

A large jet engine is shown in a workshop setting, mounted on a red frame. The engine is split vertically down the middle. The left half is a dark, metallic, realistic-looking engine with a glowing orange-yellow core. The right half is a bright blue, semi-transparent, digital-looking engine with a glowing blue core. The background shows industrial structures and blue lighting.

COMPUTE BEFORE FLIGHT

HOW THE VIRTUAL ENGINE CAN ADVANCE AERONAUTICS RESEARCH

More topics

- ▶ LYING DOWN IN THE NAME OF SCIENCE
Bedrest studies explore spaceflight-related diseases
- ▶ SUN AND SALT
DLR research into solar thermal power plants

About DLR

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

Climate, mobility and technology are changing globally. DLR uses the expertise of its 55 research institutes and facilities to develop solutions to these challenges. Our 10,000 employees share a mission – to explore Earth and space and develop technologies for a sustainable future. In doing so, DLR contributes to strengthening Germany's position as a prime location for research and industry.

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DLR STATEMENT

As we write this issue of the DLRmagazine, the world is contending with the terrible news about the war in Ukraine. We are watching the developments with grave concern and condemn Russia's aggressive actions. As one of the largest research organisations in Europe, the German Aerospace Center (DLR) is committed to engaging in international cooperation for the benefit of society and industry. Hailing from 96 countries, DLR staff stand for the peaceful coexistence of all nations and peoples.

DLR and the German Space Agency at DLR have been cooperating with Russian institutions on a number of research projects, in some cases with the participation of other German research organisations and universities, and international partners. The Executive Board has taken measures to terminate all bilateral collaboration with Russian institutions on current and planned projects and no new projects or initiatives will be undertaken with institutions in Russia. In taking these steps, DLR is acting in close coordination with its national and international partners.

Dear reader,

Modern engines should be as quiet and emission-free as possible without compromising on power. For decades, this has been the focus of the DLR aeronautics institutes, who have been working on developing better engines and testing them using various test benches. For some time now, however, there have been new components to this research – simulations and digital models. These innovations allow researchers to digitally test new concepts in advance without the need for costly prototypes, speeding up the development of new engine designs. In this issue, DLR scientists Stanislaus Reitenbach and Kai Becker talk about the role that the virtual engine could play in the future.

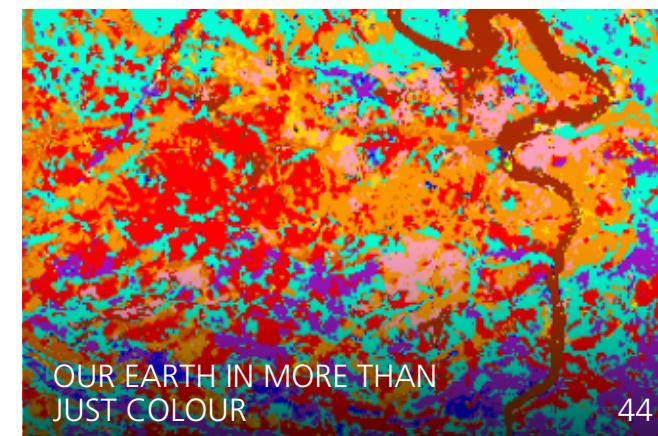
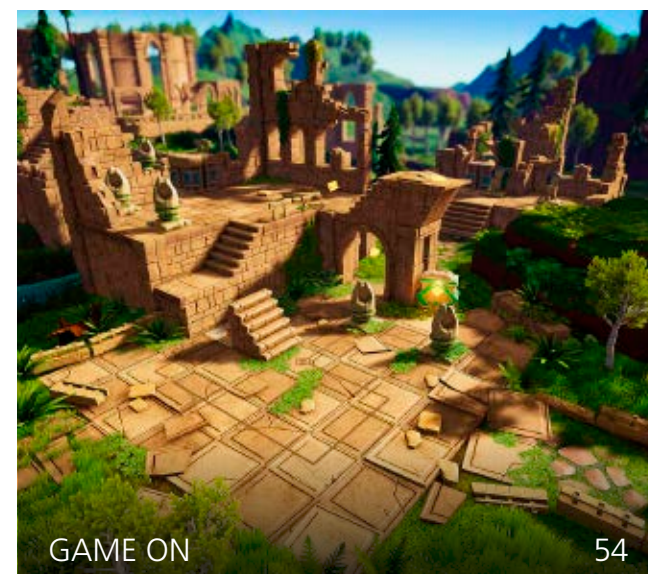
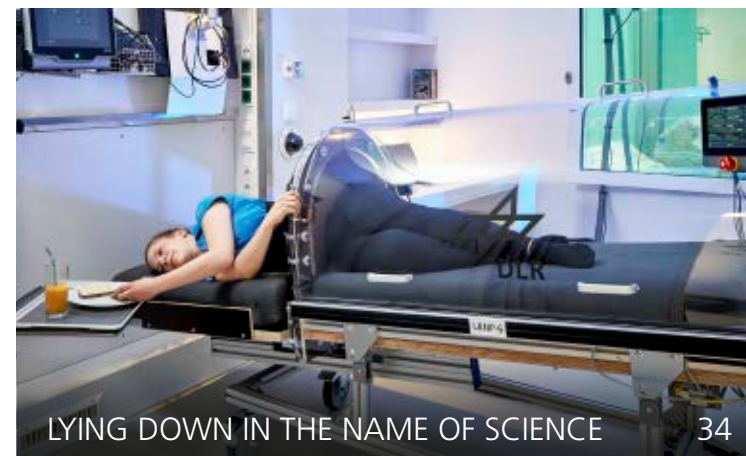
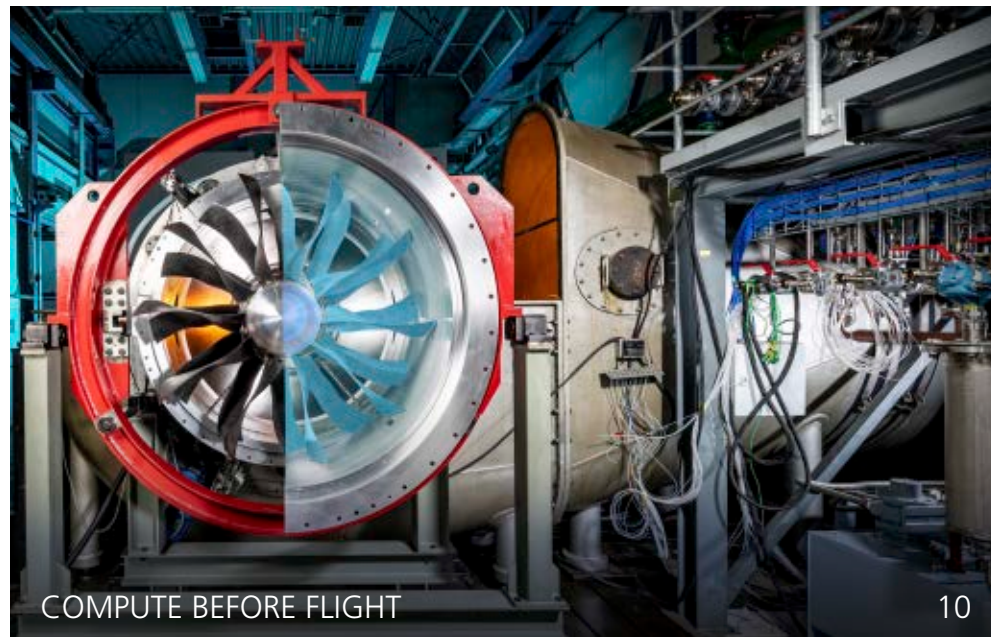
It is not just engines that are being digitalised. In Hamburg-Finkenwerder, a factory is being built that takes up almost no space – because it is digital. Here, DLR researchers are working with industrial partners to investigate and evaluate new concepts and technologies for aircraft design, components and production.

In the area of aerospace medicine, a very special mission is poised for launch this summer. Two mannequins modelled on the female body are scheduled to fly towards the Moon on board NASA's uncrewed Artemis I mission. On the way, the MARE experiment will measure radiation exposure during the flight. Through the Artemis programme, the first woman will travel to the Moon. Since the number of female astronauts is set to increase in the future, there is a great demand for data on the impact of spaceflight and microgravity on the female body. As part of this research, regular bedrest studies have been carried out at the DLR site in Cologne since 1988 involving both female and male participants who remain in a tilted, head-down position for extended periods. This edition of DLRmagazine contains an overview of bedrest studies conducted in recent years. And for those who long for some sunshine, the article on the Évora Molten Salt Platform takes you on a trip to Portugal, where DLR is operating a parabolic trough test facility using molten salt.

Last but not least, this issue contains a little surprise: a poster of ESA astronaut Matthias Maurer on his spacewalk. On the back, you'll find a comprehensive overview of the International Space Station (ISS).

We hope you enjoy this issue.

Your Editorial Team



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LESS EMISSIONS THROUGH ELECTRIC LIGHT VEHICLES

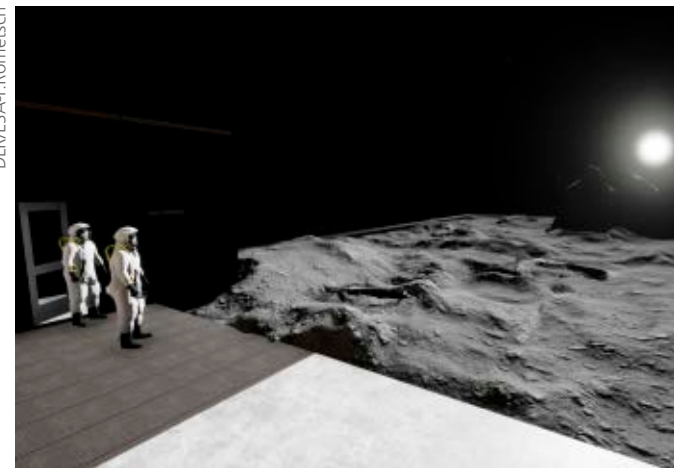
Half of the kilometres currently driven by car in Germany could theoretically also be covered by light electric vehicles (LEVs). This would reduce greenhouse gas emissions by more than 40 percent compared with journeys by conventionally powered passenger cars. This would mean around 57 million metric tonnes less emissions per year. This is the conclusion of a study conducted by DLR on behalf of LEVA-EU, the association representing the interests of light electric vehicles. For their study, researchers from the DLR Institutes of Vehicle Concepts and Transport Research looked at the entire spectrum of light electric vehicles. These range from kick scooters, e-bikes and e-load bikes, electric scooters and motorcycles to three- and four-wheeled small cars.



Light electric vehicles can be used flexibly and cause fewer climate-damaging emissions

THE MOON IN COLOGNE

Construction of the LUNA test and training facility will soon commence at the DLR site in Cologne. Astronauts who will fly to the Moon will be trained here. In the 700-square-metre hall, which is nine metres tall, the specific environmental conditions of the Moon will be simulated realistically. A lunar dust or regolith simulant will cover the entire floor of the hall, there will be lunar-like craters as well as rocks and a crane system that simulates the reduced gravity of the Moon. LUNA will provide a test centre for technology and a training ground for astronauts and long-term spaceflight missions, as well as the operation of a lunar station. LUNA is a joint project between DLR and the European Space Agency (ESA), which operates the European Astronaut Centre (EAC) in Cologne. It will benefit from proximity to the facilities and expertise of the EAC and the DLR research institutes, such as the Department of Space Operations and Astronaut Training and the Institute of Aerospace Medicine, including its :envihab facility, making it an attractive site for preparing humans to explore farther into space.



This is what it the interior of the LUNA lunar analogue facility will look like

DRONES MEASURE AIRFLOWS AROUND WIND TURBINES

Wind that flows around wind turbines forms air vortices. These influence the power that the turbines can feed into the energy grid. With a swarm of around 100 drones, DLR is researching these flow phenomena in the ESTABLIS-UAS project. The aim is to understand the three-dimensional, turbulent structures and thus the loads acting on the plants. The small drones fly in a fixed formation and measure wind characteristics, temperature and humidity directly at the turbines. The measurement results are used to create a model that can improve the layout of wind turbines. ESTABLIS-UAS stands for Exposing spatio-temporal Structures of Turbulence in the Atmospheric Boundary Layer with In-Situ measurements by a fleet of Unmanned Aerial Systems. The project is being led by the DLR Institute of Atmospheric Physics and funded by the European Research Council (ERC) within the context of the ERC Starting Grants programme.



A first test to measure the flow phenomena with 20 drones has already been successful

SATELLITES REVEAL TREE LOSS IN GERMANY

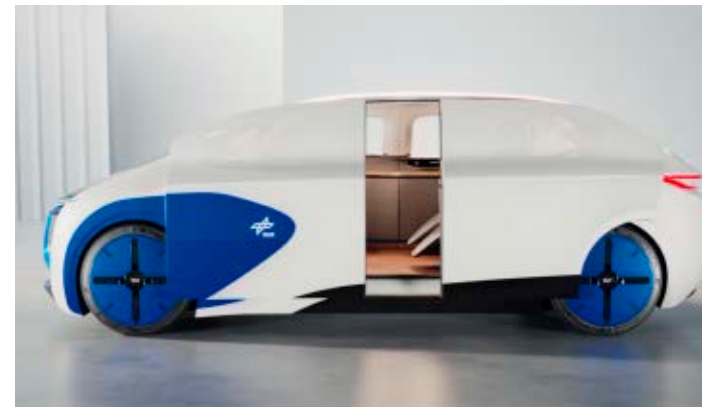
DLR/Thornfeld



Forests affected by bark beetle are cleared using heavy equipment. As a rule, nothing is left behind except branches and twigs.

Healthy trees have a full, dense crown. If you walk through the forest, however, you may well notice that the tops of the trees are rather sparse in foliage. Logging has also increased in certain areas over recent years. DLR scientists have used satellite-based Earth observation data to show the extent of the loss caused by dead and removed trees. The results are alarming: from January 2018 to April 2021, tree loss was recorded over around 501,000 hectares in Germany. This equates to almost five percent of the entire forested area and is considerably higher than previously assumed. The main triggers for this phenomenon are the unusually intense periods of heat and drought over this period, which have in turn led to infestation by harmful insects.

SUSTAINABILITY AND COMFORT ON LONG JOURNEYS



DLR's Interurban Vehicle

DLR's Interurban Vehicle (IUV) is a forward-looking concept for medium- and luxury-class vehicles. It is five metres long, two metres wide and can carry up to five people. The IUV incorporates fuel cells, batteries and new approaches to energy management. It is designed for emission-free, comfortable driving over distances of up to 1000 kilometres. Autonomous driving functions take the pressure off the driver and allow new scope for the interior design. Thanks to the ingenious combination of different lightweight construction methods, the IUV, including its energy storage systems, weighs less than 1600 kilograms when empty. Its safety standards are also outstanding. The IUV is part of the Next Generation Car project, in which a total of 20 DLR institutes are collaborating on technologies for future-generation cars.

REGIONAL NEWS

BERLIN: The DLR site in Berlin-Adlershof is celebrating its 30th anniversary this year. The major research divisions of Space and Transport are concentrated here, and around 700 people work at the site. The DLR_School_Lab, which is committed to promoting young talent, will turn 20 this year.

BONN: Every three years, the European Space Agency (ESA) teams up with DLR to hold the Living Planet Symposium. This focuses on the satellite-based Earth observation work carried out by both organisations. Modern Earth observation satellites record measurement data that reveal the condition of our planet, such as the oxygen content of the oceans or the health of forest areas. The symposium will take place from 23 to 27 May.

COLOGNE: The DLR Institute for Software Technology is working with NASA to create a software library that can be used to investigate the potential of quantum computers for aerospace applications. Such applications can provide route optimisation for transatlantic flights, allocate aircraft at major airports and assist with planning for satellite missions.

HANOVER: The Hannover Messe will take place from 30 May to 2 June. At this trade fair, technologies and ideas for the transformation of industry will be presented with a focus on digitalisation, sustainability and decarbonisation. DLR's stand D18 in Hall 13 will provide insights into the topic of renewable process heat, present the Wind Energy Research Farm and showcase examples of successful technology transfer.

NEUSTRELITZ: The International Space Weather Camp will take place at this site in June and August. Young scientists will come here to learn the basic theory behind space weather research and its applications. The Neustrelitz site is also celebrating its 30th anniversary this year. In addition, the new Tri-band antenna will commence operations at the site on 1 July.

OBERPFÄFFENHOFEN: To investigate how humans will be able to land safely on the Moon in the future, ESA astronaut Roberto Vittori tested various landing manoeuvres in DLR's Robotic Motion Simulator. The facility was developed at the Institute of System Dynamics and Control and allows extreme tilt angles and manoeuvres. The ESA project evaluates human-machine interfaces and assistance functions for spacecraft.

OLDENBURG: The Institute of Networked Energy Systems has published a simulation model for the future electricity market, called AMIRIS (Agent-based Market model for the Investigation of Renewable and Integrated energy Systems). This software examines the behaviour of the players involved once different energy policy regulations are factored in, making it possible to identify the general conditions for an effective and economical energy policy.

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All articles can be viewed online in the news archive with images or videos.

[DLR.de/news](https://www.dlr.de/news)

SUCCESSFUL AND DIVERSE HARVEST IN DARKNESS AND ETERNAL ICE

A fruitful endeavor in an inhospitable environment – NASA guest scientist Jess Bunchek successfully completed her mission at DLR's EDEN ISS greenhouse in Antarctica. Bunchek has been living and working as a member of the 41st overwintering expedition at the German Neumayer III Station, operated by the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI) for almost one year. During her time on the perpetual ice, she was able to cultivate numerous vegetables and herbs without soil and using artificial light – producing an abundant harvest for the overwintering crew, which was isolated for months. Bunchek also studied the psychological impact the fresh fruit and vegetables had on the crew. The results of the joint DLR and NASA test will help prepare for future crewed missions to the Moon and Mars, as well as plant cultivation in climatically unfavourable regions on Earth.



DLR/NASA/Bunchek

Kohlrabi (left) and broccoli (right) in the EDEN ISS Antarctic greenhouse

A SPACEWALK TO REMEMBER

An exciting moment of the Cosmic Kiss mission when the hatch on the US Quest Airlock of the International Space Station (ISS) opened on 23 March 2022 at 13:55 CET, and German ESA astronaut Matthias Maurer embarked on his very first spacewalk. The 52-year-old materials scientist from St. Wendel in Saarland successfully completed the six-and-a-half-hour extravehicular activity (EVA) with NASA colleague Raja Chari. Their main task was to repair part of the Station's cooling system. They also replaced an external camera on the Station's large boom structure, on which the solar arrays are mounted, as well as upgrading other hardware. Maurer performed another extremely important task by fully connecting the commercial Bartolomeo platform on ESA's Columbus module to the ISS. Following Thomas Reiter, Hans Schlegel and Alexander Gerst, Maurer is the fourth German astronaut to complete an EVA.



