be tested on the flight. CHARM-F (CH4 Airborne Remote Monitoring) is an aircraft-borne integrated path differential absorption (IPDA) lidar. It can be used to quantify gradients of concentration as well as carbon dioxide and methane land-atmosphere fluxes, both from anthropogenic point sources and from broader natural sources

### You are also involved in the establishment of the new DLR Institute of Data Science in Jena.

■ Yes, I am supporting the set-up of a climate informatics group that will work in collaboration with our institute, the Friedrich Schiller University in Jena and the Max Planck Institute for Biogeochemistry. Our goal is to develop innovative, efficient methods for data management and data analysis. Climate informatics is an exciting new research area that takes Earth system data from models and satellites to a new level. If we enhance the ESMValTool with suitable data science methods, we can find new ways of detecting changes in the climate system early on. In addition, by making use of IT methods and the research at our Institute we want to further reduce existing uncertainties in climate model projections.

### In the climate debate, there are also people who deny anthropogenic climate change. What does climate modelling have to say about that?

■ ‘Sensitivity simulations’ are used to distinguish the effect of humans on the climate from other, naturally occurring factors. By doing this, model simulations that only take into consideration natural forcings are compared with those that consider both natural

and anthropogenic forcings. The above-mentioned fifth IPCC Assessment Report came to the conclusion that human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere and in positive radiative forcing. Furthermore, there are observations of global warming and other climate indicators, as well as our own improved understanding of the climate system.

### Determining the greenhouse effect is critical for climate projections. Where do you get the necessary data?

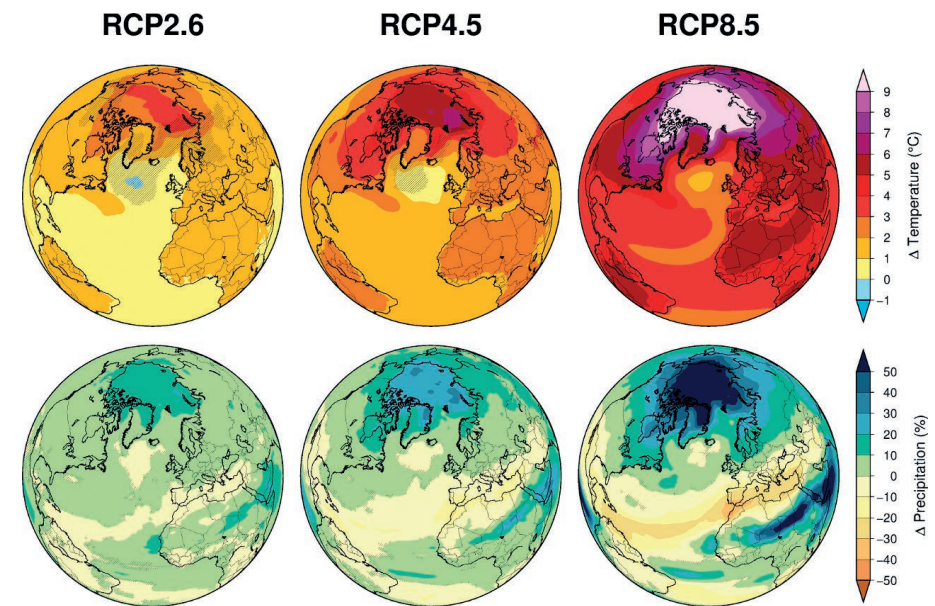
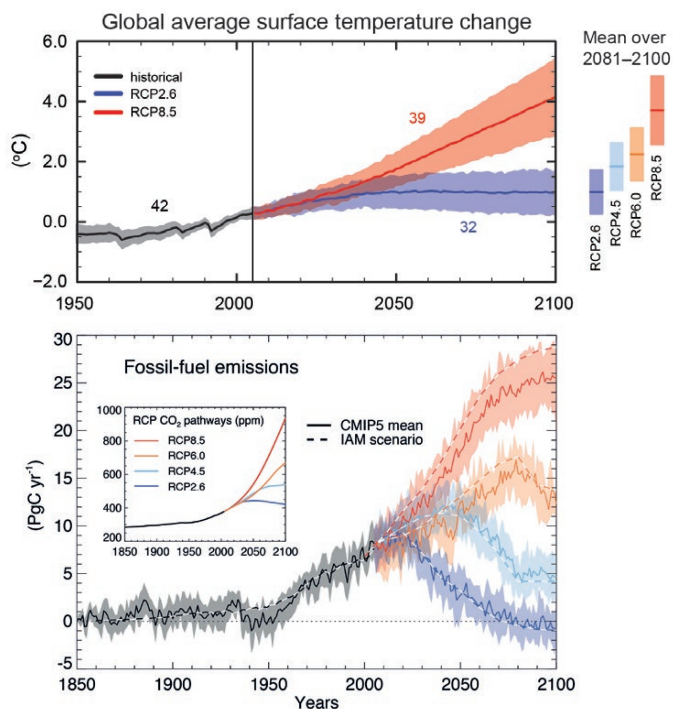
■ To evaluate the model, we primarily need long-term measurements, such as those supplied by the DLR Earth Observation Center (EOC) and the ESA Climate Change Initiative (CCI) programme. The emission of the two most significant greenhouse gases – carbon dioxide and methane – can be measured in situ, meaning directly in the atmosphere using research aircraft or satellites. We expect a breakthrough in our understanding and the analysis of regional methane emissions in the coming years, when the German-French MERLIN satellite mission is launched in 2020. To prepare for this mission, the MERLIN aircraft demonstrator CHARM-F is currently being used in measurement campaigns by our Institute on board the

At the UN Climate Change Conference in Paris (COP21) in December 2015, a total of 195 countries reached a general, global climate protection agreement that is binding under international law – a first. The agreement comprises a global action plan aimed at limiting global warming to significantly less than two degrees Celsius, in order to counteract dangerous climate change. To do so, greenhouse gas emissions, in particular, must be significantly reduced as quickly as possible and, in the coming decades, be cut to zero.

Top diagram:  
Current results of the IPCC on the future changes to the global surface temperature, depending on different emission scenarios (Representative Concentration Pathways, RCPs). The blue curve here corresponds to the two-degree target, while the red curve is a ‘business as usual’ scenario.

Bottom diagram:  
RCPs and associated atmospheric carbon dioxide concentrations (inset). It should be noted that the RCP2.6 scenario, which represents the two-degree target, requires negative emissions in the second half of the 21st century, meaning that the net amount of carbon dioxide must be removed from the atmosphere.

Source: IPCC 2013, AR5, Fig. SPM 7 and Fig. TS19



Climate model projections based on three different scenarios, where carbon dioxide concentrations increase from RCP2.6 (Representative Concentration Pathways) to RCP8.5.

The upper row shows changes to the two-metre temperature, as calculated towards the end of the 21st century (averaged for the years 2090 to 2099) compared with the period 1986 to 2005. The associated relative changes in precipitation are shown in the bottom row. All these results are the averages of a total of 26 different CMIP5-generation climate models, so-called ‘multi-model means’.

(Illustration generated with ESMValTool [www.esmvaltool.org](http://www.esmvaltool.org)).

High Altitude and Long Range Research Aircraft (HALO). We specifically target and measure both anthropogenic and natural sources of methane and carbon dioxide. With MERLIN, we will be able to collect a global data set from an altitude of 500 kilometres and monitor methane emissions released by permafrost soils or ocean sediments as a result of global warming.

### The two-degree target of the UN Climate Change Conference in Paris is a major challenge. Can DLR climate research support the implementation of this goal in Germany?

■ For Germany, as an industrial location, the challenge lies in maximising effective climate protection measures while minimising the impact on the competitiveness of the economy. DLR has been making significant contributions to key research areas for many years. Technological solutions for preventing greenhouse gas emissions entail a transformation of the energy sector, industry and the aviation and transport sectors. Since the necessary measures will have far-reaching economic consequences, they must first be evaluated according to the best of our scientific and technical knowledge. This requires an in-depth understanding of the Earth system, particularly with regard to its carbon and energy processes. The scientific foundations and analytical processes are constantly being expanded by our Institute and the international research community. With satellite missions such as MERLIN or Tandem-L, DLR is capable of developing the global climate and environmental observation systems of tomorrow. Such observation systems are essential if we are to verify the effectiveness and compliance of climate protection measures. Furthermore, the other economic and social consequences of the planned measures must also be taken into account. In addition, our Institute is investigating the climate impact of transport and aviation emissions, including those that are not caused by carbon dioxide emissions (for example, contrails, cirrus clouds and ozone). We are also working on optimising flight paths. The resulting cost-benefit analysis is compared with alternative concepts for design and flight guidance in order to find ways to reduce the impact of aviation on climate.



**Veronika Eyring**

is Head of the Earth System Model Evaluation Group at the DLR Institute of Atmospheric Physics in Oberpfaffenhofen and is Professor of climate modelling at the Institute of Environmental Physics at the University of Bremen. Since 2014, she is Chair of the CMIP Panel, which coordinates climate modelling simulations worldwide. Professor Eyring is currently supporting the establishment of a working group in the area of climate informatics at the new Institute of Data Science in Jena.

### CMIP – Coupled Model Intercomparison Project

CMIP was launched 20 years ago as a research initiative to compare the first global climate models. Today, several hundred scientists pool their expertise here. The aim of CMIP is to gain a better understanding of past, present and future climate change. To be able to compare modelling results, CMIP develops – among other things – standards for simulations, data formats and evaluation algorithms. This gives climate researchers the possibility of sharing, comparing and assessing their findings. CMIP model output therefore represent one of the most important sources of robust and reliable climate information.



# ENVIRONMENTAL SATELLITE SENTINEL-5P MONITORS OUR ATMOSPHERE

Image: ESA/Stephane Conjaia, 2017



Sentinel-5P is the first Copernicus satellite dedicated to monitoring the atmosphere. The TROPOMI measuring instrument investigates numerous trace gases and their impact on air quality and our climate.

Sentinel-5P is the first mission of the European Copernicus Earth observation programme dedicated to detecting and monitoring potentially hazardous trace gases in Earth's atmosphere (such as nitrogen dioxide, ozone, formaldehyde, sulphur dioxide, methane and carbon monoxide) over a long period of time. The European Earth observation satellite was launched into space on board a Rockot launcher on 13 October 2017 from the Plesetsk spaceport in northern Russia. Further questions that it aims to answer are global and regional concentrations of particulates, the causes behind changes in the atmosphere and their impact on the climate, air quality and people's health. In measuring trace gases, Sentinel-5P is bridging the gap between the European environmental satellites ENVISAT and Sentinel-5. In Sentinel-5P, the 'P' stands for 'Precursor'. By 2030, the envi-

ronmental monitoring programme will include 20 Earth observation satellites, providing a hitherto unparalleled level of quality and quantity.

The satellite, which weighs around 820 kilograms, is located at an altitude of 824 kilometres. With a swath width of 2600 kilometres, almost 1000 high-resolution spectral channels and high spatial resolution, Sentinel-5P will define new technical standards in the continuous mapping of our entire planet: TROPOMI measures in the ultraviolet, visible, near and short infrared wavelength ranges, and is able to monitor a wide variety of air pollutants. The trace gas data will be used in the Copernicus Atmosphere Monitoring Service to provide information on regional air pollution as well.

# ALTERNATIVE NAVIGATION SYSTEM FOR EVEN SAFER MARITIME TRANSPORT



Covering approximately 50,000 square kilometres, the planned test field includes a broad spectrum of challenging areas for maritime transport. The ferry traffic in the Baltic Sea would also benefit from the alternative navigation system.

The R-Mode Baltic project was launched in October 2017 for increased maritime safety. Under the leadership of DLR, experts are developing a terrestrial backup system that maritime transport users can switch to in emergencies as an alternative to global navigation satellite systems (GNSS), such as GPS or Galileo. Technological feasibility is set to be demonstrated with the set up of an R-Mode test field in the southern part of the Baltic Sea. The project brings together other scientific research institutions, government agencies and industrial partners.

Seafaring vessels use satellites to determine their precise position to within a few metres. It is particularly important that exact posi-

tional information is constantly available in coastal waters and ports, or near offshore wind farms and oil platforms. A disruption or even failure of the navigation system used, for example as a result of changes in signal propagation in the ionosphere in particular, for instance during elevated solar activity, as well as intentional GNSS jamming, can have serious consequences. To avoid this, experts will modify current differential GNSS (DGNSS) reference stations, as well as automatic identification system (AIS) base stations along the Baltic coastlines of Germany, Poland, Sweden and Denmark. DGNSS reference stations normally broadcast corrective information for precise positioning using GNSS. AIS base stations send security-relevant warnings and other signals to seafaring vessels. Modifying the ground-based stations will enable the radio stations to transmit the new R-Mode signal in addition to the communication signals they already handle. A challenge here will be time synchronisation across large distances. The demonstration will involve syncing several R-Mode broadcasting stations located more than 100 kilometres apart.