NASA

Final work on the Bartolomeo external platform

DLR



The DLR research observatory in Empfingen will be named after the early modern astronomer Johannes Kepler

DLR RESEARCH OBSERVATORY TO BE NAMED AFTER JOHANNES KEPLER

Johannes Kepler Observatory – this will be the name of DLR's new research observatory. Work is currently underway to put the facility into operation at the Empfingen Innovation Campus. In future, it will be used to determine the trajectory and characteristics of near-Earth objects as quickly, precisely and reliably as possible. This information will make it possible to, for example, avoid collisions between space debris and satellites. The observatory's telescope is the largest of its kind in Europe for observing objects in orbit. The telescope, with a primary mirror measuring 1.75 metres in diameter, is housed in an almost 15-metre-high round tower with a rotating dome. The focus of the work will be on high-precision orbit measurement using special lasers. The DLR researchers are looking to detect and locate objects down to 10 centimetres across and determine their trajectory as precisely as possible.

Falklands Maritime Heritage Trust, National Geographic



Endurance – Ernest Shackleton's research ship – which sank in 1915, has been found in good condition.

SHIPWRECK OF THE 'ENDURANCE' FOUND

Over a century ago, Ernest Shackleton's ship 'Endurance' sank in Antarctica, trapped and crushed by the ice. The crew survived and the incredible rescue operation made the polar explorer's expedition legendary. This year, the wreck was located in the Weddell Sea. DLR provided its remote sensing expertise to help find the best path through the sea ice and ensure safety during the search. The researchers used high-resolution images from the TerraSAR-X mission to monitor sea ice conditions over the presumed position of the sunken ship to validate sea ice predictions and detect hazards. These data enable the visualisation of the different structures in the sea ice, which is subject to constant change. Radar satellites like TerraSAR-X provide images of the surface of Earth and the ice and show different structures in the sea ice. These images are extremely valuable for the navigation of ships operating in polar regions such as the Agulhas II icebreaker on the hunt for Shackleton's ship.

DRAMATIC WARMING IN THE ARCTIC

In mid-March 2022, the international HALO-(AC)3 research campaign began investigating transformations of air masses in the Arctic. Using three German aircraft and two further aircraft the researchers focused particularly on northwards-flowing warm air reaching into the central Arctic. The counterpart, cold air outbreaks with southwards-moving cold air from the Arctic, were also investigated. The campaign aims to study the processes causing the above-average increase in temperatures in the Arctic during the last decades. At two to three degrees Celsius over the last 50 years, this increase is much larger than the warming that has taken place in other regions on Earth. The effects of this increase in temperature are not limited to the climate system in the Arctic, but are suspected to modify the regional weather in the mid-latitudes, as well. Thus, the HALO-(AC)3 campaign aims to contribute to a better understanding of the processes behind the dramatic climate changes in the Arctic.



TROPOS/Holger Siebert

The tethered balloon BELUGA ready to be release in Ny Ålesund

A MATTER OF SPACE DEBRIS

Satellites that are no longer functional collide with others and create a vast quantity of uncontrolled objects. Experts fear what is known as the Kessler syndrome, a situation in which pieces of debris collide with one another and break into smaller pieces that go on to do the same, generating an ever-larger field of debris. More than 900,000 pieces of space debris now endanger safety in low-Earth orbit. But what is the best way to remove hazardous pieces of space debris from Earth orbit? Mini robots on the ISS are helping researchers answer this question. Honey the Astrobee must grasp and transport Bumble the Astrobee. To pull it off, Honey needs to understand Bumble's trajectory, position itself correctly and avoid a collision at all costs. Artificial intelligence (AI) helps the cube-shaped robot to accurately assess the situation. The experiment is part of the TumbleDock/ROAM project, which DLR is carrying out together with its partners on the ISS.



NASA

Mini robots during the experiment

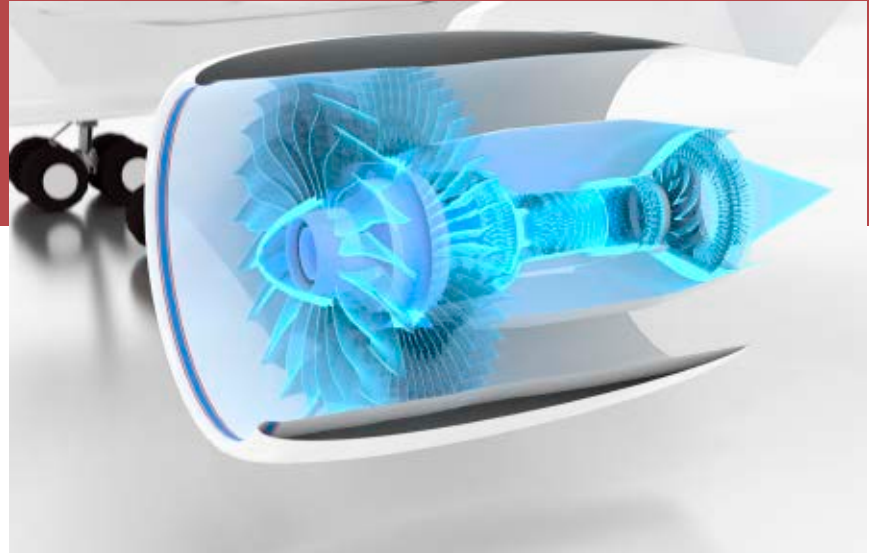


COMPUTE BEFORE FLIGHT

How the virtual engine can advance aeronautics research

In conversation with Stanislaus Reitenbach and Kai Becker

Engines are the heart of the aircraft. Without them, these heavy, high-tech birds would be grounded. DLR's aeronautics institutes have been working tirelessly for decades to refine engine designs. For some time now, the focus of research has been shifting towards the use of virtual models and simulations. DLR researchers Stanislaus Reitenbach and Kai Becker are convinced that simulations and digital models will prove indispensable for aeronautics in the future, particularly when it comes to engines. Reitenbach works in the Engine Department at the Institute of Propulsion Technology in Cologne, while Becker is working on developing the necessary platform at the Institute of Test and Simulation for Gas Turbines. Here, they explain the benefits of virtual engines, and how to get them into real aircraft.



Visualisation of a virtual engine

What exactly is a virtual engine?

Reitenbach: Like many other industries, the aviation sector is undergoing a digital transformation. In this process, the complex systems of the real world, such as engines, are being transferred to the virtual world. A virtual or digital engine contains all the geometric and physical features of a propulsion system. To 'build' it, we use computer-aided design tools and numerical simulation methods while taking into account relevant disciplines, such as aerodynamics, structural mechanics and thermodynamics. We see this platform as a way to address multidisciplinary questions. It also allows us to calculate and evaluate the entire system on an ongoing basis. Ultimately, it should reflect all stages in the life and development cycle of a real engine.

Many specialist disciplines play a part in this design process. Who benefits from such models?

Becker: It depends. Generally speaking, you could say this benefits all those who have anything to do with an engine – from development

and production through to testing and certification, and indeed manufacturing, sales and maintenance. We are also seeing great interest from industry. All the leading engine manufacturers are looking into this area. The form that the virtual engine ultimately takes will depend on the nature of the information needed by the user. Different methods provide different levels of detail; there are elaborate 3D simulations or less detailed performance calculations. We combine this information to create an appropriate model for each individual case.

That brings me to the question of the current state of research.

Reitenbach: Although this is still a relatively new area of research, we have already seen some ground-breaking developments. DLR is working on multidisciplinary simulation methods that can make highly accurate assessments about various aspects of propulsion systems, and these are already being used in industry for real products. In addition, we have developed a platform on which researchers from different scientific fields can work together on a model using a uniform database. To bring everything together, we have founded

the Virtual Engine Technical Committee (FAVE) at DLR, where DLR's aeronautics institutes advise on developments in this area.

Becker: DLR has been conducting research into many different topics for decades. What is new is that we want to focus on collaborative work and linking up the different product phases. It is no coincidence that DLR has founded institutes in recent years that focus on the field of virtual engines. In addition to the Institute of Test and Simulation for Gas Turbines, there are the Institute of Electrified Aero Engines, the Institute of Maintenance, Repair and Overhaul, and the Institute of Software Methods for Product Virtualization. The digital platform is also changing the way we work. We are moving away from the conventional sequential approach, where you start with the first phase, for example the preliminary design, and once that is completed, it is followed by the second phase – in this case the detailed design, and so on. Now that the individual disciplines are working closely together, several processes can run in parallel, and information is exchanged and stored across the different phases. This also allows us to access existing information if a new engine is to be developed. This is a very exciting advancement.

Are there any examples of a virtual engine already being used?

Becker: At my institute and in many other institutes we have test rigs that are designed not for the entire engine, but for components. Using a virtual representation of these components we can compare tests and simulations. We can then transfer the models to the overall system and observe the interactions between the components and their effects.

Reitenbach: Although DLR does not build aero engines, it supports both industry and its own research departments in all areas of the product lifecycle – in both design and production – using virtual engine methods. In addition to the test rigs, research groups are also working on predictive maintenance processes and digital twins. However, virtual engines are now a popular area of focus in the industry, as is clear from the numerous collaborations and new projects that have been launched in recent years.



Kai Becker sees stronger networking between the participating institutes as an important prerequisite for the topic of virtual engines

"What is new is that we want to focus on collaborative work and linking up the different product phases."

Kai Becker

How is the virtual engine linked to the real one?

Reitenbach: Ultimately, it is only indirectly connected to the real aircraft. There are two main aspects here, the environmental and the economic benefits. New, high-performance numerical methods and their use in a virtual model of the entire propulsion system help to improve real engines in terms of energy consumption and maintainability. In terms of economic benefit, the innovative and highly interconnected processes of the virtual engine enable us to significantly reduce the long and cost-intensive product development times, which involve very time-consuming and high-risk testing right up until market launch.

Becker: It really pays off to look at the interactions between a wide variety of aspects, be it between different components or their impact, for example on overall efficiency and fuel consumption. This can then be measured against the goals that the air transport sector has set for itself, such as becoming more environmentally friendly.

Are there any limitations? In other words, are there instances in which you need a real engine?

Reitenbach: One thing is clear – a virtual engine alone is not enough to get an actual aircraft flying. Although the simulation processes and methods can already depict and predict many physical aspects, the test rigs, experiments and data from operations remain essential in meeting high safety requirements in future. Nevertheless, virtual

engines can help to reduce the immense costs of real testing and complex maintenance processes. The virtual engine is not an end in itself, but a means to achieve the ambitious goals of the aviation industry.

Becker: It is a virtual representation – an amalgamation of digital information and numerical processes. Of course, this representation can only be as good as the quality of the simulation tools that are used to create it. To validate the numerical methods, I need experimental data – and I can only obtain this from a real engine.

RESEARCH FOR FUTURE ENGINES

DLR will launch the ADAPT (Assessment and Digitalisation of forthcoming Propulsion Technologies) project this year. The project was initiated by the Virtual Engine Technical Committee (FAVE), with the participation of 11 DLR institutes. Two objectives are to be pursued over the course of the four-year project (2022–2025) – the collaborative, multidisciplinary design of future engine concepts and associated studies of the key technologies; and the digitalisation of the engine system to realise the vision of a 'virtual engine' using numerical simulations and an intelligent linking of software tools.

DLR INSTITUTES THAT CAN CONTRIBUTE TO THE VIRTUAL ENGINE



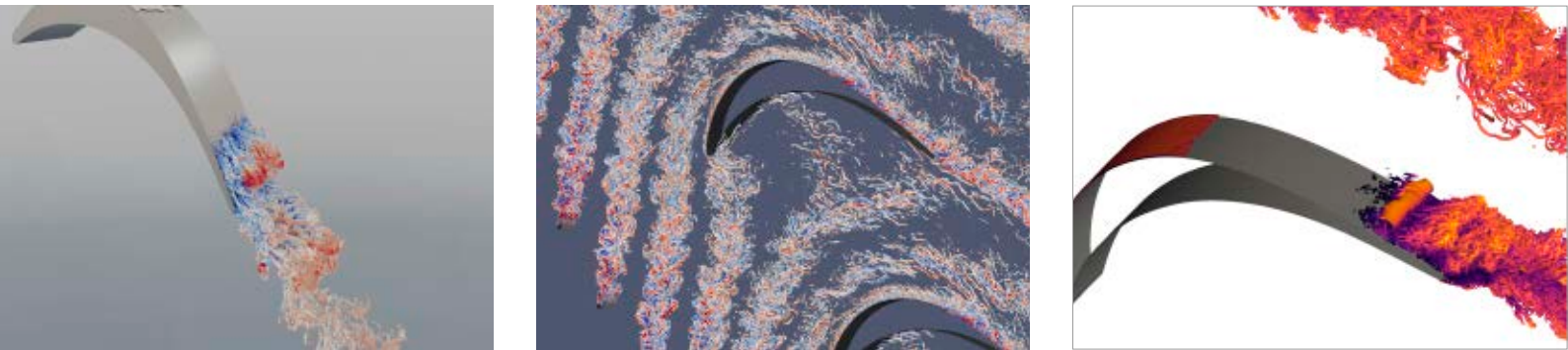
It all sounds like a very challenging undertaking. What comes next? When will the virtual engine be usable as a tool for industry and research?

Reitenbach: We have our test rigs and we have our virtual methods. In the future, these two areas must be brought closer together. One term that comes up again and again in this context is the digital test rig. I believe that is where we are heading. Today, we are already in a position to optimise all the key components of aircraft engines in an interdisciplinary manner using highly accurate simulation methods. With each further stage of development, increasingly integrative methods and virtual operating scenarios, we are coming closer to a highly efficient, safe, quiet and almost climate-neutral engine. The virtual engine will be extremely helpful in addressing this extremely complex problem.

Becker: We also want to apply the concepts and ideas developed for this purpose to related areas of research.

This interview was conducted by **Anne Zilles**. She works in programme coordination for digitalisation and supports the Virtual Engine Technical Committee on behalf of the Aeronautics Division.

Stanislaus Reitenbach is certain that the virtual engine will drastically change development and design processes and help achieve the air transport industry's ambitious goals



The TRACE software was developed at the DLR Institute of Propulsion Technology and enables numerical experiments and in-depth analyses of turbomachinery gas flows

"The virtual engine is not an end in itself, but a means to achieve the ambitious goals of the aviation industry."

Stanislaus Reitenbach



WELCOME TO THE DIGITAL LAUNCH FACTORY

A digital factory for new aircraft is being established in Hamburg

by Björn Nagel



Before being implemented, new designs for aircraft or parts of the digital factory are tested in the virtual reality environment.

When manufacturers such as Airbus plan a new aircraft, they do so behind closed doors. Of course, they do not want their competitors to know which ground-breaking technologies they might be incorporating into the design. As a result, it becomes difficult for suppliers and researchers to support the latest products with their ideas. To change this situation, DLR and Airbus are working together to create a 'factory' in Hamburg-Finkenwerder where new concepts and technologies will be evaluated and tested. What makes it remarkable is that it takes up no space at all, because it is digital.

Hydrogen or synthetic kerosene? The question of which energy carrier will power future aircraft is one of the most pressing in air transport. Physical parameters such as mass, drag, energy efficiency and climate impact, all of which are important when addressing this issue in flight mechanics, are already being calculated in cooperation with DLR's specialist institutes. However, these parameters alone do not allow predictions to be made about the actual potential of a particular technology. That also depends on how cost effectively it can be manufactured as an industrial product.

Simulations provide a glimpse into the future

It is not possible to reliably assess how complex adapting the manufacturing process for commercial aircraft to new technologies – such as modified tanks or engines – will prove to be. The manufacturing systems are far too complex for this. In addition, the requirements for industrial production processes are at least partly secret. Accordingly, researchers can only partially take these requirements into account in their work. As part of the EPSIA project, which has the goal of



Concepts for the climate-neutral production of new aircraft configurations are being investigated in DLR's Digital Launch Factory

increasing efficiency in production planning and control using prescriptive analytics and is funded by the German Federal Ministry for Economic Affairs and Climate Action, DLR and Airbus are working together to develop a digital factory environment. In the 'Digital Launch Factory', DLR will act as a virtual manufacturer and evaluate the industrial viability of new aircraft.

Energy-efficient and climate-neutral

One of the targets that the German government has set for the country in line with the European Commission's Green Deal is to effectively implement climate protection in air transport and bring the necessary technologies to a state of market readiness. Air transport is to be climate neutral and sustainable by 2050. To achieve this, aircraft shall consume only half the amount of energy that they do now. It also means that future aircraft configurations will look very different to the way they do today. In terms of the external shape, this could mean higher wingspans or new propulsion concepts. The internal structure will have to allow space for climate-neutral technologies such as hydrogen tanks, fuel cells and batteries. However, climate protection does not stop with innovative aircraft concepts that call for new technologies and construction methods; the production processes themselves need to become greener, as they have important potential in the form of energy-efficient, sustainable manufacturing. With that

in mind, the Digital Launch Factory team is creating simulations for the assembly of the most important aircraft components, and these can be adapted to different configurations. The calculations also show the extent to which energy and material costs can be reduced and how far it is possible to go in terms of implementing a closed material cycle. Whenever new product architectures or manufacturing processes are developed or existing ones modified, new simulations can be integrated into the virtual factory. DLR's personnel are conducting such research as part of initiatives such as the cross-sectoral 'Factory of the Future' project.

Agile, modular manufacturing

The Hamburg-based team is focusing on the industrial aspects that relate to Germany's added-value contributions to air transport products today, such as the integration of the cabin and systems into the fuselage. Until now, the fuselage has been manufactured first, followed by integration of the subsystems and installation of the cabin monuments. Among other things, researchers at DLR are looking at integrating the subsystems into pre-assembled units such as the cabin crown module. This contains all of the systems and cabin components above the row of windows, including the luggage racks, ceiling panels and air conditioning ducts. The supplier delivers the prefabricated modules, thus reducing the number of components that need to be installed in the aircraft at the same time. This new method also considerably reduces the assembly time for the aircraft interior, as there is no need to wait for the fuselage to be completed. The time required for the complex alignment of the individual panel elements is also shorter. In summary, the design of the aircraft cabin has a direct impact on the production process. DLR researchers are working on designing cabins under the constraints of efficient industrialisation so that they are safe, comfortable and customisable (see the article in DLRmagazine 167). The ability to customise cabins is a key selling point for aircraft manufacturers.