# DLR EXPERTISE FOR DIGITAL PRODUCT DEVELOPMENT

Computer-based models and simulations have become an indispensable part of product development. To support small and medium-sized enterprises (SMEs), in particular in the digitalisation and virtual development of new products, the DLR Institute of System Dynamics and Control has founded the 'Systems & Control Innovation Lab' (SCIL). Here, businesses gain access to new design technologies and software tools for the modelling and control and regulation of complex mechatronic systems. Thanks to the use of non-linear and robust control concepts not available as standard, such as those developed at the Institute, extremely varied technical systems can be operated more efficiently, safely and more cost-effectively. The availability of experts in the diverse fields of system dynamics and mechatronics gives the partners access to the latest knowledge.

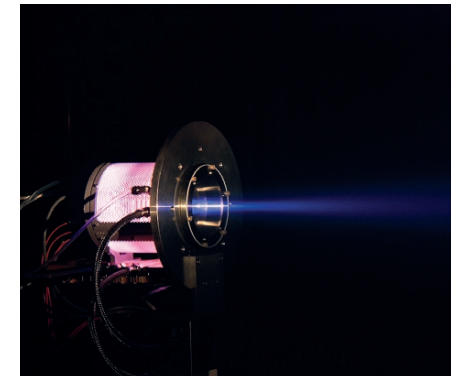


The STREICHER Group, an international company operating in the field of construction and machinery and plant engineering, already uses the SCIL as a platform for joint research and development. The topics range from simulation feasibility studies to the development of training simulators as well as the digital analysis of products. A digital twin, for example, helps the group research the effects of different design alternatives and carry out simulations and tests. The digital twin is a computer-based copy of the actual machine, created simultaneously and expanded. This helps to ensure that the product designs fulfil the specifications.

The DLR Institute of System Dynamics and Control founded the 'Systems & Control Innovation Lab' (SCIL) in Oberpfaffenhofen

# ELECTRIC PROPULSION SYSTEMS 'MADE IN GERMANY'

Electric propulsion systems are considered to be particularly promising space technology. Although they produce less thrust, their fuel efficiency is significantly higher than that of conventional chemical engines. The German Federal Ministry for Economic Affairs and Energy (BMWi) is therefore supporting their development via the DLR Space Administration, and now with commercial success: The ArianeGroup has received a first production contract for RIT 2X electric propulsion systems for Boeing telecommunication satellites as part of a joint development programme. The propulsion systems are being developed, manufactured and tested by ArianeGroup in Lampoldshausen. Satellites can thus be made considerably lighter and more durable. Additionally, the payload capacity can be increased because of the lower fuel mass needed. Electric engines are therefore of particular interest to interplanetary long-term missions – or for high-performance communications satellites.



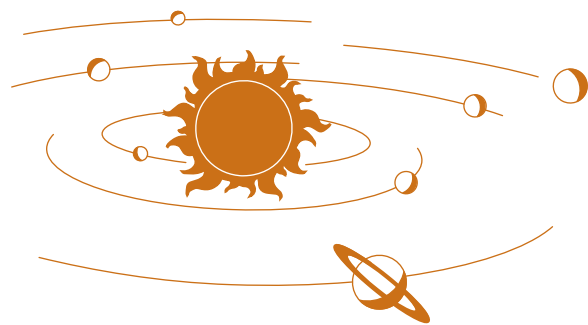
Radio frequency-ion thruster (RIT) test at DLR

In contrast to chemical drives, in which the energy is stored in the fuel itself, the energy for electric propulsion systems comes from the satellite's solar cells. The RIT engines use electromagnetic waves in the radio frequency range in order to ionise the propulsion gas – such as xenon, generally used in electric engines – which generates an electric charge. Subsequently, the ionised gas is accelerated by use of a high-voltage grid. As a result, the satellite experiences thrust and is driven in the desired direction. For this operation, the engines require a sophisticated combination of high voltage and high currents provided by the power supply unit.



# BINARY 'WOW' MOMENTS

**P**hotographs, maps, atlases, globes and detailed information about nearly all planetary missions – that is what the Institute of Planetary Research houses at the Regional Planetary Image Facility (RPIF). The DLR RPIF is a NASA facility for German-speaking regions. What lies here is a true treasure trove – images from spaceflight into the depths of the Solar System and planetary research stored as ones and zeros that are accessible to all.



## The Regional Planetary Image Facility – out-of-this-world library

By Ulrich Köhler

Going to space is the past, present and the future, all at once – or so they say. This is not to mention the fact that space has long been writing history as well. We just celebrated the 60<sup>th</sup> anniversary of the launch of Sputnik 1, the first man-made satellite. It will soon be 50 years since Earthlings set foot on the Moon, for the first time on a celestial body, back in 1969. That historic event brings an image or two to mind. They are legendary, iconic, fabulous historical records. And with just a little effort we can imagine the future, because we can already 'picture' it in our heads. So even in the future, the image already exists: an image, albeit in words. However, the present floods our brains with images – every hour of the day, from the moment we are awake, visual overkill, 24/7. And what of the past? In our heads, the past is played back in a series of thoughts, words and, above all, images. Archives – like the DLR Planetary Image Library – are the opposite of the hamster wheel of today's visual overload. Here, the images rest, waiting to be rediscovered. Those familiar with the material know that it is there when needed.

Which of today's social media platforms would Neil Armstrong have used to report his 'giant leap' directly his followers almost in real time? That is a tough choice, but the only certainty is that, as with any historic event, images would and do play a major role. They are collected and archived – in the past, in a drawer, a metal cabinet or in an acid-free environment; today, they are kept in a data store, in the 'cloud' or at least on a smartphone or PC.

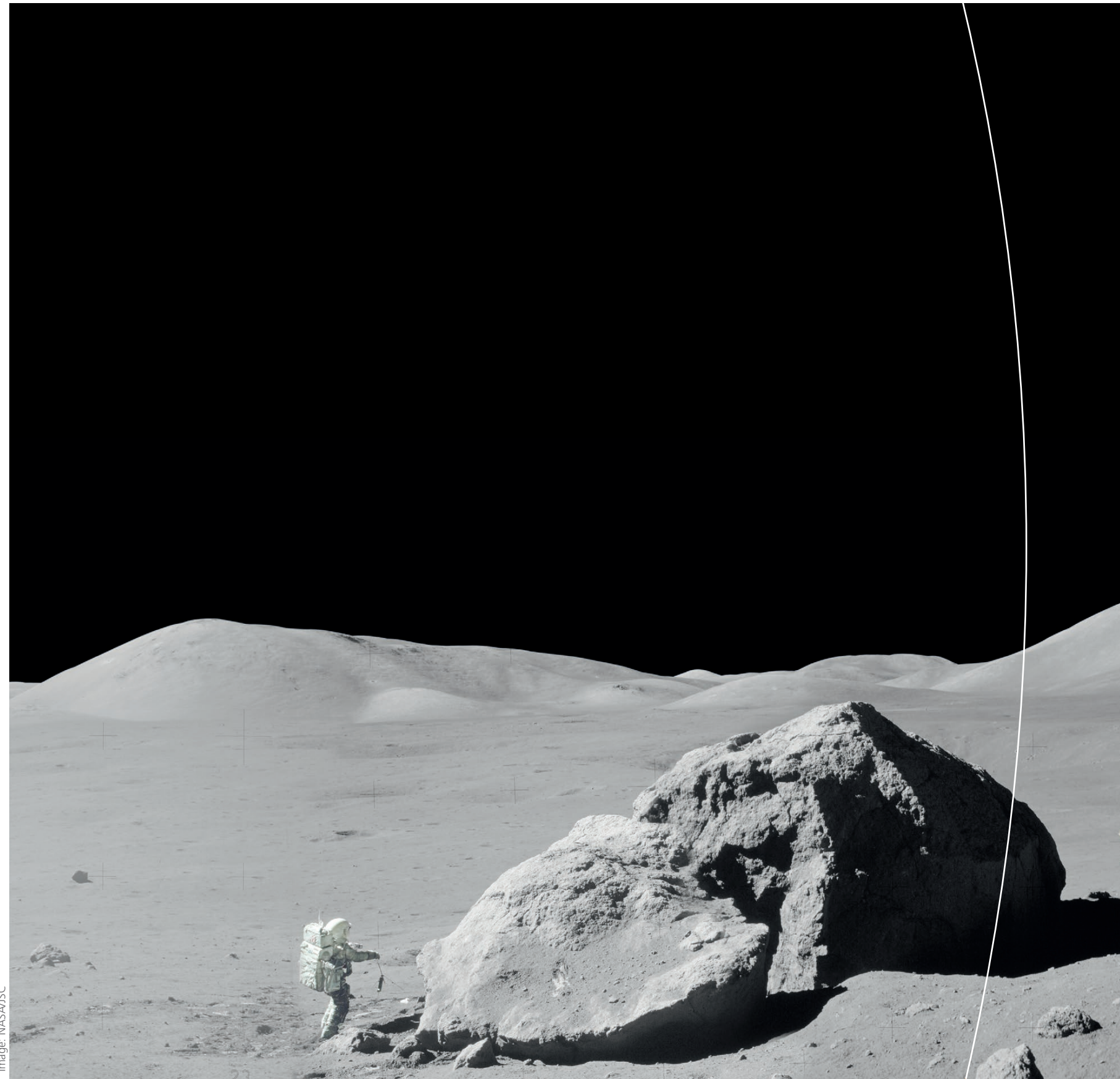


Image: NASA/JSC

Space, humans and science – the world-famous images of the Apollo moon landings are the ones that are forever being requested at the Regional Planetary Image Facility. One of the most prominent images shows geologist and astronaut Jack Schmitt at 'Tracy's Rock' near the Apollo 17 landing site.



At the Planetary Image Library, data manager and librarian Susanne Pieth together with Ralf Jaumann, director of the German RPIF, manage a treasure trove of historical images from the pioneering ages of Solar System exploration, including several hundred first copies of lunar images from the five Lunar Orbiter probes from the 1960s.



Globe collection – from Mercury to Jupiter’s moons



The Voyager era – Jupiter’s Great Red Spot



Image: NASA/JPL

Sensational image from 1976 – Viking lands on Mars

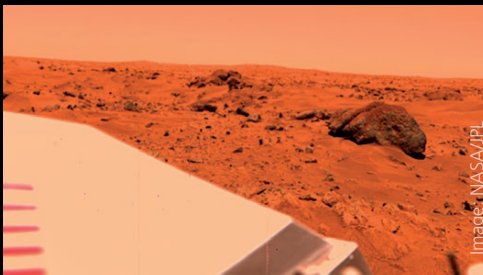
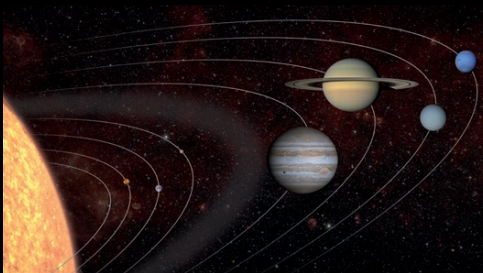


Image: NASA/JPL

All kinds of images, from Mercury to Neptune – even Pluto



Photographic records of the intensive experiments carried out on the Moon: a 360-degree panoramic view of the landing site.



Image: NASA/JSC

## When the Solar System got a ‘face’

Spacefaring nations collect and document images of the planets and numerous other bodies in the Solar System in professional archives. In doing so, they have been providing science with comprehensive data on every individual mission for centuries. But, generally speaking, we see little or nothing of this mass of data on spaceflight – which is always associated with the term ‘Big Data’. Now more than ever, the results of this research are being made accessible to a wider audience. The data interface for the German-speaking public is located in three offices on the third floor of the DLR Institute of Planetary Research in Berlin-Adlershof.

Back in the pioneering days of the 1960s and 1970s, images brought the age of spaceflight into our living rooms – even though initially they were just something for specialists. The first missions to our planetary neighbours, Venus and Mars, also took place in those years. We humans could suddenly see far more than what was possible through the limited – albeit breathtaking – view through a telescope. In 1959, the Soviet Union succeeded in photographing the far side of the Moon for the first time – with surprising insights. But none of these were major media events. Technically speaking, the images were still crude, of poor resolution, and not exactly eye-catching.