This is what a future aircraft with hydrogen tanks (shown in blue) could look like



DLR INSTITUTE OF SYSTEM ARCHITECTURES IN AERONAUTICS

In Hamburg, 60 personnel are working on making future aircraft and their components safer, more powerful and more efficient. Their research focuses on the 'digital aircraft', in which all the properties are represented virtually during the design, testing, manufacturing and certification process. In this process, various subsystems are coupled together to form an overall system. This combination of subsystems is referred to as a system architecture. As part of their work, the researchers look at the individual systems and the ways in which they interact.

But not everything is digital in the Digital Launch Factory; some aspects are actually set up in the laboratory, in collaboration with Airbus, Diehl and other industry partners at the ZAL Center of Applied Aeronautical Research in Hamburg. This includes a robot-assisted pre-assembly station, where experts test how collaborative robots can automatically install the subsystems in the assembly modules. They feed their findings directly into the algorithms of the digitalised factory. This is the first step towards Industry 4.0, where the real and virtual worlds will be networked together. Assemblies like the crown module can initially be built using automation through joint projects with Europe's largest aircraft manufacturers. Processes can then be scaled up for full production using the virtual factory. Pre-assembly in real life is vital in order to allow researchers to validate the digital factory using these data.



Mutual exchange throughout the lifecycle

Another goal of the Digital Launch Factory is to connect experts in areas ranging from design through to production. Co-design is an approach whereby the design and production of a product are both taken into consideration during all phases of development. This minimises costly reworking of the product design during the production phase. In addition, this method also looks at manufacturing aspects already during the design of new aircraft configurations. The benefits of co-design are such that this is a key area of focus for research in the German aviation industry. Data, models and tools will be used more consistently as part of digitalisation.

The Digital Launch Factory is a key building block that DLR can use to model and study aviation as an overall system. Revolutionary changes such as climate-neutral flight can only be implemented efficiently if design, industrialisation and operations are synergistically coordinated. For the researchers in Hamburg, the first step is to get all of the key DLR institutes and industry partners around the table, so that together they can closely examine the interactions between the aircraft as a product and its manufacturing process.

Björn Nagel is the Founding Director of the DLR Institute of System Architectures in Aeronautics.

In the A319 mock-up, various installation and removal scenarios and the methods for virtualising reality such as 3D scanning are being tested.

IN BRIEF

A CONTROL CENTRE TO REPLACE SEVERAL AIRPORT TOWERS

Air traffic at small airports often increases significantly at the weekend. This puts a lot of pressure on air traffic controllers in particular. New research shows that 'remote tower centres' could help relieve this pressure, and indeed revolutionise air traffic control. Instead of the towers that you see at airports today, several airports would be connected to control centres that would monitor them remotely. A whole pool of pilots would be deployed flexibly from there as needed. In late 2021, the DLR teamed up with Frequentis to set up a remote tower centre prototype at the Institute of Flight Guidance, from where Lithuanian and Polish air traffic controllers monitored a total of 15 simulated airports remotely. The test run revealed that, broadly speaking, monitoring airports remotely from a control centre really works. The challenge was allocating the various airports to the expert staff and existing workplaces to best possible effect. Digital planning tools were developed and tested for this purpose as part of Digital Technologies for Tower, an EU project.



The Remote Tower Center at the DLR Institute of Flight Guidance



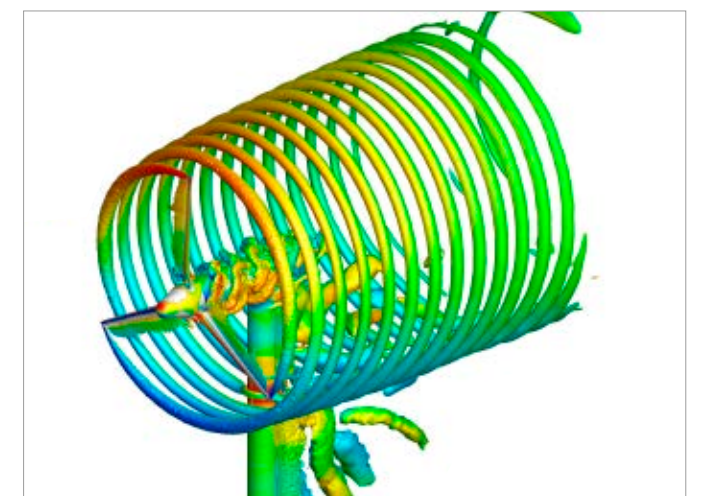
Visualisation of the demonstration aircraft Dornier 328 with hydrogen fuel cell

DEMONSTRATION AIRCRAFT FOR FUEL CELL TECHNOLOGY

The climate-neutral air transport system of tomorrow needs carbon-dioxide-free propulsion technologies. For regional aircraft, such as a future 40-seat class, this could be hydrogen-electric drives powered by fuel cells. In the 328H2-FC project, H2FLY, Deutsche Aircraft, Diehl Aviation and six other partners under the leadership of DLR are developing a fuel cell system with one and a half megawatts of power output for use in air transport. For this purpose, a Dornier 328 aircraft is being converted for hydrogen-electric passenger flight. DLR is responsible for the fuel cell test stand, the tank system, its testing and the interface between fuel cells and tank system, as well as the fuel cell housing with integrated sensors, safety components and cooling. The project is being funded by the German Federal Ministry for Economic Affairs and Climate Action with approximately 30 million euros.

NEW SUPERCOMPUTER IN GÖTTINGEN

Together with the Gesellschaft für wissenschaftliche Datenverarbeitung mbH Göttingen (GWDG), DLR has put the Caro computing cluster into operation. The supercomputer achieved a performance of 3460 TeraFLOPS – 3460 trillion calculations per second – during trial operations. This puts it in 135th place in the list of the 500 fastest computer systems in the world. In future, Caro will carry out complex simulation calculations and will be used by researchers from all of DLR's major fields of work. For example, complex thermochemical processes will be simulated in the Amadeus project to investigate instabilities in rocket combustion chambers. In the field of transport, the Caro cluster will be used to optimise the ventilation of passenger compartments in high-speed trains. The sister facility Cara in Dresden has been in operation since 2020.



For example, DLR will use the new Caro supercomputer in Göttingen to simulate the airflow at future wind turbines to make them more efficient and quieter.



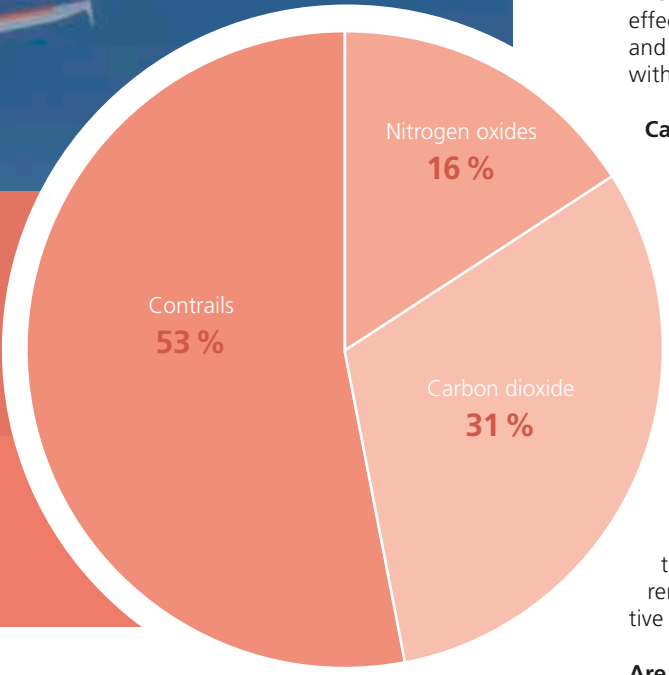
Christiane Voigt leads the Cloud Physics Department at the DLR Institute of Atmospheric Physics in Oberpfaffenhofen. She has been measuring aircraft emissions and contrails for more than 10 years and uses these observations and models to derive strategies for the development of a climate-neutral aircraft fleet. She is also a professor of atmospheric physics at the University of Mainz.

CLEANER SKIES

How reducing aircraft particle emissions can benefit the climate

In conversation with Christiane Voigt

It has long been known that carbon dioxide contributes towards global warming; the Intergovernmental Panel on Climate Change (IPCC) deems it the most harmful anthropogenic greenhouse gas. Although the aviation sector is thought to account for only two percent of global carbon dioxide emissions, its contribution to global warming is far greater. DLR researcher Christiane Voigt leads the Department of Cloud Physics at the DLR Institute of Atmospheric Physics. She and her team study condensation trails, commonly referred to as contrails, which account for a surprisingly large additional contribution to the climate impact of aviation. In this interview, Voigt tells the DLRmagazine how these icy clouds could give a decisive and rapid boost to efforts to reduce the global warming caused by aviation.



Climate impact of aviation

According to an international assessment to which DLR contributed, global aviation is responsible for around four percent of anthropogenic climate change. What are the key contributions?

Contrails are the biggest contributors; they account for over half of the total effective radiative forcing from aviation. In second place is carbon dioxide, which warms the atmosphere, followed by

nitrogen oxide emissions, which produce ozone and thus also contribute towards warming. However, the particles emitted by aircraft only form contrails in specific conditions; regardless of these, they can influence the clouds. There is more research needed on how this happens.

What climate effects do contrails have?

Contrails trap thermal radiation from the Earth within the atmosphere, which results in warming. During the daytime, they also prevent a fraction of the solar radiation from reaching the ground. This cooling effect is weaker and, in total, contrails have a warming effect on climate on the global average. As clouds are short lived and change very quickly, there are many uncertainties associated with them.

Can their short lifetime also be an advantage?

Yes. Contrails last for just a few hours, so they only trap energy within the atmosphere for a short period. Once they have dissipated, thermal energy from Earth is able to radiate back into space unhindered, so the warming effect disappears. Global warming due to carbon dioxide is very different, though, as it has an atmospheric lifetime of more than 100 years.

This could be an opportunity to rapidly reduce the climate impact of aviation ...

Reducing contrails would have an immediate effect. When it comes to carbon dioxide, reducing atmospheric emissions by a few percent, for example with more efficient aircraft technologies, represents progress. The carbon dioxide reduction remains crucial for the future, but by reducing contrails the effective radiative forcing due to air transport could ideally be halved.

Are these new findings?

The climate study mentioned earlier is not the first to address contrails. Researchers have been working on a comprehensive assessment of the radiative forcing of contrails for more than a decade. The results of this work were published last year, with a significant contribution from DLR. They reveal the high potential of contrails for climate-friendly aviation. I see them as the jokers in the air transport card game. These new insights require new ways of thinking that are gradually being adopted within the aviation community. Previously, policy was focussed on reducing carbon dioxide emissions, and measures are being taken accordingly. That



the air warms up again – which takes an average of two to four hours – the ice crystals evaporate and the contrail dissipates.

How can we reduce their formation?

■ In principle, there are two different options. One strategy is to fly below or above regions where the warming effect of the contrails is particularly strong. This requires very accurate weather forecasts and high-resolution contrail models. We investigated the quality of these models, especially at cruise altitudes, in the CIRRUS-HL measurement campaign in summer of 2021. In cooperation with German and European partners, DLR currently plans eco-efficient flight routing and also demonstration experiments to investigate the feasibility of contrail avoidance by flight routing.

Another promising strategy for climate-friendly aviation is to reduce aircraft particle emissions. The aircraft measurements from DLR's Future Fuels and Eco2Fly projects enabled us to prove the direct connection between the chemical composition of the aircraft fuel, the emission of soot particles, the ice particle concentrations in contrails and their climate impact.

What is the role of Sustainable Aviation Fuels?

■ First, Sustainable Aviation Fuels (SAFs; see box) are produced from renewable resources, so they have a lower carbon footprint and less impact on the climate. In addition, their low aromatic and higher hydrogen content also leads to lower soot particle emissions compared to conventional fuels. With our measurements, we were able to show that the combustion of a fuel mixture containing 50 percent biofuel reduces soot emissions and the number of ice particles in contrails by about half. The ice crystals grow a little larger, sediment faster and have a shorter lifetime. Ultimately, climate simulations show that this reduces the global climate impact of contrails by approximately 20 percent, with even more significant benefits regionally. In a new joint project with Airbus, Rolls-Royce and Neste, we are investigating the particle reduction that could be achieved by 100 percent SAFs. In November 2021, we performed aircraft measurements from Toulouse, with promising results.

Are there any other options for reducing particle emissions?

■ In addition to sustainable biofuels, synthetic fuels produced from alternative energies also have great potential to reduce climate impact, especially if they can be produced on a larger scale and at low cost in the future. The DLR Institute of Combustion Technology is conducting research into this area. While Europe and the USA tend to focus more on SAFs, Germany is also promoting the production of synthetic fuels.

There are new engine technologies that emit fewer particles, too. For instance, in lean-burn engines, the combustion chamber is operated at a more uniform temperature distribution, which results in lower emissions of nitrogen oxides and particles. We examined these engines in autumn 2021 together with Airbus and other French partners. Our measurements revealed that these engines can significantly reduce the emissions of larger soot particles at cruise. Now, we investigate the related effects on contrails.

DLR's Falcon research aircraft measures emissions behind an Airbus A319neo

is still important, but we need to adopt a new way of thinking and create incentives to reduce contrails quickly and comprehensively. Industry is already showing a clear interest in taking the necessary steps.

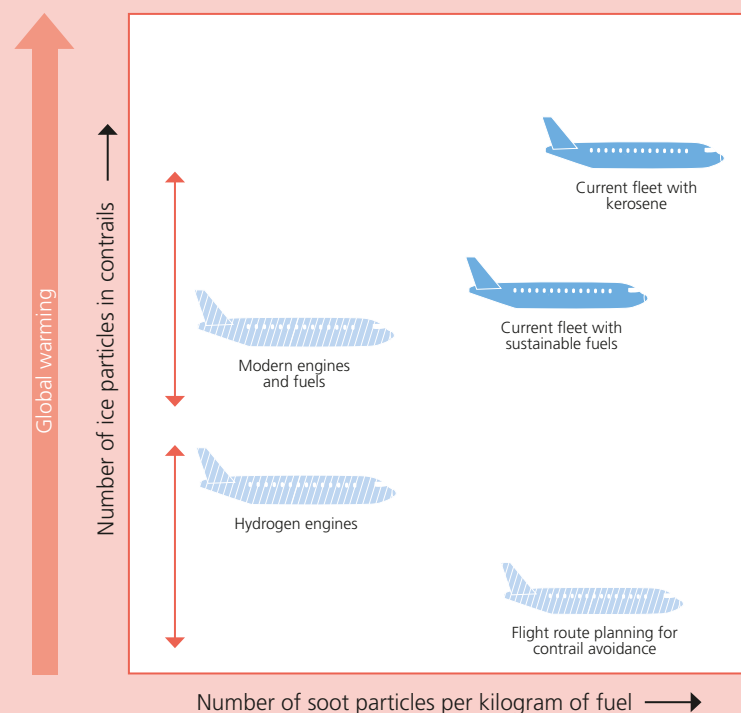
How can we benefit from contrails?

■ First, we need to understand exactly how contrails form. When fuel is burned in the engine, it produces soot particles and liquid aerosols, which are emitted with the exhaust gas. At cruising altitudes between eight and 14 kilometres, the spreading exhaust plume cools down quickly. At temperatures below minus 40 degrees Celsius, ice crystals form on the activated tiny soot particles. As long as the atmosphere remains cold and ice saturated, these crystals can grow into contrail cirrus clouds by absorbing water vapour from the ambient air. When

WHAT ARE SAFS?

Sustainable Aviation Fuels (SAFs) are synthetic, renewable or waste-derived fuels. They meet sustainability criteria and strict technical requirements. Different feedstocks are used for their production, such as vegetable oils, algae, fats, alcohols, sugar, hydrogen or captured carbon dioxide. The sustainable raw materials avoid a high consumption of natural resources and help preserve an ecological balance. After processing, the hydrocarbon mixture meets the same technical requirements as conventional kerosene aircraft fuels. The use of SAFs can reduce an aircraft's carbon footprint compared to conventional petroleum-based fuels and therefore plays an important role in meeting the air transport industry's environmental and sustainability goals.

TECHNOLOGIES FOR CLIMATE-FRIENDLY AVIATION



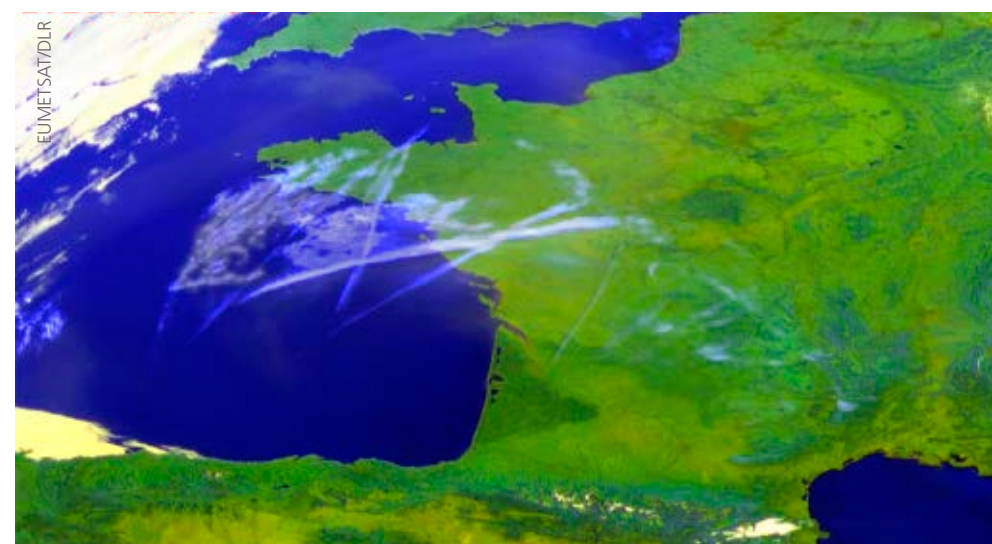
Soot particles lead to the formation of ice particles in contrails, whose climate impact grows with increasing particle numbers. Producing fewer soot and ice particles reduces the climate impact from aviation and counteracts global warming. SAFs and other clean aviation fuels lead to reduced soot particles and contrails. Their implementation into the global market would have fast and positive effects for the climate. Modern lean-burn engines significantly reduce soot particle emissions. Their influence on contrails is currently studied. In the longer term, the use of new hydrogen-based propulsion systems or fuel cells could lead to the avoidance of carbon dioxide and particulates – promising significant climate benefits. The contrails caused by such technologies have not been assessed yet and need to be studied urgently. As an interim solution, contrails can be avoided through targeted flight route planning. This requires high-resolution contrail models and weather forecasts and advanced air traffic management.

What about hydrogen-based technologies? Are these the systems of the future?

■ Both direct hydrogen combustion in modified engines and hydrogen fuel cells have the major advantage that they do not emit any carbon dioxide. This would eliminate more than a third of the warming from aviation. Almost all particle emissions can be strongly reduced. Contrails are still likely to form at high altitudes due to few background particles present in the atmosphere. However, hydrogen-based contrails and their effect on the climate are among the most important open questions that need to be addressed in order to design a future climate-neutral aircraft fleet. Similar to energy policy, we should consider taking the best possible profit of all potential

solutions in order to find the optimal strategy towards climate-neutral aviation. In addition to increasing the engine efficiency to reduce carbon dioxide and particle emissions, this includes targeted air traffic management and contrail avoidance, the use of SAFs and optimally designed fuels, and the integration of hydrogen technologies and new engine concepts into the green aircraft fleet of the future.

This interview was conducted by **Julia Heil**, who is an editor in DLR's Department of Communications and Media Relations.



Satellite image of a large contrail/cirrus cloud region over the Atlantic Ocean on 23 June 2020

UPGRADING A CLASSIC

DLR is researching next-generation turbines for aviation and energy supply

by Denise Nüssle

Inner workings of the research turbine. The stator blades are clearly visible.



Melanie Schuchardt and Christian Schindler from the DLR Institute of Propulsion Technology check the data transmission from the research turbine to the control room

Power plant gas turbines weighing over 100 tonnes are among the most powerful machines in the world, capable of supplying power to cities with millions of inhabitants. Much smaller 'siblings' specially designed for use in aviation are key components of aircraft engines. Researchers at the DLR Institute of Propulsion Technology in Göttingen are now keen to upgrade this long-established technology and give it new impetus. Their goal is to enable turbines to operate much more efficiently and flexibly, and with different, primarily renewable fuels.

To put it simply, gas turbines use the energy from a hot mixture of gases to drive rotor blades. In a power plant, this kinetic energy is transformed into electricity using a generator. In an aircraft, it is ultimately used for propulsion.

"We need state-of-the-art turbines in gas-fired power plants as a technology that can help bring about the energy transition. They are also necessary for the air transport sector, where, coupled with alternative fuels, they constitute the most promising opportunity to significantly reduce the environmental and climate impact of long-haul flights at the moment. We can improve efficiency quite considerably in both areas of application," says Christian Sattler, Divisional Board Member for Energy and Transport at DLR.

Since gas-fired power plants can be brought online comparatively quickly, they will increasingly be used as a reserve source of power in the near future. This will allow short-term outages in electricity production from renewable resources to be compensated for and peak loads covered reliably. In this way, they can contribute towards secure and stable power supply in an energy system based on an ever-growing proportion of renewable but fluctuating resources, such as solar and wind energy.

Turbine technology has another advantage in terms of climate and environmental protection, which can be exploited in the energy and mobility sector. It is not dependent on a specific fuel. They therefore work not only with natural gas and kerosene, but also with biogas, synthetic fuels or hydrogen, either mixed with fossil fuels or used completely on their own.

Greater flexibility in operation and fuels

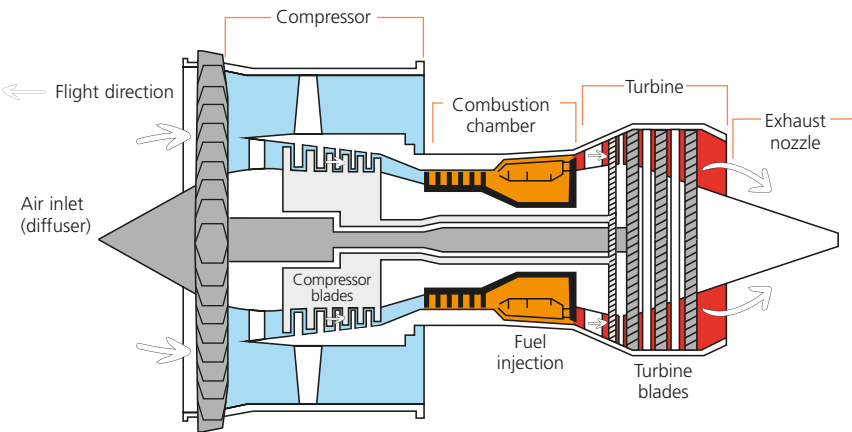
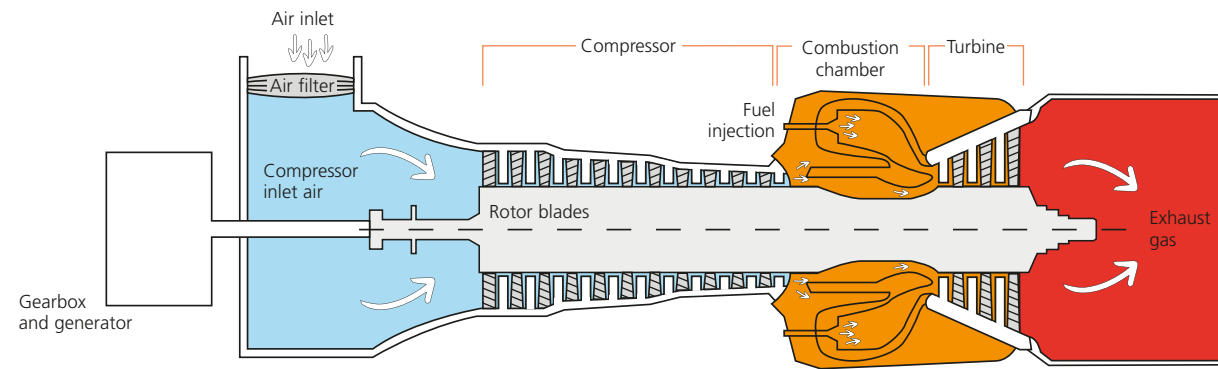
The wish list for new turbines is long, ambitious and places high demands on research and development. In addition to more flexible operation, the requirements include designs that allow for different fuels, increased efficiency and reduced emissions. Such turbines need to be as quiet, compact and lightweight as possible if they are to be used in aviation. "Up until now, operating scenarios for power plants have been relatively straightforward. The turbine would be started up and then run efficiently and consistently at maximum output for a long time. You would determine the operating point and design and optimise the turbine accordingly," says Frank Kocian, Head of the Turbine Department at the DLR Institute of Propulsion Technology. "First and foremost, achieving greater flexibility in operation means doing away with the notion of a continuous load. In other words, in future, turbines will have to run efficiently and reliably even at only partial load."

If different fuels are used in future, this will have an impact on the combustion chamber, the turbine and the way in which these two components interact. Fuels have different combustion processes and temperatures, both of which affect the flow behaviour of the hot gas, so the combustion chamber and turbine need to be adapted for this. Researchers are increasingly focusing their attention on processes involving the two components with this in mind. At DLR, scientists are looking to investigate these processes in greater depth and ensure that they are better coordinated.

Cooling makes a difference

Generally speaking, turbines have to withstand a great deal of strain, or more precisely mechanical stresses at extreme temperatures of up to 1700 degrees Celsius. The higher the combustion temperature, the more efficiently the energy contained in the hot gas is converted into kinetic energy. But cooling air is very expensive. "That is why we are as

IN COMPARISON – A STATIONARY GAS TURBINE AND AN AIRCRAFT JET ENGINE



Gas turbines are used to generate electricity in power plants and as jet engines in aircraft. The mode of operation is basically the same for both. The compressor draws in the supplied air and compresses it. The air then flows into the combustion chamber, into which fuel is injected. There, the fuel burns and the gases expand many times over. These combustion gases hit the blades of the turbine, causing them to rotate. The turbine drives the compressor to draw in and compress the combustion air.

In a stationary gas turbine in a power plant, the turbine also drives a generator via a gearbox to produce electricity. In a turbine jet engine in an aircraft, the turbine drives the fan. The fan generates a flow of air that is routed between the actual gas turbine and the engine cowling and exhausted to the rear, thus generating the required thrust.

sparing with cooling air as we possibly can be," says Robin Brakmann, Group Leader for Heat Transfer. Getting the cooling right for the turbine blades is one of the biggest technical challenges and a key area of focus for engineers. They are particularly keen to ensure that the cooling air is used effectively and efficiently.

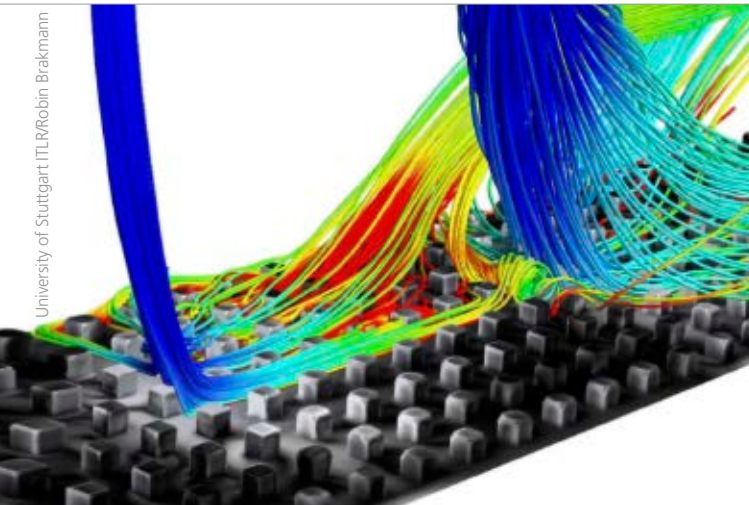
When turbines are operated in a more flexible way and using different fuels, the cooling parameters also change. If hydrogen is burned, for example, there is much more water in the exhaust gas, which leads to a greater thermal load on the turbine blades. The flow can also change depending on the fuel, resulting in vortices and localised hotspots. "We have to avoid the blades overheating at all costs," says Brakmann. "Otherwise, they will wear out faster and have to be swapped out during expensive repairs." Up until now, the tendency has been to err on the side of caution and provide lots of cooling air to the turbine to avoid compromising on safety or the lifespan. Lots of small

jets of air are blasted onto the inside walls of the turbine, rather like a shower head. "We want to be able to predict the cooling effect with greater precision, especially at hotspots or particularly sensitive sites," says Brakmann. "That is why we need a better understanding of how cooling mechanisms work within the complex system of a turbine." New and improved models will play a key role here, as previously the simulation could differ from the actual measurements by up to 20 percent.

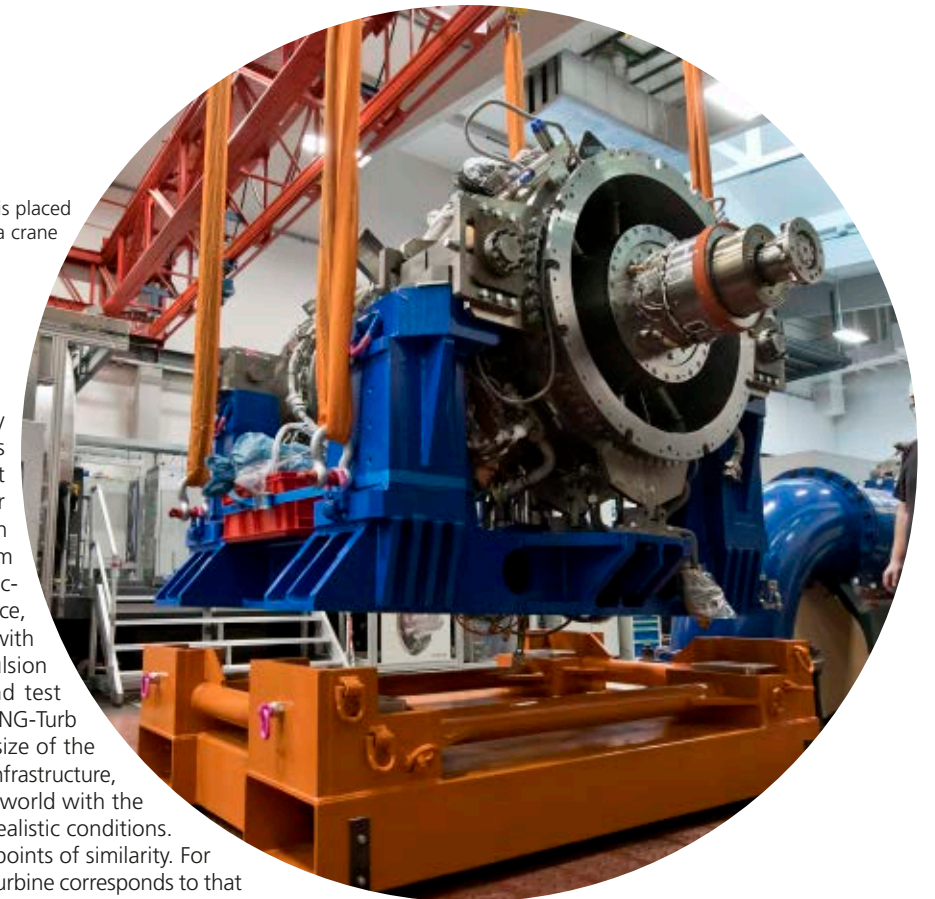
Pushing materials and structures to their limits

The use of new materials is another important aspect of next-generation turbines. Special fibre-reinforced high-performance ceramics and high-tech alloys – some of them nickel-based – can withstand extremely high temperatures. New manufacturing processes, such as 3D printing, open the way for creating more complex and intricate textures and surfaces, which in turn improves the cooling effect. "Small and subtle structures on the blades increases their surface area. This facilitates heat exchange," says Brakmann. Metallic materials are ideal for creating such surfaces and textures, but a complex cooling system is needed to ensure that the temperatures do not get too high. Ceramics, meanwhile, can withstand high temperatures, but it is much harder or even not yet possible to produce comparable surfaces and textures due to the complex manufacturing processes that fibre-reinforced ceramic materials require.

Visualisation of a complex surface texture to enable better cooling. The 'pin fins' increase mixing in the flow and enlarge the surface area.



The 12-tonne research turbine is placed on the NG-Turb test stand with a crane



The digital twin – where experimental turbines and test stands meet

With the Next-Generation Turbine Test Facility (NG-Turb) in Göttingen, Frank Kocian and his team at DLR have one of the world's most cutting-edge turbine test stands at their disposal for research. It is also used for research projects in tandem with major partners from industry, like Siemens Energy, which manufactures turbines for power plants, and Rolls-Royce, which produces aircraft engines. Together with Siemens Energy, the DLR Institute of Propulsion Technology has developed a one-of-a-kind test turbine and successfully integrated it into the NG-Turb test stand. The turbine is roughly half the size of the original used in power plants. Thanks to this infrastructure, DLR is one of only a few institutions in the world with the ability to conduct tests at this scale under realistic conditions. The important thing is to maintain the key points of similarity. For instance, the Mach number of the research turbine corresponds to that of a real machine. This is the only means of ensuring that the main technical parameters can be reproduced in a comparable way. Keeping the temperature conditions equivalent is important, too; if they are not correct, the cooling effects on the blades will not be meaningful.

At around 1.5 metres long, the test turbine has approximately 1000 measurement points. Airflow measuring sensors, stationary pressure transducers and optical measurement methods are all used. The latter make it possible to view the gas flow inside the turbine using special lasers, without interfering with it. The measured data provide an insight into what temperatures and pressures prevail at which point, how the gas flows behave inside and what the condition of the blades is. Determining the efficiency as precisely as possible and analysing the temperature distribution and cooling processes are also part of the metrological investigations. A combustion chamber simulator can also be installed to analyse the processes involved in the interaction of the combustion chamber and turbine.

"Our test campaigns generate large amounts of high-quality data. We then compare these with our calculations and models on the computer," says Kocian, describing the interaction between practical tests and simulation. In this way, the researchers are gradually working their way towards a 'digital twin' – a digital likeness of the entire test turbine, including its cooling system. This provides a complete picture of the physical processes taking place inside the turbine. "A digital twin can speed up the development of turbines and make the process much more efficient. For example, it enables us to carry out virtual certification – testing and approving designs completely on the computer."

Denise Nüssle is a Media Relations editor at DLR.



Installing the turbine shaft



More than 200 participants from inside and outside DLR contributed to the strategy

DRIVING INNOVATION FORWARD

DLR's digitalisation strategy

by Mark Azzam and Elke Heinemann

Digital transformation is changing our economy and society, shaping aspects of infrastructure development such as network expansion, social issues such as data protection, and scientific and technical fields such as artificial intelligence. Accordingly, digitalisation has a central role to play in the future viability of Germany and Europe. It is also of great importance for DLR when it comes to research and administration. This new strategy focuses on the contributions DLR can make to powering digital transformation at all levels, strengthening future research areas and ensuring our personnel reap maximum benefit from new opportunities in their everyday work and research.

Five strategic approaches that prioritise fields of action

DLR's digitalisation strategy defines five strategic fields of action that reflect existing strengths and potential and seek to work together as innovation drivers for all research areas. Artificial intelligence is being promoted in all DLR research areas and is increasingly used in research management. The acquisition, management and utilisation of data will be improved across DLR, as will the interaction between digital and physical engineering. The research and development of innovative autonomous systems will be expanded and the digitalisation of DLR as an organisation will be further advanced by using intelligent tools for everyday work and making processes more efficient with digital support.

The priorities set out in the strategy complement one another: artificial intelligence methods and tools can be used to analyse large amounts of data, as well as to increase the speed and efficiency of autonomous systems and digital design processes. Data management, in turn, provides the foundations for handling growing amounts of information – take the virtual engine, for example, which is becoming increasingly precise and thus even more extensive. In order to support efficient and effective research, the digital organisation ensures that the right infrastructure and management processes are deployed as needed.

Over 100 measures pave the way for transformation

During the development of the strategy, more than 100 different measures were formulated within DLR's administration and the research areas of aeronautics, space, energy and transport as well as the cross-sectoral areas of security and digitalisation, all designed to achieve the strategic objectives. For example, the use of renewable energy in decentralised systems requires intelligent energy management procedures. Artificial intelligence and efficient data management are essential for Earth observation and satellite and aircraft-based remote sensing, whether for disaster management or atmospheric research. The vision of an entirely digital certification process for aircraft based on simulations can only succeed if the interface between digital and physical testing and development processes continues to evolve. If road transport is to be highly automated and networked in the future, the underlying systems must be safe and reliable. These examples illustrate how closely the digitalisation strategy is interwoven with DLR's research areas.

Mark Azzam was Executive Board Representative Digitalisation at DLR until April 2022. **Elke Heinemann** is an editor in the DLR Department of Communications and Media Relations.