But all of that changed in 1976. NASA landed the two Viking probes on Mars, and together with their namesakes in orbit, they spent several years observing the Red Planet. Razor-sharp images of a new world came in high resolution and in colour. These pictures garnered thousands of ‘wows’! NASA did not hold back the images. This was the time of magazines and journals. In addition to television – which was becoming increasingly popular, albeit slowly at first – the printed image was the communication tool of choice: LIFE, Time Magazine, Paris Match, Stern and the iconic yellow magazine published every month by the National Geographic Society.

## The power of images – even in space

Spaceflight attracted a great deal of attention in those days. NASA enjoyed great success, as did the Soviet Union, around Venus for the most part: It even landed there several times, beneath the veil of clouds that is impenetrable to cameras. However, the number of sensational images from the Venus missions can be counted on two hands, as these were handled very restrictively in those days. But, above all, it was the six Apollo missions to the Moon that cast a spell over us. NASA understood the power of images and strapped a Swedish Hasselblad (with German optics from Zeiss) to the chests of all its moonwalkers; the images brought rich scientific rewards to advisory geologists.

Hundreds of fantastic photographs taken by the 12 astronauts revealed what the surface of the Moon is like. The images include icons of human history, such as Buzz Aldrin’s famous footprint in the lunar dust. These pictures, as well as the colour images of Mars mentioned above – which were soon overtaken by the first close-ups of Jupiter (Pioneer 10 and 11, but mainly Voyager 1 and 2 in 1979) and Saturn (Pioneer 11 and again the two Voyagers, in 1980 and 1981) – marked a brief period in which humankind seemed to know no boundaries.

## Sixteen planetary image libraries worldwide

Today, there are 16 RPIFs – nine in the United States, four in Europe, and one each in Canada, Japan and Israel. The director of the German RPIF is Ralf Jaumann from the DLR Institute of Planetary Research, and the facility is managed by Susanne Pieth and Marianne Weiland. The individual image libraries are networked via the NASA Planetary Data System (PDS) and offer extensive research options in its databases. But despite the Internet, Big Data and digital archives, many tasks can still only be handled by actual people on site. This is because the only ones that know where to find the real historical treasures in the depths of their collection are the librarians. Almost everything provided by the RPIF is free of charge; at most there are printing or copying fees.

## Guardians of otherworldly images

In the late 1970s, NASA was beset with more and more image requests from media, schools, universities, the general public, planetariums and museums. So it set up a few regional image libraries and data centres – initially in the United States – in which such requests were processed quickly and bureaucracy-free. NASA was aware of its obligation to let the public share in the adventure of spaceflight – after all, it is taxpayers’ money taking off with each rocket on journeys stretching for millions of kilometres through the Solar System. The Data Center system became very popular. After a while, NASA recognised that these products could also become successful export material and decided to no longer restrict this data to the domestic public.

The US looked for partners for their library system, and found them in Canada, Europe, Israel and Japan. Contracts were drawn up and a network was established. Each was responsible for a specific region, and the data centres were now called RPIFs – Regional Planetary Image Facilities. There was also to be an RPIF (pronounced ‘Arpiff’) in Germany. An agreement was drawn between NASA and DLR in autumn 1985. Back then, the German RPIF was established in the small Planetary Exploration Department of the then Institute of Optoelectronics in Oberpfaffenhofen.

This department – headed by the charismatic planetary researcher Gerhard Neukum – developed successful experiments such as the High Resolution Stereo Camera (HRSC) for ESA’s Mars Express mission, sometimes in draughty containers in Oberpfaffenhofen, and has today grown into an institute in Berlin with almost 150 employees. The small RPIF has expanded with it, serving the entire German-speaking region with four large rooms covering 200 square metres. As the most active RPIF outside the USA, it has been responding to requests from all over Europe and other continents for years. For visitors and local staff, it provides an orderly, well-stocked reference library.

A special treasure at the library is the image mosaic collection – topographical and thematic maps of every planet and many moons in the Solar System, and globes for most of them. To emphasise the historical science aspect, for example, there are a complete set of several thousand original copies of the Viking missions to Mars and, above all, the large Lunar Orbiter images, which were used in 1967 to 1969 to plan the landings for the Apollo programme – all using analog technology.

Also unique was the collection of slides that filled half a dozen cupboards in the ‘prehistoric’ pre-PowerPoint era. Then came digitalisation, and all the images from the Viking and Voyager period were converted into ones and zeros and fed into an image database. Today, there is a lot more space in the RPIF to pore over one of the hefty atlases of the Solar System.

## Magical moments for exhibition visitors and viewers of illustrated books



Image: NASA

The RPIF is anything but a passive archive waiting for interested visitors. Rather, it is a disseminator of DLR’s extensive knowledge of planets, moons, asteroids and comets, and communicates this through words and images. Every year, DLR scientists organise lectures for school students at the RPIF. The “Magical Moments: Wonders of the Solar System” exhibition, created by the Gasometer Oberhausen in cooperation with DLR for the International Year of Astronomy in 2009, was illustrated by the RPIF. Almost one million people marvelled at the images, which are not only scientifically important but also aesthetically valuable. Beginning in 2016 and ending in January 2017, the exhibition ‘Comets: The Rosetta Mission’ was held at the Museum of Natural History in Berlin – and was also a huge success, with hundreds of thousands of visitors. However, unsurpassed so far is ‘The New Image of Our Neighbour Mars’, the DLR exhibition seen in 3D by more than three million people across the globe since 2005. Furthermore, the most valuable didactic product is the 120-page brochure ‘Our Solar System’, the fourth edition of which will soon be available, and distributed free of charge at DLR events and a big attraction during astronomy lessons in German schools. Every year at the annual meeting of RPIFs in the United States, Berliners can report to NASA: mission accomplished!

**Ulrich Köhler** is a scientific staff member at the DLR Institute of Planetary Research and is responsible for public relations. Therefore, he is also the RPIF’s ‘best customer’.



# CATHEDRAL OF COSMONAUTICS

Nostalgia meets modernity at the Museum of Cosmonautics in Moscow

By Manuela Braun



Walking inside this museum is like walking into a church. Straight ahead in the semi-darkness, bathed in soft light, stands Yuri Gagarin: six metres tall, arms fully extended, and wearing a cosmonaut helmet. Colourful stained glass shines behind the mighty bronze statue. This view alone would almost make you overlook the other – equally impressively lit – displays left and right. The Museum of Cosmonautics in Moscow is more than a mere museum – it embodies Russian pride in its pioneering activities in spaceflight: the first beeps from a satellite in space came from the Russian Sputnik probe in 1957. In 1960, the dogs Belka and Strelka became the first living creatures to return from a flight in Earth orbit. And finally, in 1961, Russia succeeded in sending the first human to space and one time around Earth – that person was Yuri Gagarin.

The Memorial Museum of Cosmonautics was opened in 1981 on occasion of the twentieth anniversary of the first manned spaceflight. At the time, it was but an 800-square-metre exhibition hall showcasing some 100 exhibits. This was fairly small for such a great spacefaring nation, so in 2006 the museum closed for renovation and reopened in 2009. Now, the exhibition space covers an impressive 4000 square metres, and is home to several thousand exhibits. The aim of portraying the splendour of space has been achieved, said the then Mayor of Moscow, Yuri Luzhnov, at the reopening ceremony. Although it must be said that this space museum is a much better accolade to Russia's achievements than an appreciation of space itself.

## Audio guide to another world

Under the gaze of Gagarin, you are literally drawn into the light of the first exhibition hall where the 'Dawn of the Space Age' exhibition is set up in an equally spacious manner. A proud and slightly solemn voice is heard through portable headphones that are really worth getting at the entrance for 150 roubles, which is about two euro. Some exhibits have English descriptions, but these are generally shorter than the Russian ones – and at times they are simply non-existent. Although the audio guide only includes information about selected exhibits, it does help to prioritise. The small cabinets in which small, lovingly handwritten notes, black and white photographs and historical cameras, for example, are displayed, remain something of a mystery, but are still nice to look at.



Space travel is also represented in this stone monument on the roof of the museum



Landing in a remote icy area – mannequins in cosmonaut suits warm themselves around an artificial fire with a Soyuz capsule in the background. The museum shows that spacemen must be prepared for anything.



A carefully polished 1:1 scale model of the first lunar probe, Luna 1, seems to glow in the first hall. Even though it is not mentioned in the exhibit label or the audio, it was due to arrive at the Moon two days after its launch in 1959. But, instead, Luna 1 raced past it at a distance of 6000 kilometres, becoming the first space probe to swing into orbit around the Sun. The Russians received its last signal when it was at a distance of 600,000 kilometres. On the other side of the darkened hall shines the metallic silver Sputnik 1. A model of Sputnik 2, which carried the dog Laika into space, is also on display. The exhibit descriptions here are extremely short and factual – there is no mention of the fact that there had been no plans of bringing the dog back to Earth, or of how the flight progressed. Hence, some of the historic tales of spaceflight are sadly missing. Instead, the museum relies on facts and technical details, unless those involved are pioneers such as Yuri Gagarin or rocket and spacecraft designer Sergei Pavlovich Korolev.

Special space champs

A group of German school children gathers around the Sputnik 5 capsule, in which the dogs Belka and Strelka, along with mice, rats and plants, orbited Earth. The actual, battered spacecraft is exhibited alongside the animal cosmonauts, which are displayed in two glass cabinets. ‘Are they models?’ – the museum guide quickly asks the staff. No, the two dogs were stuffed after they died and now, behind glass and protected from dust, stand as exhibits and heroes of spaceflight in the Museum. The exhibit description elaborates: “There was a small area with an automatic feeding machine, toilet and ventilation system for the dogs.” The audio guide also explains that the two stray dogs were specifically selected because the colours of their coats were easy to identify and distinguish in the images from the camera installed inside the spacecraft.



Their flight and soft landing were the acid test for the first manned spaceflight, ultimately benefiting Yuri Gagarin. Strelka came to fame again later: one of her six pups was given to the daughter of United States President John F. Kennedy by Nikita Sergeyevich Khrushchev, the former leader of the Soviet Union.

Spacesuits, training equipment and Matryoshka dolls

The first hall alone has so many exhibits of historical significance that you now have to get a move on in case you had planned a short visit to the Space Museum. The easiest thing might be to pass the next room – the main attraction there is the recreation of rocket designer Sergei Korolev’s office, with an old desk in front of a blackboard, two telephones, and the main figure wearing a smart suit and gesturing energetically. But when you walk into the next hall and enter a gallery, your gaze falls on cabinets, spacesuits, training equipment for flight in space, a model of two Soyuz spacecraft docking, experiments such as the Matryoshka dolls that DLR uses to investigate the radiation load on astronauts on the ISS and – one floor below – rockets such as the Saturn V and the Buran spacecraft. From the almost religious-looking, dim-lit main hall showcasing the relics of the age of the cosmonaut pioneers, you now continue to a brightly illuminated area.

The various levels are important and necessary: on the top floor, you look into the habitation module of a Soyuz rocket, and on the lower floor the landing module awaits visitors. The upper section was once used for training purposes, but the landing module with its scorched surface has actually been to space and back. The amazing thing about it is that it is still functioning and, with the appropriate preparation, could go back into space. The entire spacecraft is several metres high, and about 2.7 metres in diameter.

A few metres further, three mannequins recreate a scene of cosmonauts warming up around a fire after landing in the snow – with the landing capsule behind them. This is seen over and over again in the museum – life-size historical pieces, impressive models, followed by slightly old-fashioned scenes involving dolls and mannequins that you would not expect to see in a modern museum nowadays. However, this is precisely what gives the Museum of Cosmonautics its own special charm.

Living like cosmonauts

A highlight of the exhibit on the upper level is surely the core module of the Russian space station Mir. What does an actual space toilet look like? To which table do the cosmonauts float to eat, and where do they sleep? A footbridge leads into the interior of the cosmonauts’ habitation module, the original of which orbited Earth from 1986 to 2001 before finally burning up during atmospheric re-entry.