EXAMPLES FROM THE STRATEGIC FIELDS OF ACTION

ARTIFICIAL INTELLIGENCE

- Human-machine collaboration in air traffic management
- AI in remote sensing
- Real-time predictive control and management of energy systems
- Automated anomaly detection for data reduction of airborne and spaceborne services
- Combining physical models and machine learning techniques
- AI tools for supporting industry



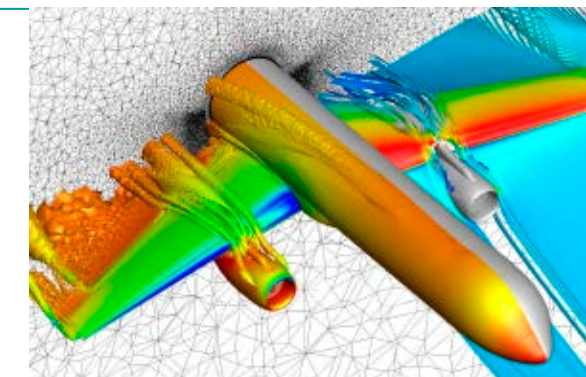
WEALTH OF DATA

- Digital networking of test stands for future propulsion systems
- Digital methods for space exploration
- Data sources for mobility research
- Data and system integrity for maritime security management systems
- Electronic laboratory notebooks and real-time visual data analysis
- Institutional data repository



INTERFACE BETWEEN DIGITAL AND PHYSICAL DEVELOPMENT PROCESSES

- Digital twins for engine, component and aircraft technologies as well as in energy research and also for critical infrastructure components
- Concepts and tools for interdisciplinary and highly integrated digital development processes
- Virtual satellite
- Digital development tools for the component and structural development of road and rail vehicles
- Methods for the evaluation of complex system architectures



INNOVATIVE AUTONOMOUS SYSTEMS

- Autonomous air delivery in flight test operations at the National Experimental Test Center for Unmanned Aircraft Systems in Cochstedt
- Robotic exploration
- Development of the leading field of study – automics
- Resilience of intelligent systems
- Basic AI methods for safe autonomous as well as swarm-based systems
- Automated networked systems for road and rail transport



ORGANISATIONAL DEVELOPMENT

- Expansion of the human resources portfolio regarding digital expertise, digital leadership and remote leadership
- Introduction of new working models and AI-based monitoring and management tools
- Digital applications in quality and product safety
- Central advisory, project support and coordination services for digitalisation projects
- Digital records and digital processes in funding management



LASER TEST UNDER A STARLIT SKY

At the DLR site in Lampoldshausen, the Institute of Technical Physics operates a 130-metre-long, free-space optical test range. Here, DLR researchers carry out measurements and experiments with lasers and other optical technologies to demonstrate how realistic environmental conditions influence the propagation of optical radiation. Using the test range, researchers investigate technologies that can be used to detect and locate space debris or protect against unmanned aerial vehicles. They are also investigating the extent to which lasers can be used to detect chemical, biological or explosive hazardous substances from a safe distance, so-called standoff detection. These spectroscopic techniques are being further developed to detect leaks in hydrogen storage tanks and pipelines. The facility is equipped with modern control technology, structural safety measures and IT infrastructure including research data management.

WITHIN A FRACTION OF A SECOND

Achieving improved positioning and timing with an iodine clock, a frequency comb and a laser terminal

by Katja Lenz

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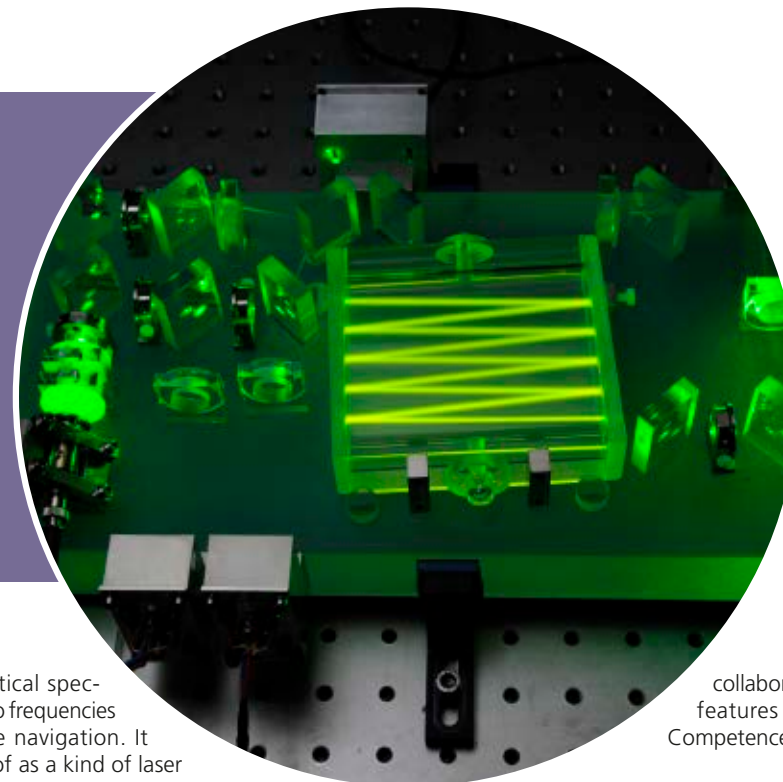


For thousands of years, people have been inventing better time-measuring devices. Yet mechanical clocks, which include wristwatches and pocket watches, are still inaccurate by one second a day. For quartz clocks, which use an electronic oscillator regulated by a quartz crystal, this reduces to one second a year. Atomic clocks, however, lose about one second every million years. These are based on the vibrational frequency of certain atoms. In the case of laser-optical clocks, it takes a billion years for it to be maybe one second off. It is hard to imagine more accuracy than that. This type of optical clock – more precisely an iodine-based atomic clock – is the focus of the Compasso project, which aims to make the Galileo system more precise than ever before.

But what do clocks have to do with navigation? “Clocks are a key technology in any satellite navigation system,” says Stefan Schlüter, Compasso Project Manager at DLR’s Galileo Competence Center. Satellites are constantly sending out signals that allow the recipients to determine their location. The more precisely the signal propagation time between the transmitter and receiver can be determined, the more exact the positioning. In addition to optical clocks, researchers at the newly founded Galileo Competence Center at the DLR site in Oberpfaffenhofen are also working on a frequency comb and a laser terminal that can be used by future generations of Galileo satellites.

How does an optical clock work?

Generally speaking, a clock consists of a pendulum that oscillates as regularly as possible, together with a counter that records these oscillations. The faster the oscillation, the finer the time measurement. In optical clocks, an atom serves as the ‘pendulum’. “The atom emits at a defined wavelength in the optical frequency range – in visible light, in other words,” says Stefan Schlüter. “In the Compasso project, this atom is molecular iodine with a wavelength of 532 nanometres.” Light with this wavelength is green. The frequency comb acts as the interface



The iodine-based frequency reference, in which a hyperfine line of iodine molecules is measured with a laser, can make the clocks of the Galileo satellites more precise. The frequency reference is being developed at the DLR Institute of Quantum Technologies under the leadership of Prof. Braxmaier and Dr Schuldt, whose many years of research in the field of quantum-optical scientific space missions led, among other things, to the Compasso mission concept.

between the optical spectrum and the radio frequencies used for satellite navigation. It can be thought of as a kind of laser ruler for measuring light. The comb consists of around 100,000 to 1,000,000 narrow-band laser frequencies. The combination of a frequency comb with an optical clock is necessary because the clocks oscillate extremely rapidly, and no other electronic devices are capable of counting these oscillations. The frequency comb converts their output so that the clocks can be used in combination with conventional systems.

The optical iodine clock has been developed by the DLR Institute of Quantum Technologies, and the frequency comb by its industry partner Menlo Systems. The laser terminal is manufactured by Tesat. Other DLR institutes are also involved. The laser terminal makes it possible to transmit the signal generated by the frequency comb and the time data to the ground, while at the same time providing highly accurate distance measurements. The focus on technology transfer and the close

collaboration between research and industry are key features of the work conducted by the Galileo Competence Center.

Galileo, the European satellite navigation system, has been in operation since 2016 and is still undergoing improvements. In a few years, 30 satellites will be orbiting the Earth at an altitude of 23,222 kilometres. Galileo is already highly accurate. “In comparison, however, the new technologies offer up to 10 times more accuracy and also more rapid position determination, ideally down to the centimetre range. In addition, the resilience and autonomy of the system would increase,” explains Schlüter. This would be precise enough to show which lane a car was travelling in, and its distance from other vehicles. Accuracy is also important for satellite-based Earth observation, as time-series measurements can be used to detect changes on Earth’s surface, such as water levels or glacial melting. It is also relevant to financial markets and energy supply – areas that do not require position determination but do require highly precise timing information. The smaller the subdivision of seconds, the more actions can be performed with an exact time stamp.

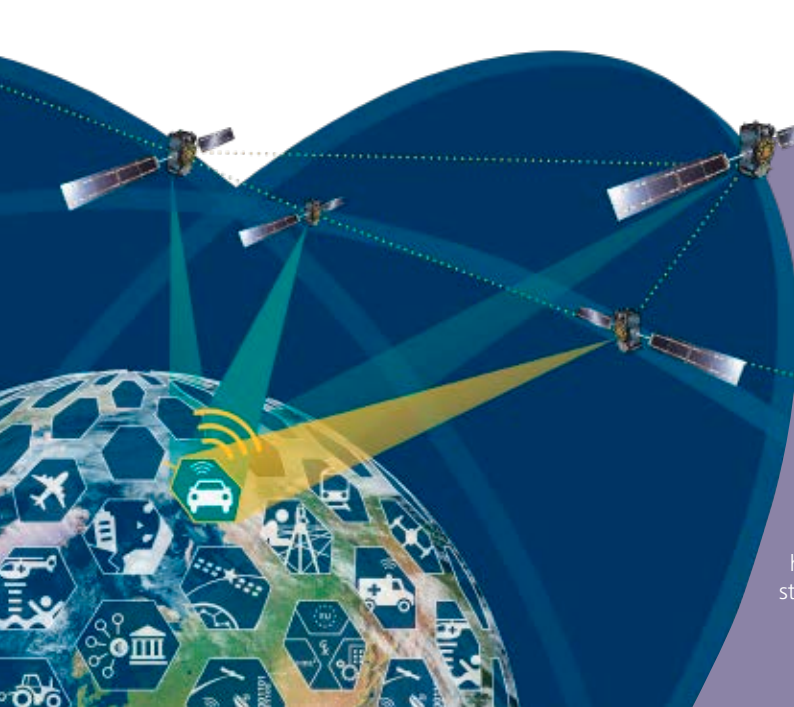
Compasso is expected to be operated from the Columbus Control Centre from 2025

THE GALILEO COMPETENCE CENTER

The Galileo Competence Center at the DLR site in Oberpfaffenhofen is working on the best navigation technologies that deliver the greatest benefits. It was founded in 2019 and officially opened in October 2021. Users, ground facilities and satellites are all given equal consideration here. The goal is to implement sustainable concepts and technologies for the European satellite navigation system and to contribute to the further development of Galileo. Some 40 personnel currently work for the Galileo Competence Center, and it is constantly expanding; it is expected to have 150 researchers by 2024.

One of its main tasks is the technical implementation and demonstration of future-proof concepts and technologies. The scientific basis for these is provided by DLR institutes and facilities with which the Galileo Competence Center works closely. It is thus able to draw upon well-founded scientific and technical expertise and years of experience with the requirements of various user groups. Another focus is the use and promotion of quantum technologies. With its expertise, the Center is intended to serve as a point of contact between policy makers, researchers, industry, the European Commission and other partners.





FOUR SATELLITES FOR ONE POSITION

To determine a position, the distance from the satellites to a receiver on Earth must be determined. This is derived from the time it takes for the signal from the satellite to reach the receiver. The positions of the satellites are known, but since the clocks of the user and the Galileo system are not synchronised, at least four satellites are needed to determine the absolute position. Satellite clocks have to work with extreme precision; a timing inaccuracy of just one milli-second results in an error of 300 kilometres on Earth – roughly the distance between Cologne and Bremen. The more satellites that can have their data received and work together, the more accurate and stable the position determination on Earth.

Test phase on the ISS 'research balcony'

Before they can be incorporated into satellites, these technologies need to be proven, first in a laboratory on Earth, and then on the International Space Station (ISS). The Galileo Competence Center is responsible for this. Together with industry, it is advancing the new technologies developed by DLR institutes so that they can be used for Galileo satellites and ground systems. The optical clock, frequency comb and laser terminal are expected to fly to the ISS on board a space transporter in 2025. When they arrive, they will be integrated onto the Bartolomeo platform – a balcony-like structure attached to the exterior of the European Columbus Module on the ISS. The platform

offers five square metres of space for research in the space environment. The Compasso components will remain there for one and a half years, before returning to Earth for analysis.

How can precision benefit satellite navigation?

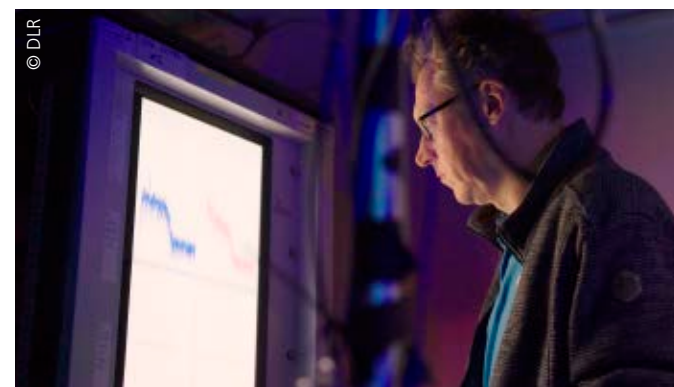
Compasso uses new quantum optical technologies. Compared with conventional systems, these developments promise greater precision and reliability, and will allow more application areas to be addressed. "The transport sector is no longer conceivable without global satellite navigation signals," says Schlüter. "This ranges from individual journeys, to rail, shipping and air transport, and all the way through to automated driving." Rail traffic collisions could be avoided by highly accurate positioning in rail transport. Shipping could optimise coastal and port navigation using these means, while maritime rescue operations would also benefit from more reliable positioning. In air transport, it would make precision landings possible even in the event of poor visibility. For agriculture, meanwhile, better navigation could lead to the more resource-efficient use of fertilisers and fuel.

The name 'Compasso' comes from the first commercial scientific instrument developed by Italian astronomer Galileo Galilei (1564 to 1642) – a geometric and military 'compass'. This resembled a proportional compass – made up of a pair of rulers – and is considered to be a precursor of the slide rule. It could also be used to measure distances on nautical charts. In Galileo Galilei's day, navigation was still hampered by a great deal of uncertainty. But that is history; these days, navigation is determined based on tiny fractions of a second using highly accurate clocks.

Katja Lenz is a Media Relations editor at DLR.

DLR INSTITUTES AND FACILITIES INVOLVED IN THE COMPASSO PROJECT

- Galileo Competence Center
- Institute of Communications and Navigation
- Institute of Quantum Technologies
- Institute for Software Technology
- Space Operations and Astronaut Training
- Institute of Space Systems
- Institute of Optical Sensor Systems



Compasso project leader Stefan Schlüter checks the signals from the frequency comb



The iodine clock was developed by the Institute of Quantum Technologies. The technology is now being prepared for space with the Galileo Competence Center.

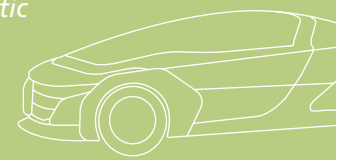
YOUR QUESTIONS ANSWERED

Our researchers answer questions from the community

Asking questions is key to improving your understanding of how and why things work as they do. Particularly in science, an inquiring approach is indispensable for addressing and better understanding complex topics. We regularly receive questions about a wide range of scientific subjects on our social media channels, by letter or by email. If you too have a question you would like to ask, please contact us at magazin@dlr.de.

Question from Tobias H. via email

I'm a commuter and interested in vehicles with alternative propulsion systems for environmental reasons. DLR's SLRV would be a realistic alternative to my current car. Does DLR have any concrete plans to offer the SLRV as a production car for private sale?



The Safe Light Regional Vehicle (SLRV) is a small vehicle powered by a fuel cell propulsion system. It has a sandwich panel chassis, so the car body weighs only 90 kilograms, and it is fuelled by hydrogen. Although it has already been driven on test tracks, it is a research prototype. In other words, DLR will use it for research, for its own projects and together with partners from industry and other scientific institutions. Before a vehicle like the SLRV could find its way onto the road, some further development and corresponding investment would have to happen – in terms of safety for road approval, design, equipment, storage compartments and full-body cladding for protection against moisture. Since DLR is a research institution that is largely publicly funded, we develop technologies up to the prototype phase. If there is interest, development for the market and series production is then the task of companies. Here, DLR can advise, support and license certain technologies or approaches, for example.

Michael Kriescher works in Vehicle Architectures and Lightweight Design Concepts at the DLR Institute of Vehicle Concepts

Question from Andrej D. via email

I recently saw the film 'Don't Look Up' in which an asteroid destroys Earth. Since then, I have kept revisiting this scenario. Could it actually happen that an asteroid will pose a serious threat to our planet in the near future?



You can sleep soundly! The probability of something happening to us in our lifetime as a result of an asteroid impact is almost zero.

Of the slightly more than one million asteroids known today, almost all orbit the Sun between Mars and Jupiter. Of those that have a diameter of more than 100 metres, about 27,000 follow orbits that also take them into the inner Solar System and, in some cases, they cross Earth's orbit. These Earth orbit crossers – we refer to them as Near Earth Objects (NEOs) – are observed very closely by telescope to keep track of their precise trajectories. None of them are currently expected to collide with Earth this century. However, some of them, and this is also correct, will come close to Earth in the coming decades: These are the

'potentially hazardous asteroids' that pass Earth at a distance of less than seven and a half million kilometres. Even this group, about a fifth of the known NEOs, does not contain an asteroid that will hit Earth. The flyby distances are usually at least several tens of thousands of kilometres, and most are further away than the Moon (400,000 kilometres). We do not really know how the orbits of these asteroids will change as they fly close to Earth – that is, whether they will come closer to it at their next encounter or whether they will move further away.

Bodies smaller than 100 metres are not all known; these too can cause considerable damage. Examples are the 60-metre asteroid that destroyed forests in the Tunguska region of Siberia over an area the size of Berlin in 1908, or as recently as 2013, the 20-metre asteroid that exploded at an altitude of 30 kilometres above the city of Chelyabinsk in Western Siberia, causing thousands of windowpanes in the city of millions to shatter (but without any fatalities). According to our current knowledge, events like Tunguska happen once or twice per century.

Ulrich Köhler is responsible for public relations at the DLR Institute of Planetary Research



Long-term stays in space put an immense strain on the human body: muscles and bones deteriorate, and body fluids shift from the legs to the head due to the lack of gravity. The altered pressure conditions do not just result in cold feet and a puffy face; this shift in fluids can give rise to an array of medical issues. Among other things, it affects the eyes. Astronauts increasingly report altered vision, with around 70 percent experiencing this when they return from space. To counter this, researchers seek a better understanding of the complex physiological changes that occur under space conditions. For decades, examining the effects of lying in bed head-down has been a proven method to investigate this phenomenon.