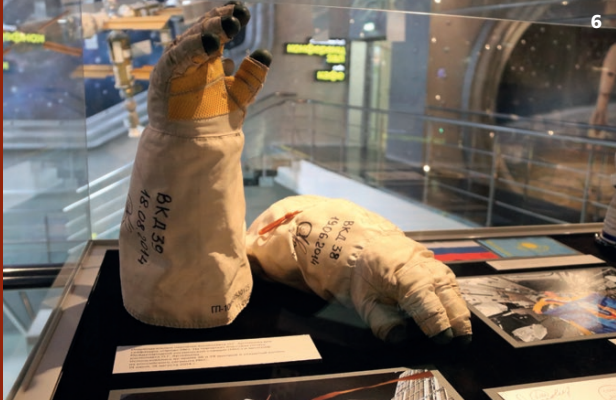
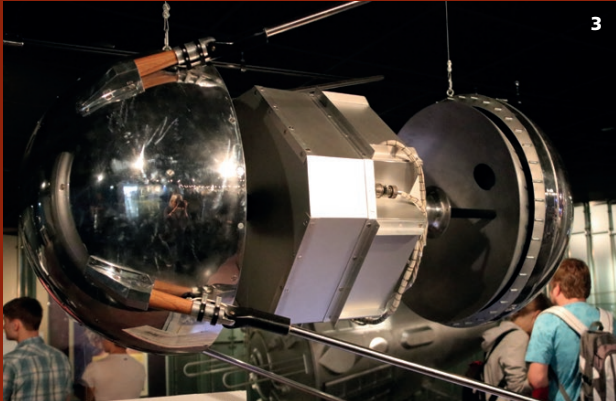
As far as the remaining exhibits are concerned, you just have to decide what to look at more closely. There are no English descriptions for the smaller exhibits, and the audio guide is often silent as well. Space food in tubes, neatly organised, surgical equipment for a medical emergency and scary-looking dentistry tools lie inside the cabinets, supplemented by photos of the cosmonauts. Two certificates from the Guinness Book of World Records bear witness to the fact that cosmonaut Sergei Krikalev was the first person to cultivate plants that in turn produced seeds in microgravity. His gardening skills also extended to a small cosmic lemon tree in space.

From robotic arms to room doors

Walking on, you encounter the German-Russian experiment ROKVISS, in which DLR controlled a robotic arm on the outside of the Russian ISS module from the ground, as well as a black rag doll in a training suit sitting on an original revolving chair, which has clearly seen its best years. In former years, cosmonauts had to put their sense of balance to the test on this training device. Autographed astronaut gloves, meteorites you can handle and a reproduction of a room door from the Cosmonaut Hotel in Baikonur – the range of exhibits is astounding.

Illuminated models of the lunar sample return mission Luna 16 and the first unmanned lunar rover, Lunokhod 1, are displayed in a life-size exploration set. In 318 days, Lunokhod 1 drove across over 10 kilometres on the Moon, sent over 20,000 images and panoramas back to Earth and, in doing so, enabled 80,000 square metres of the Moon’s surface to be investigated. An entire hall is devoted to space medicine – looking at the almost ancient equipment and apparatus from the early days of human spaceflight gives the visitor a sense of the true pioneering spirit of the first astronauts. Finally, in a small separate section, a couple of curiosities await. What could be more Russian than Matryoshka dolls – wooden figures nested one inside the other, normally depicting a farmer’s wife with a headscarf and apron? In the age of spaceflight, the farmer’s wife became the rocket, out of which the space dogs peered, or cosmonaut Gherman Titov, who took the first photographs of Earth and was the first person to eat and sleep in space.

The collection found at the Museum of Cosmonautics in Moscow is a true treasure trove – even if, admittedly, it might be overwhelming at times. Some exhibits could do with additional information, but on the other hand many objects on display are probably only appreciated by the cosmonauts who used them. For example, the layman can barely notice the difference between the various spacesuits. Yet the feeling of being right at the heart of the history of spaceflight never leaves you, thanks primarily to the original exhibits. It is inspiring, breathtaking and even gives you goosebumps.



1 Sculpture of Yuri Gagarin 2 View of the lunar probe and rover 3 Pioneer satellite Sputnik 1  
4 Space dogs: Belka and Strelka 5 Revolving chair for cosmonaut training  
6 Cabinet with original spacesuit gloves

Museum of Cosmonautics

Address	111 Prospekt Mira Moskau
Metro station	VDNKh
Opening times	daily 10 to 19 h Thursdays 10 to 21 h
Entry fee	closed on Mondays
Photo pass	250 roubles
Video pass	230 roubles
Audio guide	230 roubles 150 roubles

[www.kosmo-museum.ru/?locale=en](http://www.kosmo-museum.ru/?locale=en)



# OVERVIEW WITH EUREKA MOMENT



The illustrated book **Overview. A New Perspective of Earth** (Amphoto Books) owes its creation to a stroke of luck: Benjamin Grant wanted to view a distant satellite image of our planet on his computer. He typed ‘Earth’ into the mapping program and what appeared was a zoomed-in image of the city ‘Earth’ in Texas, which, thanks to an irrigation system, lay in a patchwork of green and brown circles. The chance hit showed Grant how extraordinary, revealing and even surprising the pin-sharp satellite images of Earth can be. He has collected over 200 satellite images for the illustrated book, and assigned each to a category: ‘where we harvest’, ‘where we play’, ‘where we move’, ‘where we waste’ and even ‘where we are not’ are some of them. Each image includes a brief note on the corresponding coordinates that helps classify the image.

The overview from space helps us familiarise ourselves with a formation of structures and colours. Sometimes, it is the contrast that makes the images so appealing: The strictly linear, extremely densely populated districts of Delhi are in sharp contrast with the ring-shaped settlements of a commune near Copenhagen. The similarity of eight satellite images that show populated areas in geometric structures differ in form but are recognisable in composition, above all in the accuracy with which their development follows certain lines. The juxtaposition of satellite images of the same area from different years shows the development of landscapes. This will often lead to a Eureka moment, as a clear view of the bigger picture is only possible from space. Those who would like to be astonished by satellite images beyond those featured in the illustrated book are advised to browse the author’s website: [www.dailyoverview.com](http://www.dailyoverview.com).

Manuela Braun

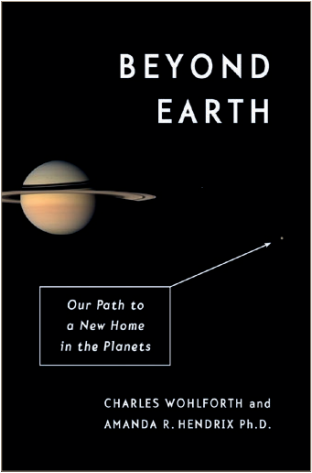
# PSYCHOLOGICAL STUDY IN THE ANTARCTIC



Almost 100 years have passed since the first expedition to the Antarctic island Everland – back in 1913 with simple tools, to the more recent one in 2012 with modern equipment. Rebecca Hunt’s novel **Everland** shows one thing above all in the switching between two periods of time – equipment alone is not always enough; it is mostly down to the people, who are put to the test by the hostile environment. Even before the start of either expedition – each with three participants – the relationship between the researchers cannot be described as harmonious and is instead characterised by distrust and dislike. In both cases, a newcomer endangers the venture. The very first pages of the novel make it clear that nobody survives the 1913 expedition. What really happened and who abandoned who remains unresolved, however. Knowing this makes for a more skeptical read of the 2012 expedition in which tensions also start to build within the team.

Rebecca Hunt does not make it easy for the reader; not only does she jump between the two expeditions, the events within time periods are also not recounted chronologically. This means it is not always easy to follow the sequence of events. Things often remain unspoken, almost hazily, which contributes to the mysterious tone, but at times leaves the reader somewhat lost – even more so with a number of false clues about what happened during the first expedition. The novel will require some time and effort to plough through, but promises an ‘adventure story, absorbing thriller and psychological drama’ – even if it does not engross the reader right from the start.

Manuela Braun



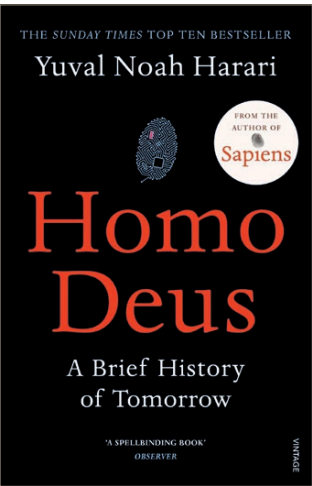
# BEYOND EARTH

At the moment, there is a lively discussion going on about space travel and plans for building a Moon base and sending astronauts to Mars. The expectations are high. If you are interested in the topic, this is certainly the book to read. In **Beyond Earth. Our path to a new home in the planets** science writer Charles Wohlforth and planetary scientist Amanda R. Hendrix join the lively discussion and explain why the current obstacles caused by bureaucracy, politics, and science are still so great that these space projects are not feasible in the near future.

Wohlforth and Hendrix then discuss current and planned exploration of the Solar System. In every chapter, the results of their research are processed in fascinating little segments. They are about humanity’s high expectations and the reality that today’s technology has not come that far. The authors also argue that it is Saturn’s moon Titan, not Mars, that offers the best conditions for life without support from Earth. But despite the many problems for which solutions must still be found, both believe that humans will eventually leave Earth and inhabit other planets. The biggest drive – the human capacity for invention and appeal of adventure.

Dirma van Eck

# FROM HOMO SAPIENS TO HOMO DEUS



Today, people have it good: Compared with past centuries, hunger, disease and war generally no longer have such extreme consequences. Building on this argument, in **Homo Deus. A Brief History of Tomorrow** (Penguin Books), Yuval Noah Harari outlines his vision of the future. From Homo Sapiens who conquers the world and makes sense of the world, to the same Homo Sapiens who loses power, Harari’s vision spans 575 pages. How do people who strive for happiness and immortality change – simply because they can? What will the impact of biotechnology and artificial intelligence be? The weighty tome is easy to read, pleasantly written and offers a plethora of information and food for thought. This represents both an advantage and a disadvantage at the same time: the more pleasant the non-fiction book is to read, the quicker Harari pulls his readers into his view of the world. However, this should not be made too easy for them – readers who pause every now and again and question what the author is so elegantly postulating will get more out of the book.

Manuela Braun

## RECOMMENDED LINKS

A HISTORY OF AVIATION IN IMAGES  
[goo.gl/weJ8jU](http://goo.gl/weJ8jU)  
The NASA Armstrong Flight Research Center has created a gallery of historic flight experiments online. The more than 300 clips already available (with a further 200 announced) show test flights over the Mojave Desert in California from 1946 to today. In addition to space shuttles, lifting bodies, early unmanned aerial vehicles and more, tests from the Stratospheric Observatory for Infrared Astronomy (SOFIA) are also featured.

TIME GAME  
[appstore.com/spacefrontier](http://appstore.com/spacefrontier)  
The free time sink game Space Frontier is the right choice for those who like both action and rockets. The task – to fire and detach the stages of your rocket at the right moment to launch it as high as possible. But a word of warning: Jettison each stage as late as you can, but not too late, otherwise – wham! The app is available for mobile devices in the usual stores.

DLR\_GRADUATE\_PROGRAM  
**DLR.de/Graduate\_Program**  
The DLR programme is aimed at young scientists. The objective is to train doctoral students systematically and to a high level, enabling them to undertake excellent scientific work, as well as enhancing their management and social skills. The new brochure is available for download at [DLR.de](http://DLR.de).

VIEW FROM THE CUPOLA  
[bit.ly/2uEDunQ](http://bit.ly/2uEDunQ)  
Google is granting everybody access to views that would otherwise only be available to the crew of the International Space Station. Without sound, as though the viewers themselves were weightless, the view from the Cupola of the ISS can be enjoyed using Google Streetview.

TAKE A VIRTUAL STROLL ON MARS  
[accessmars.withgoogle.com](http://accessmars.withgoogle.com)  
Thanks to the data collected by NASA’s Curiosity rover, it is now possible to explore the dunes and valleys of the Red Planet. The ‘Access Mars’ experiment is produced by the Jet Propulsion Laboratory, together with Google Creative Lab. Now, you can take a walk with Curiosity – learn all about this amazing mission, visit the different mission sites and find out if Mars is suitable for life. The free app is available for use on all desktop and mobile devices and virtual reality/augmented reality (VR/AR) headsets.



## About DLR

DLR, the German Aerospace Center, is Germany's national research centre for aeronautics and space. Its extensive research and development work in aeronautics, space, energy, transport, digitalisation and security is integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space programme. DLR is also the umbrella organisation for the nation's largest project management agency.

DLR has approximately 8000 employees at 20 locations in Germany: Cologne (Headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Bremerhaven, Dresden, Göttingen, Hamburg, Jena, Jülich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Oldenburg, Stade, Stuttgart, Trauen and Weilheim. DLR also has offices in Brussels, Paris, Tokyo and Washington DC.

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Three-dimensional digital image of pores in a nickel-based super-alloy for highly-stressed components in aircraft turbine engines (Colour is computer-generated), DLR Institute of Materials Research



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