A bedrest campaign commissioned by the US space agency NASA to evaluate countermeasures to Spaceflight Associated Neuro-ocular Syndrome (SANS-CM) began at the DLR Institute of Aerospace Medicine in Cologne in autumn 2021. CM stands for the countermeasures to delay or even prevent the undesirable effects of microgravity on the human body. Low-pressure chambers are used in the study. These 'draw' blood and other body fluids back into the lower half of the body.

Lying with your head tilted six degrees down – space conditions on Earth

When people lie in bed with their head tilted six degrees below the horizontal, their body fluids are distributed in the same way as they would be in microgravity – over half a litre of fluids shift to their upper body. Being subjected to these conditions, the participants become 'terrestrial astronauts'. Here on Earth, under the controlled conditions of the study, the researchers can examine more people with far less effort and cost than would be possible in space. Bedrest studies are considered the gold standard of aerospace medical research into the degenerative processes that occur within the human body in microgravity conditions. Nevertheless, they are complex and costly undertakings that depend not only on international collaboration, but also on the commitment of stakeholders from a wide variety of disciplines.

LYING DOWN IN THE NAME OF SCIENCE

Bedrest studies explore spaceflight-related diseases

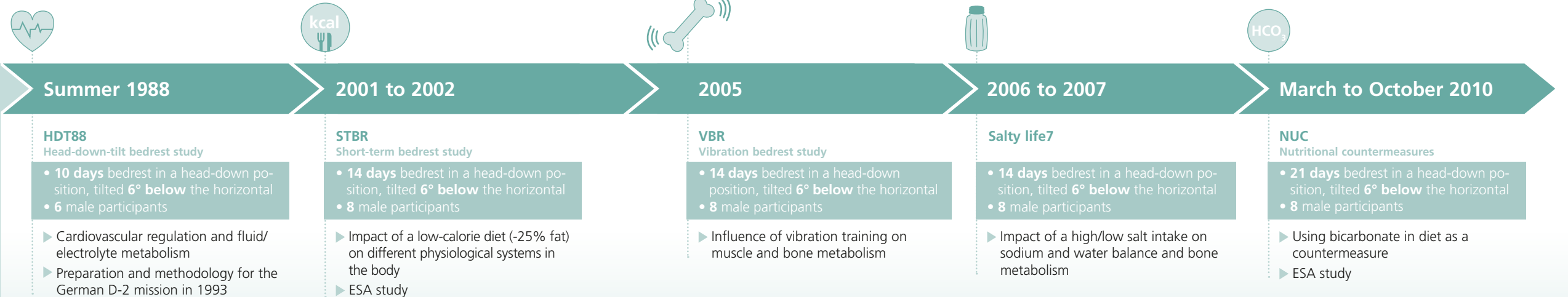
by Philipp Burtscheidt

In the current NASA bed rest study, the test persons lie in special negative pressure chambers. These are used to test whether negative pressure can help against the undesirable effects of microgravity.



HISTORY

Bedrest studies go back a long way at DLR. The first bedrest study was conducted in 1988 in preparation for the D2 mission. At that time, the Columbia space shuttle took German astronauts Ulrich Walter and Hans Schlegel into orbit for 10 days with the Spacelab space laboratory. Three decades later, the research is focusing on potential long-term missions, such as to the Moon or Mars.





Pneumatometrical measurement of intraocular pressure is carried out in the lying position and in the sitting posture, which is intended as a control.



The change in the length of the eye axis is measured to rule out the contraction of the eyeball

WORKING TOWARDS EYE HEALTH IN SPACE AND ON EARTH

In space, people experience eye problems and increased intraocular pressure due to the lack of gravity. On Earth, the same can happen when lying down for a long time. As eye damage can go unnoticed by those affected and can lead to irreversible blindness, it is vital to gain a better understanding of the origin and progression of the disease and develop appropriate countermeasures for people in space and on Earth.

One of the focuses of research is the eye. Why does the optic nerve swell? Why does raised intracranial pressure cause the eyeball to contract, leading to longsightedness? The precise causes and correlations of spaceflight-related eye conditions are unclear. Those affected do not realise that their blind spot – the optic nerve – swells up, and this can be dangerous. The retina, choroid and optic nerve also change. Why such conditions only affect some astronauts is still a mystery; theories abound, but there is no conclusive proof.

What is certain is that eye problems can occur, so taking preventive action and countermeasures is a must. During the bedrest studies, the optic disc of the participants swells. However, the eye recovers a while after the study comes to an end. When staying in space, however, it is a different story. Some astronauts' eyes never fully recover, needing to wear glasses on a daily basis upon their return to Earth. With the goal of sending humans to the Moon and Mars, stays in microgravity are set to last longer and longer in the future, and ensuring the health and safety of such astronauts is of vital importance.

From former bedrest studies to SANS-CM

The VaPER study in 2017 was the first to detect the swelling of the optic nerve head. The test participants – which included women for the first time in the history of bedrest studies at DLR – lay in bed with their head tilted six degrees below the horizontal for 30 days. They did not use pillows – another first. Not using a pillow might sound like a trivial detail, but it marked significant progress, as it

THREE QUESTIONS FOR DLR PROJECT LEAD EDWIN MULDER

Why are bedrest studies being carried out?

We can think of the human body as a machine that is geared towards efficiency. Whatever it doesn't need, it dispenses with. That leads to problems when people spend long periods in space. As such, scientists have been conducting research into countermeasures since the very advent of human spaceflight. We can use bedrest studies to simulate the degenerative processes that take place in the body in microgravity by creating standardised conditions on Earth. The changes experienced by the participants in the study are similar to those experienced by astronauts in space.

In terms of quality, the results are practically on a par, so we can determine the effects that occur in weightlessness in the lying phases of our bedrest studies. Our measurements on Earth provide us with knowledge that we can apply to human spaceflight. Quantitatively speaking, the results derived from studies on Earth are usually somewhat lower than in space, so they appear weaker. However, qualitative comparability is key to the significance of bedrest studies as analogue to the experience in space.

What is the reason for the head-down position, with the body tilted six degrees?

Lying horizontally is sufficient for examining changes to muscles, tendons and bones. The lack of mechanical stress can be simulated by lying down and keeping the body at rest. However, if you want to replicate the fluid distribution in a body in weightlessness to investigate its negative effects and devise the necessary countermeasures, participants must be positioned at an angle, with their head slightly downwards. Lying in a head-down position, with the body at a six-degree angle and without a pillow has become the standard setup for bedrest studies that examine the eye.

This angle is not absolutely optimal, but it is sufficient to observe physiological changes similar to those that occur under microgravity conditions. In the past, we have also conducted studies in which participants lay in bed, tilted head down at a 12-degree angle. The results were slightly better, but the inclined position is so extreme that the lying phase would become too uncomfortable for the participants over time. Expecting them to lie like that for weeks would not be reasonable. Six degrees is



Edwin Mulder

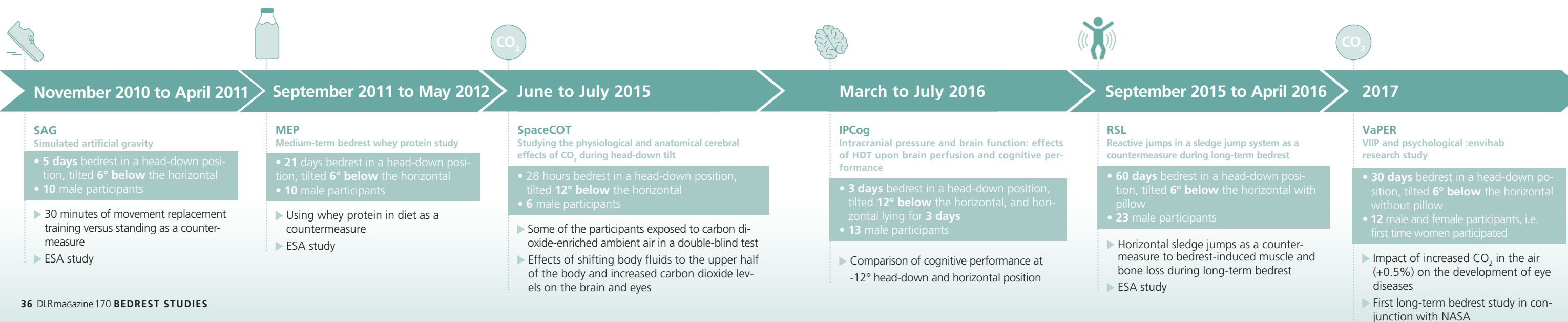
studied sports science in Amsterdam, the Netherlands, and has always been interested in astronaut training. He has been involved in bedrest studies at the DLR Institute of Aerospace Medicine since 2010. He is the Project Lead for the SANS-CM bedrest study and works as a Business Developer at the institute. In this capacity, he also devises programmes for other areas of research that focus on space psychology issues, organising isolation studies and the like.

the ideal compromise: you get meaningful results and are also able to see the study through. This set-up is also very good for testing countermeasures with simulations.

What impact will DLR's bedrest studies have on international aerospace medicine?

About two thirds of all studies of this type are carried out at DLR. The agencies invariably focus on possible countermeasures. We can make a lot of things possible here with our :envihab facility. NASA has now closed its own facility for conducting bedrest studies and entrusts our team in Cologne with this work. ESA also carries out its studies with us. This demonstrates their trust and satisfaction with what we do and makes us feel very proud. At the beginning of the year, NASA signed a new contract with us for the coming years. We are very much looking forward to continuing our long-term cooperation.

As far as we're concerned, it is a win-win situation. Bedrest studies are very expensive and require intensive preparation. Conducting such studies would not be feasible for DLR alone, so cooperation with the international scientific community and financial support are fundamental. Over the years, a global network of specialists has formed, from a wide variety of disciplines in the field of space medicine. We play a key role in that network.



was necessary for the researchers to be able to detect the changes to the eye by performing special tests. Previously, the eyes of the test participants had not changed in the same way they would in space.

The results of the follow-up study AGBRESA (Artificial gravity bedrest study) in 2019 confirmed the change to the optic nerve papilla. Rides on DLR's short-arm human centrifuge were investigated as a possible countermeasure, with the centrifugal force artificially replicating the effects of gravity. During these 30-minute sessions, the participants' body fluids shifted back towards the feet and their intracranial pressure decreased. However, AGBRESA showed that 30 minutes is not enough to counteract the adverse effects of microgravity on the body. What is more, longer 'rides' or several spread out throughout the day would not be possible on a space station or a long-duration spaceflight mission. The researchers realised that they needed to come up with a countermeasure that astronauts would be able to incorporate into their daily routine – for hours, if necessary.

If the current SANS-SM study proves lower body negative pressure to be a suitable countermeasure, the next step would be to develop negative pressure trousers that could be worn over long periods without astronauts having to interrupt their work routine. The DLR institutes of Aerospace Medicine and Materials Physics in Space have worked with



During the lying phase, six participants spend three hours twice a day in the vacuum chambers, in which the pressure is about three percent lower than in the environment.

the Systemhaus Technik at DLR and together with NASA to develop a lower body negative pressure device (LBNP), with the aim of testing the suitability of such a measure in everyday life. Such devices enclose the body from the waist down. With a reduced pressure of 25 mmHg, they draw blood and other fluids into the lower half of the body. 25 mmHg equates to about three percent of the atmospheric air pressure on Earth.

Many tests and experiments were carried out during the lying phase to determine the effectiveness of the device. Under the leadership of the ophthalmologist and Head of the Department of Clinical Aerospace Medicine, experts from DLR regularly checked intraocular pressure, examined the retina and optic nerve, and used magnetic resonance imaging (MRI) to scan the brain. They also constantly monitored the cardiovascular system. Coherence tomography recorded changes to the retina and optic nerve. NASA uses this method on the International Space Station (ISS), and the DLR device is also being employed in the studies. It can be used to pinpoint changes to the retina with micro-metre precision.



Eating while lying down and in a head-down position makes for a strange experience, at first.



2019

2021 onwards

AGBRESA
Artificial gravity bedrest study

- 60 days bedrest in a head-down position, tilted 6° below the horizontal without pillow
- 24 male and female participants

- ▶ Investigation of altered gravity as a countermeasure: first use of the DLR short-arm human centrifuge in a bedrest study
- ▶ First joint bedrest study carried out by DLR, ESA and NASA

SANS-CM
Spaceflight associated neuro-ocular syndrome-countermeasures

- 30 days bedrest in a head-down position, tilted 6° below the horizontal without pillow
- 48 male and female participants

- ▶ Test of using a negative pressure device as a countermeasure against the development of eye conditions compared to sitting upright for 6 hours daily
- ▶ DLR/NASA study

In the first two SANS-CM study campaigns, 12 participants spent almost 60 days in :envihab, DLR's medical research facility. These included two weeks of preparation and initial examinations, 30 days of lying in bed and two weeks of follow-up examinations and advanced training. During the bedrest phase, six people spent three hours in a low-pressure chamber twice a day. The control group of six people sat upright in a nursing chair, also twice a day for three hours at a time. In the third and fourth campaigns, thigh cuffs will be used in conjunction with special cycling training. Who knows? Perhaps future astronauts will travel through space using negative pressure trousers thanks to the data obtained at DLR.

Philipp Burtscheidt is an editor in the DLR Communications and Media Relations department.



These pumps provide the negative pressure in the LBNP chambers, in which the participants lie with their lower bodies for a total of six hours a day. So that the operating noises are not disturbing, they are placed outside the rooms.



What is :envihab?

:envihab is DLR's unique aerospace medical research facility in Cologne, Germany. Among other things, bedrest studies are carried out here. Covering 3500 square metres, it houses eight modules designed according to a house-within-a-house principle. Research activities focus on space and flight physiology, radiation biology, aerospace psychology, operational medicine, biomedicine and analogous terrestrial scenarios such as bedrest studies. The facility has a short-arm human centrifuge, laboratories in which the effects of oxygen reduction and pressure are studied, a whole-body MRI/PET facility, zones for simulating psychological stress and recovery situations, and microbiological and molecular biological research instruments. The name :envihab combines the words 'environment' and 'habitat'.

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INTO A MYSTERIOUS METAL WORLD

A NASA exploration mission to study an asteroid made of iron and nickel

by Ulrich Köhler

The 'psyche' – a commonly used word with an almost mythical dimension. Yet you could say its origin is quite romantic. For the Ancient Greeks, Psyche was the goddess of the soul, and the consort of Eros, god of love. There are many legends surrounding the two deities. Far less mythical is the very real asteroid Psyche – a heavyweight among small celestial bodies. It will soon become the destination for a NASA mission of the same name. It is scheduled for launch on 1 August 2022, and DLR will be 'on board'. Psyche, both the mission and the asteroid, will provide further insights into planetary formation and the dynamics of the early Solar System.

From ancient times through to the present day, astronomers have named planets and moons after figures from antiquity. Since 1801, when Ceres was discovered, they have done the same with asteroids. The mythological Psyche assumed its place in the Solar System when Italian astronomer and mathematician Annibale de Gasparis discovered a 'star-like' body close to the orbit of Jupiter with the telescope at Naples Observatory in 1852. The asteroid, which was the sixteenth ever discovered, was observed as a point of light moving against a backdrop of stars. Its exact properties were unclear at the time; scientists only knew that it orbited the Sun on the outer edge of what a few decades later would be named the Main Asteroid Belt.

Only much later did it become clear that the asteroid, which Gasparis had christened Psyche due to its proximity to the orbit of Jupiter, had some unusual properties. For one, it was unusually heavy for a rock in the Main Asteroid Belt – a region of small celestial bodies that we now

know to number over a million asteroids. These asteroids are fragments and remnants from the early Solar System, when the planets formed from myriad small and, later, increasingly large bodies. The remarkable thing about Psyche is that it is much denser than other asteroids, which indicates that it must consist of metallic elements. With a density of 4.5 grams per cubic centimetre, it is only slightly 'lighter' than Earth, at 5.5 grams per cubic centimetre. However, its total mass is only one two-hundred-thousandth that of Earth. How is this possible, given that most of the asteroids on these far-flung orbits are made up of lighter, frozen materials?

Not just any old asteroid

To answer that question, we have to go back to the very dawn of the Solar System, about nine billion years after the Big Bang, to a time when a star or two exploded on the edge of our galaxy, the Milky Way. The

remaining dust, vast quantities of hydrogen and the higher elements formed at the high temperatures of these supernovae quickly contracted to create a disc of gas and dust. This inherited the rotational momentum of the galaxy and began to revolve around its centre.

Roughly 4.6 billion years ago, after accumulating from the hydrogen in the disc, the Sun ignited. Barely one percent of the mass of dust, hydrogen and higher elements was left for the planets. In a surprisingly short time, much of the remaining material formed into planetesimals – the precursors of the planets that formed within a few tens of millions of years and have been orbiting the Sun ever since. Billions of comets and millions of asteroids remained but make up only a tiny fraction of the total mass of the disc. Most of the asteroids have since been travelling around the Sun between the orbits of Mars and Jupiter.

Gravitational forces and the high population density of these small celestial bodies inevitably saw them collide with one another and, once thrown off course, with the planets of the inner Solar System. Hundreds of thousands of them were eliminated in such fashion in this cosmic

While the Psyche orbiter would easily fit into a large living room, the deployed solar panels will take up the area of a tennis court.



NASA/JPL-Caltech/Arizona State Univ./Space Systems Loral/Peter Rubin

game of billiards, essentially potted onto the surfaces of the Earth-like planets, the Moon or the moons of Jupiter or Saturn, or pulverised in Jupiter's atmosphere by its immense gravitational pull. Some of the asteroids that hit the planets and the Moon were huge – in some cases measuring well over 100 kilometres across. This is evidenced by countless craters, including the South Pole-Aitken basin on the far side of the Moon, which is the largest impact crater in the Solar System, at 2000 kilometres across.

A newcomer formed by collisions

More than four billion years ago, there were already several bodies in the asteroid belt that had undergone thermal, geochemical and physical transformation in a similar way to the young planets and Earth's Moon. Planetary researchers talk about 'differentiation' – a separation of the substances in the core, mantle and crust into shell-like layers. In an initially hot, homogeneously mixed body with a diameter of more than 300–500 kilometres, gravity causes the heavy



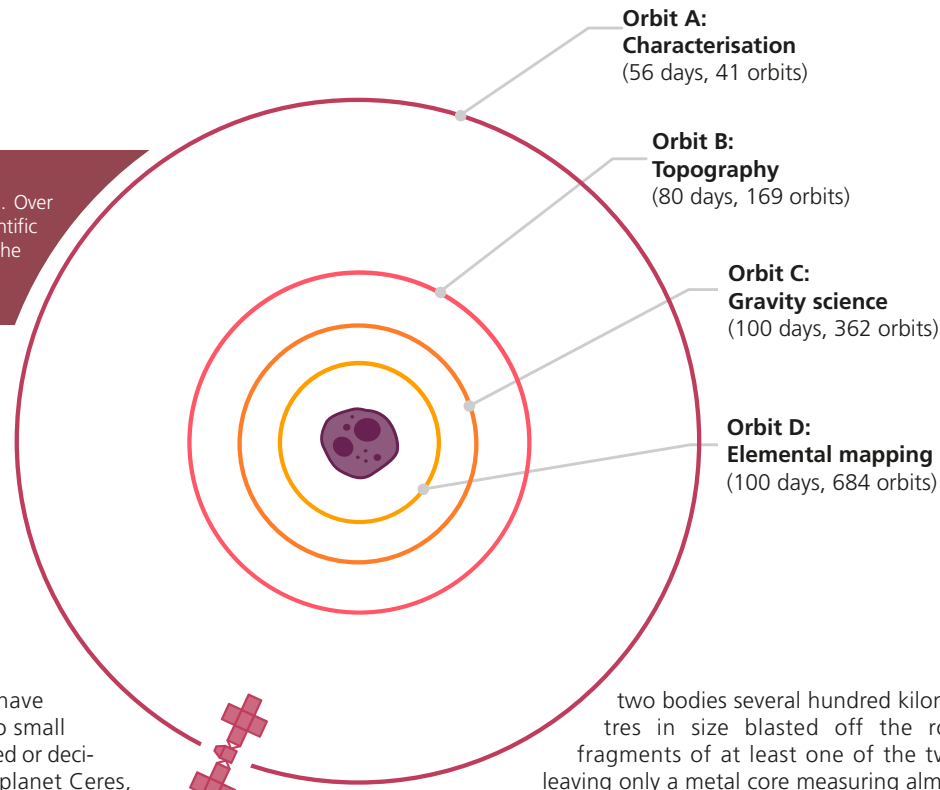
NASA/JPL-Caltech

The spacecraft will reach the asteroid in 2026. Over the course of 21 months, it will conduct scientific experiments from four orbits, each closer to the asteroid's surface than the last.

components – the metals – to sink to the geometric centre, where they form the core. The somewhat lighter rocks, which also have considerable amounts of metallic elements in their minerals, form a mantle over the core. The lightest rock components float upwards to form a top crust.

The largest of these asteroids may have grown far beyond small lumps and into small planets, which were then in turn destroyed or decimated by further collisions. The dwarf planet Ceres, which measures 1000 kilometres across, is the largest such body left. The heavily debated Nice Model, named after scientists from the Côte d'Azur Observatory, is a spectacular model of the dynamic processes that took place around four billion years ago. It goes so far as to assume that the orbit of Jupiter, with Saturn in tow, drew gradually closer to the Sun over a period of several hundred million years and pushed countless asteroids into the inner Solar System, where they collided with the four inner planets and Earth's Moon with ever-increasing frequency. This period is known as the lunar cataclysm or Late Heavy Bombardment. It was only when the two gas giants receded again and assumed their current orbits, 730 million kilometres and 1.4 billion kilometres from the Sun respectively, that the inner Solar System was 'pacified'.

Whatever dynamics prevailed in the asteroid belt over four billion years ago, it is thought highly likely that a violent collision between



two bodies several hundred kilometres in size blasted off the rock fragments of at least one of the two, leaving only a metal core measuring almost 300 kilometres across. From then on, this asteroid – Psyche – has been orbiting the Sun along the outer edge of the Main Asteroid Belt.

Cameras and spectrometers investigate the asteroid

The Psyche mission is set to examine this remarkable 'star-like' (the meaning of the word asteroid) body up close for the first time. It will make use of the standard planetary research toolbox: two redundant multispectral cameras whose filter can distinguish between metallic and siliceous (rocky) components; a gamma ray and neutron measuring device that can identify chemical elements and their abundance; and a magnetometer to determine the strength and orientation of a remanent magnetic field, which is highly probable in a metallic body. It will take the spacecraft just under three and a half years to reach its destination. Upon arrival, the probe will closely examine Psyche from four different orbits at altitudes between 700 and 85 kilometres over its 21-month mission.

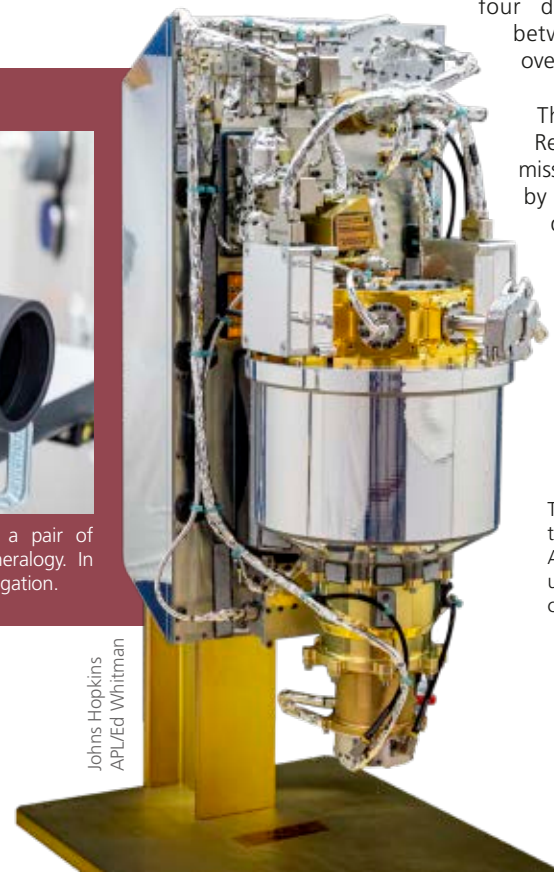
The DLR Institute of Planetary Research in Berlin is assisting the mission in the planning stages and by evaluating stereoscopic image data to create cartographic products such as image mosaics or digital terrain models. These are vital for a detailed

The gamma ray and neutron spectrometer of the Johns Hopkins Applied Physics Laboratory measures and maps the elemental composition of Psyche.

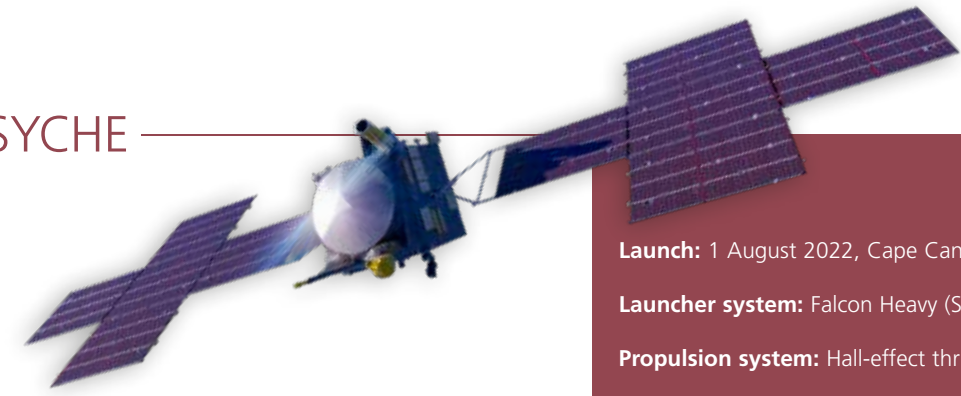


Psyche's high-resolution multispectral camera consists of a pair of identical cameras to image geology, topography and mineralogy. In addition, the cameras provide additional data for optical navigation.

Johns Hopkins
APL/Eo Whitman



PSYCHE



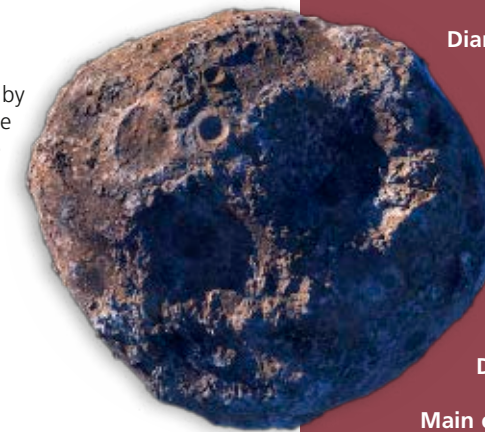
THE MISSION

Psyche is the fourteenth mission in NASA's scientifically and technologically successful yet organisationally lean Discovery class since 1997. It was approved in 2017 and is the first mission to visit an object in the Solar System that is not made of rock, ice or gas, but rather an asteroid that consists mainly of metals. The asteroid Psyche is made of the same metals that make up Earth's core, and most likely the cores of Mercury, Venus, Mars and the Moon.

Lindy Elkins-Tanton from Arizona State University is the Principal Investigator of the mission, which will be run by the NASA Jet Propulsion Laboratory in Pasadena, California. Germany is also involved in the scientific aspects of the mission, through Thomas Roatsch of the DLR Institute for Planetary Research and Ralf Jaumann from the Free University of Berlin. Three other DLR researchers are associated with the team.

THE ASTEROID

(16) Psyche was discovered in 1852 by Annibale de Gasparis, from the Naples Observatory. He named the asteroid after the goddess of the soul in Greek mythology. Psyche is the largest asteroid in the metal-rich M class of asteroids.



Diameter: 250 kilometres

Distance from the Sun: 2.5–3.3 AU¹

Orbital period: Five years

Orbital inclination: 3.1 degrees

Rotation period: 4 hours 12 minutes

Reflectivity: 12 percent

Density: 4.5 grams per cubic centimetre

Main components: Iron, nickel, silicates

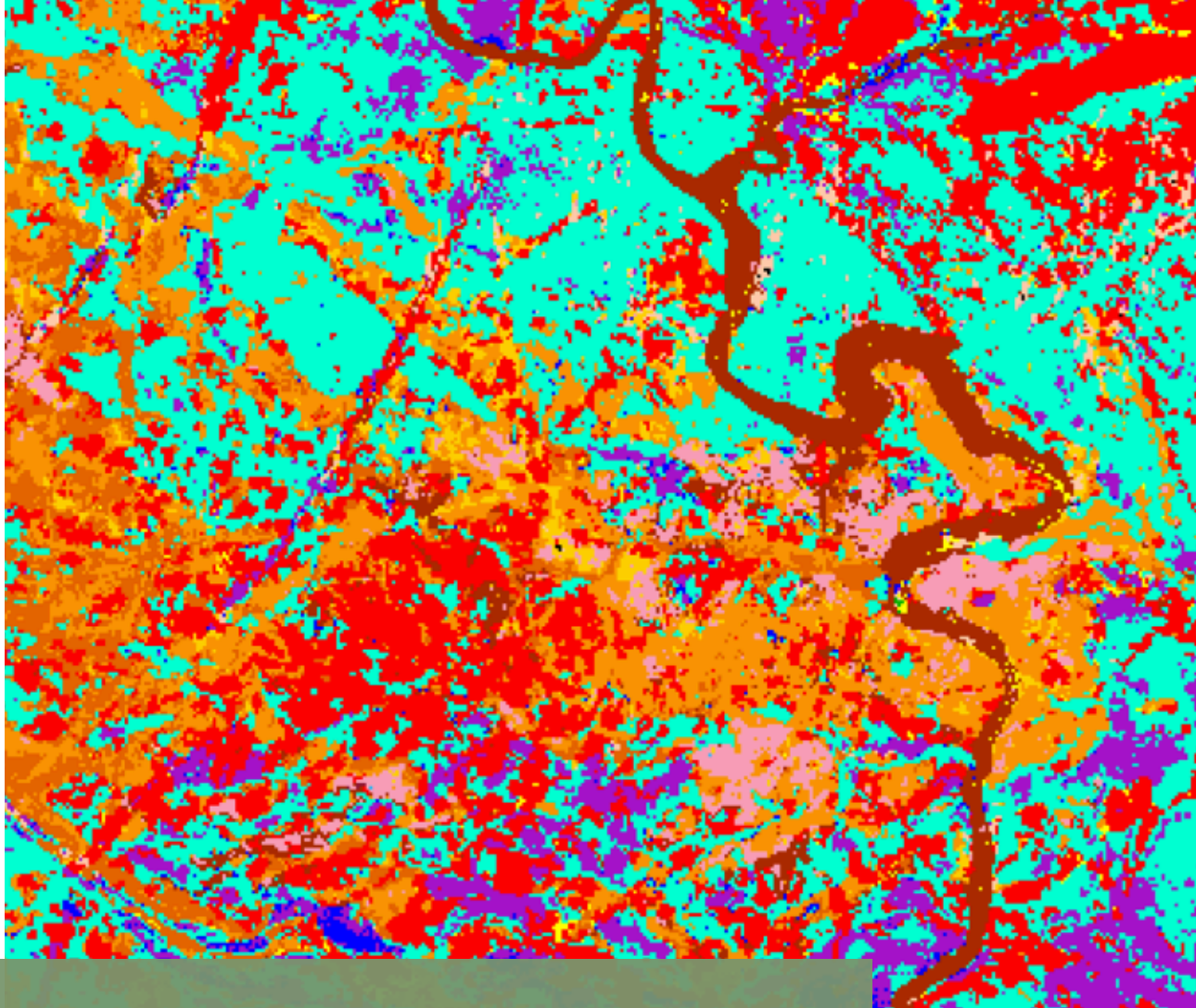
¹The average distance between Earth and the Sun is called the Astronomical Unit (AU) and measures roughly 150 million kilometres.

geological study of Psyche. DLR researchers can draw upon decades of expertise in stereoscopic image data processing and the geological analysis of the surfaces of planets, moons, asteroids and comets.

The fact that such metal-rich asteroids are the exception in the main belt rather than the rule is also reflected in the meteorite collections on Earth. This 'M class', metal-rich meteorites, is only sparsely represented, but there are some beautiful examples, known as mesosiderites. These 258 iron meteorites include some of the heaviest specimens

ever found on Earth. The iron meteorite Vaca Muerta ('dead cow'), which was found in Argentina, weighs almost four tonnes. Such 'free samples' from the Solar System – will serve as a spectral reference for the Psyche mission.

Ulrich Köhler, a geologist at the DLR Institute of Planetary Research, first saw an asteroid up close in 1991, when the Galileo spacecraft flew past Gaspra on its way to Jupiter. The first images caused a sensation at the time.



GFZ

OUR EARTH IN MORE THAN JUST COLOUR

German environmental satellite EnMAP provides data on the state of the planet
by Sebastian Fischer and Martin Fleischmann

Mineral mapping for the Haib River copper-molybdenum deposit in Namibia. The map was created using simulated EnMAP data (scale: 1 centimetre corresponds to 0.65 kilometres).

EnMAP is the first hyperspectral satellite to be developed and constructed in Germany – the name stands for Environmental Mapping and Analysis Program. On 1 April 2022, it launched from Cape Canaveral in Florida on board a SpaceX Falcon 9 rocket on the way to its target orbit. From there, EnMAP will provide data about the effects of climate change on Earth for at least five years.

All materials on Earth's surface reflect sunlight in a characteristic way, referred to as a spectral signature. Remote sensing satellites such as EnMAP can 'read' such signatures with the help of spectrometers. These instruments can record larger wavelength ranges – far beyond visible light – and combine them into images. EnMAP has 242 colour channels – a standard camera has only three. With a spectral resolution of 6.5 nanometres in the visible and near-infrared ranges and 10 nanometres in the short-wave infrared range, the environmental satellite will be able to observe features that are invisible to the human eye.

"With the launch of EnMAP, we are closing a gap in modern Earth observation. Our journey towards this achievement has been extremely important for advancing German space science and industry, as the mission has required new developments in many areas that have

pushed at the limits of what is technically feasible. The end result is a satellite that will benefit us all," emphasises Walther Pelzer, DLR Executive Board Member and Head of the German Space Agency at DLR in Bonn.

Using the images, scientists will be able to determine and even quantify the materials recorded. For example, they will not only recognise which type of crop is being grown in a field, but also how well the plants are being supplied with nutrients. Minerals in soils will also be detected and quantified. Until now, this has only been possible with observations performed from aircraft; however, these can only acquire data over a limited area. "The EnMAP data will be processed, archived and validated by the German Remote Sensing Data Center and Remote Sensing Technology Institute. They will then be made available to the



FACTS AND FIGURES

Launch: 1 April 2022 on board a SpaceX Falcon 9 rocket from Cape Canaveral (USA)

Orbit altitude: 653 km, Sun-synchronous

Satellite dimensions: 3 x 2.1 x 1.5 m

Satellite mass: approx. 980 kg

Power consumption: 800 W

Spectrometers: Visible Near Infrared Camera (VNIR) and Short Wave Infrared Camera (SWIR)

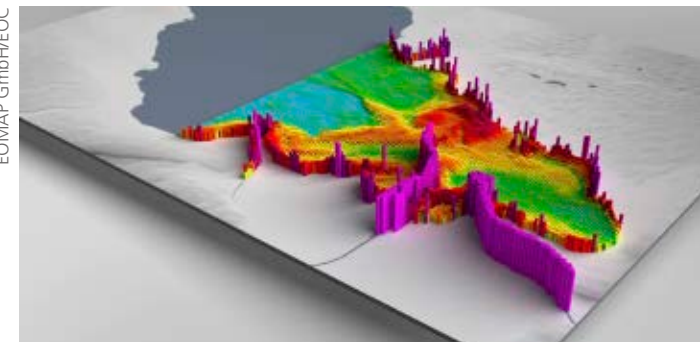
Wavelength ranges: VNIR: 420-1000 nm / SWIR: 900-2450 nm

Ground resolution: 30 m x 30 m

Spectral resolution: VNIR: 6.5 nm / SWIR: 10 nm

Additional information: Dedicated mission site: DLR.de/EnMAP_en as well as a detailed article on the mission in issue 42 of COUNTDOWN.

EnMAP GmbH/HFOC



Concentration of suspended matter in Lake Constance. Purple shows a high (approx. 20 mg/l), light blue a low (approx. 0.1 mg/l) content.

EnMAP will also provide data on sustainable raw material extraction and available reserves," says Sabine Chabrilat, Scientific Principal Investigator of the EnMAP mission, who is based at the GFZ German Research Centre for Geosciences in Potsdam. However, the satellite has its sights set on more than just the land surface; it will also monitor coastal areas and inland waters to provide information on which areas are affected by water shortages or water quality problems, as well as documenting the condition of the Wadden Sea and permafrost soils.

Sebastian Fischer is EnMAP Project Manager at the German Space Agency at DLR. **Martin Fleischmann** is deputy team leader and editor for communications at the German Space Agency at DLR.

EnMAP – THE GERMAN ENVIRONMENTAL MISSION AND ITS PARTNERS

The EnMAP environmental mission is being conducted by the German Space Agency at DLR in Bonn on behalf of the Federal Ministry for Economic Affairs and Climate Action (BMWK). OHB-System AG was commissioned to develop and build the satellite and the hyperspectral instrument. The mission is under the scientific management of the GFZ German Research Centre for Geosciences. Three DLR institutes and facilities have been commissioned to set up and operate the ground segment. The German Space Operations Center in Oberpfaffenhofen will conduct and monitor satellite operations. The German Remote Sensing Data Center and the DLR Remote Sensing Technology Institute will archive, process and validate the received satellite data and make them available to the scientific community. Companies and public authorities will also test the data and use them to prepare future services. The future use of EnMAP hyperspectral data by universities and scientific institutions and the development of special applications will be supported by BMWK funding programmes.

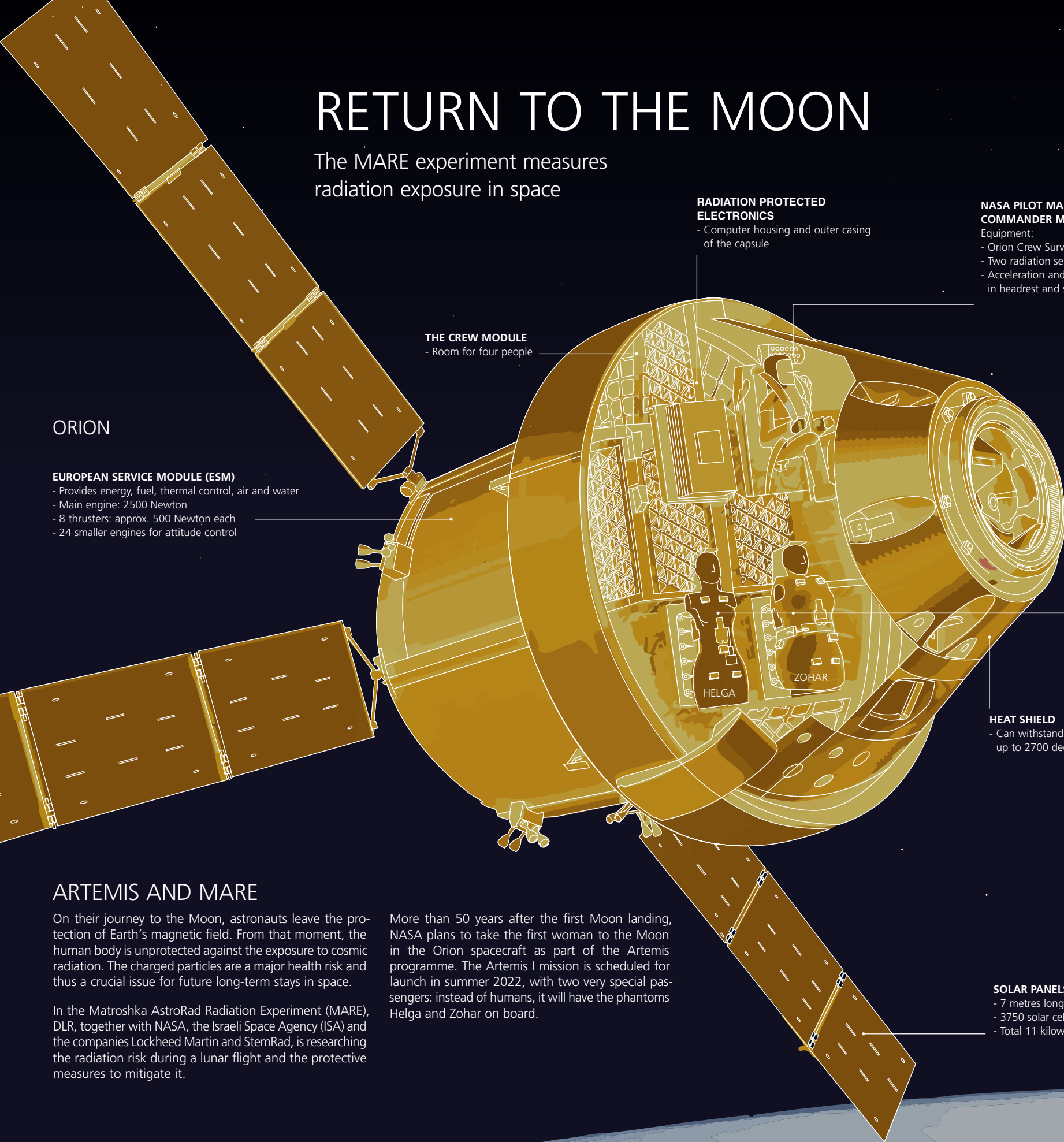


SpaceX

This photograph was taken shortly before the payload fairing for the Falcon 9 launcher was installed. It shows many of the 40 payload items, some of which are very small. EnMAP is at the top of the SpaceX Transporter-4 mission payload stack and is the largest satellite on board.

RETURN TO THE MOON

The MARE experiment measures radiation exposure in space



ORION

EUROPEAN SERVICE MODULE (ESM)
 - Provides energy, fuel, thermal control, air and water
 - Main engine: 2500 Newton
 - 8 thrusters: approx. 500 Newton each
 - 24 smaller engines for attitude control

THE CREW MODULE
 - Room for four people

RADIATION PROTECTED ELECTRONICS
 - Computer housing and outer casing of the capsule

NASA PILOT MANNEQUIN COMMANDER MOONIKIN CAMPOS
 Equipment:
 - Orion Crew Survival System suit
 - Two radiation sensors
 - Acceleration and vibration sensors in headrest and seat

HEAT SHIELD
 - Can withstand temperatures up to 2700 degrees Celsius

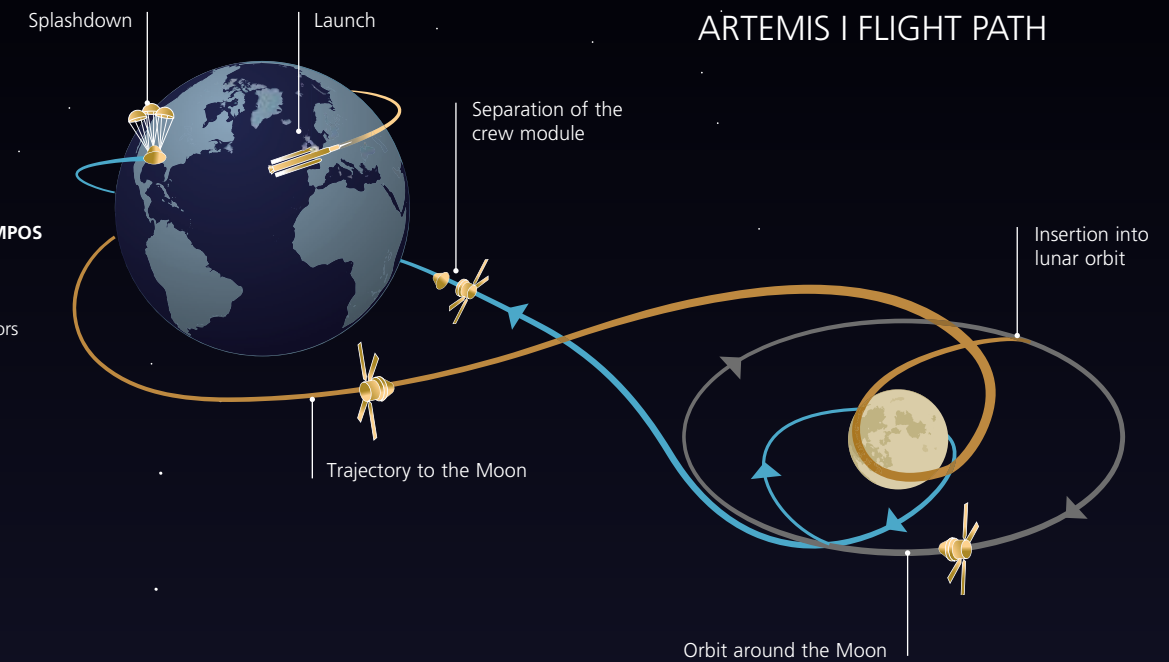
SOLAR PANELS
 - 7 metres long
 - 3750 solar cells per panel
 - Total 11 kilowatts of energy

ARTEMIS AND MARE

On their journey to the Moon, astronauts leave the protection of Earth's magnetic field. From that moment, the human body is unprotected against the exposure to cosmic radiation. The charged particles are a major health risk and thus a crucial issue for future long-term stays in space.

In the Matroshka AstroRad Radiation Experiment (MARE), DLR, together with NASA, the Israeli Space Agency (ISA) and the companies Lockheed Martin and StemRad, is researching the radiation risk during a lunar flight and the protective measures to mitigate it.

More than 50 years after the first Moon landing, NASA plans to take the first woman to the Moon in the Orion spacecraft as part of the Artemis programme. The Artemis I mission is scheduled for launch in summer 2022, with two very special passengers: instead of humans, it will have the phantoms Helga and Zohar on board.



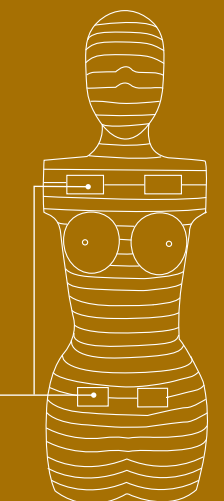
ARTEMIS I FLIGHT PATH

HELGA AND ZOHAR

Helga and Zohar are anatomically correct analogues of human torsos. They are the first female 'phantoms' to be used in spaceflight. Both dummies are made up of 38 slices of tissue-equivalent plastics that mimic the varying density of bones, soft tissue and lungs. There is a need for data on female bodies due to the growing number of female astronauts.

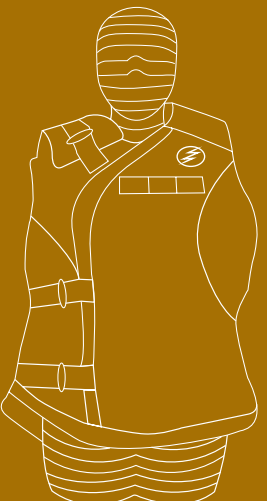
Active detectors on and in Helga and Zohar, 34 in total, including in the most radiation-sensitive organs (lungs, stomach, uterus, bone marrow).

DLR PHANTOM HELGA



Weight: 36 kg

ISA PHANTOM ZOHAR

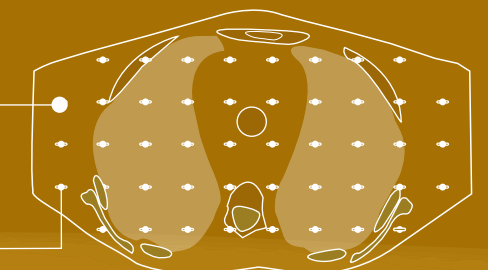


52 kg with AstroRad vest

LUNG SLICES

Crystals act as passive detectors and store information about radiation exposure (5600 per phantom)

Holes for crystals



For more information go to [DLR.de/MARE_EN](https://www.dlr.de/MARE_EN)



Personnel from the University of Évora and TSK Flagsol check part of the plant



In the test facility, molten salt flowing through the metal pipe in the middle of the parabolic reflector is heated by solar radiation.

SUN AND SALT

At the Évora Molten Salt Platform in Portugal, DLR is conducting research into solar thermal power plants.

by Elke Reuschenbach

If you travel east from Lisbon across the Tagus river, you enter the Alentejo region and, after about an hour's drive, you reach the university town of Évora. On a test site in the idyllic outskirts of the city, surrounded by old cork oaks, olive trees and grazing pastures, DLR and the University of Évora are conducting research for the energy transition with European industrial partners. Researchers, engineers and technicians are operating a parabolic trough test facility with molten salt as the heat transfer medium at the Évora Molten Salt Platform (EMSP).

Molten salt instead of thermal oil

In conventional parabolic trough power plants, mirrors focus the sunlight onto a metal pipe encased in a glass tube, in which a special thermal oil absorbs the heat. The pipes transport the heated oil to a steam generator, which drives a turbine to produce electricity, or to a thermal storage tank filled with molten salt. When the solar field provides little or no thermal energy, for example, when clouds pass overhead or at night, the power plant can run on the heat stored in the salt.

Higher operating temperatures improve the efficiency of converting solar radiation into thermal energy and electricity. However, it is not easy to increase the temperature. Thermal oil has a maximum operating temperature of 400 degrees Celsius. In contrast, molten salt can be heated up to 565 degrees. One idea the researchers are pursuing is therefore to use the molten salt already in the solar field. This is due to the fact that some

energy is lost during the 'heat exchange process' from oil to salt in the thermal storage system. By using molten salt as the sole heat transfer fluid and storage medium the heat exchanger can be eliminated, more usable energy reaches the storage system, and the cost of the storage system is reduced. The biggest challenge is keeping the salt in a liquid state. Salt melts at temperatures ranging from 130 to 240 degrees Celsius. To prevent it from solidifying when it is first filled and during operation, additional electrical heating is required. One of the aspects researchers are looking at in Évora is how the heating system operates in reality and how it can be integrated into the overall system in the best possible way.

"With the test facility in Évora, we can check our theoretical calculations and assumptions under realistic operating conditions," says Jana Stengler, Team Leader for the Fluid Systems Working Group at the DLR Institute of Solar Research. "In practice, we are faced with situations that

we did not foresee in our design calculations. For example, we can only determine how the salt affects the salt-bearing components under real operating conditions. This will enable us to adapt and improve the components accordingly."

Solar thermal power plants instead of fossil fuel power?

In sunny countries such as Spain, the USA or Chile, solar thermal power plants already constitute a key energy system component. Although the costs for electricity production are higher than those of photovoltaic plants during the day, these systems can absorb thermal energy in connected heat storage facilities during daylight hours and store it for up to 12 hours, even while the steam generator is operating at full load. Storing comparable quantities of electricity in battery storage systems would be much more expensive. In addition, battery storage systems at gigawatt-hour scales do not yet exist. Solar thermal power plants can ideally complement photovoltaic plants by producing electricity primarily in the daytime margins, at night, and when there is not enough wind power available on sunny days. In countries with enough sunny hours, they are even suitable to take over baseload security in the future – a task mainly performed by coal-fired power plants until now.

DLR has been conducting research into concentrating solar power technologies since the 1970s. Today, most solar thermal power plants use technologies developed by DLR researchers. "Although the annual hours of sunshine in Germany are not sufficient to generate electricity profitably with solar thermal plants, collectors using molten salt as the heat transfer medium could also be used here in other areas of application," explains Michael Wittmann, DLR project manager at the EMSP, adding: "One example is the generation and provision of process heat for industry. This is why the research in Évora also benefits the heat transition in Germany."

Elke Reuschenbach is Head of Public Relations at the DLR Institute of Solar Research.

THE ÉVORA MOLTEN SALT PLATFORM

Facility operator:
University of Évora

Total capacity of the solar field:
3.5 megawatts

Thermal output of the steam generator:
1.6 megawatts

Length of the parabolic trough collectors:
684 metres

Target salt temperature:
565 degrees Celsius

The facility is equipped with a two-tank storage system.

First tests started in October 2021.

Industrial partners: TSK Flagsol, Rioglass, YARA, Steinmüller Engineering, eltherm, RWE

Funding: The work on the Évora Molten Salt Platform is being conducted within the scope of the High Performance Solar 2 (HPS2) research project. It is funded by the German Federal Ministry for Economic Affairs and Climate Action, the Portuguese Foundation for Science and Technology (Fundação para a Ciência e a Tecnologia; FCT) and the Programa Operacional Regional do Alentejo.



Images: University of Évora / Hugo Faria

HOW HAMBURG BECAME A TRANSPORT LABORATORY

DLR researchers investigate measures to improve mobility

by Jasmin Begli

31 partner organisations, 10 sub-projects, one city: This is the Reallab Hamburg. In 2020 and 2021, the city became a hub for digital mobility research – a place for stakeholders from academia, industry, local government and the community to devise recommendations for making the mobility system environment- and climate-friendly. The DLR institutes of Transportation Systems and of Transport Research were involved in four sub-projects conducted at this unique field laboratory.

When considering the transport of the future, the focus is increasingly on the users. Citizens and mobility providers need to be involved in the process from the outset in order to make the system as responsive to people's needs as possible. This is where field laboratories such as the Reallab Hamburg come in. "DLR has been involved in several projects of this kind for many years," says Michael Ortgiese, Director of the DLR Institute of Transportation Systems. "We were able to apply a lot of our knowledge and experience regarding innovative technologies for future transport at the Reallab Hamburg." From user surveys to simulation, autonomous driving to digitalisation of the rail sector, DLR had expertise to share.

Reaching out – online and offline

"For a new, modern transport system to have a chance of succeeding, it needs people to use and promote it," says Mandy Dotzauer of the DLR Institute of Transportation Systems, who coordinated the

exchange with the public. Unless potential users are won over, changes to the transport system are unlikely to be accepted in the long term. At the Reallab Hamburg, these people were heard and given the opportunity to experience, design and try things out for themselves.

"The ZuHörMobil, for instance, allowed members of the public to get involved," says Dotzauer. "Our electric shuttle travelled around the Hamburg metropolitan area in August 2021, stopping in seven places, where people were encouraged to share their wishes and concerns regarding the mobility of the future." The ZuHörMobil provided a platform where citizens could engage with the topic of digitalisation and mobility in a playful and very personal way thanks to a wheel of fortune, a memory game and opportunities to voice their opinion – even by writing directly on the vehicle.

The project was well received: Over the 11-day campaign, DLR engaged with around 330 people. During that time, they covered many different



The ZuHörMobil, spent time on the road in Hamburg. There was space on it to leave suggestions and opinions.

topics, including cycling infrastructure, connecting older people to facilitate social inclusion, accessibility and barrier-free design, e-mobility, autonomous driving, improved public transport connections and costs and flexible driving options. The conclusion was that citizens are keen to participate. "They want more opportunities to get involved and help shape the future," says Dotzauer. "But when it comes to a new transport option, they often lack information and just want someone to explain how it works."

While the ZuHörMobil mainly attracted older visitors, an online version of the initiative was designed to appeal to younger generations. There, citizens could vote on different current and future mobility topics every two weeks. Several workshops also took place online due to the pandemic. People of all ages with an interest in the topic gathered to come up with new ideas for transport in their city. "It was very important to us that no idea be written off as too far-fetched and that all fears and concerns were respected," says Dotzauer. The researchers all agree that representing the wider public requires both an online and offline presence. Stakeholders from public administration, industry, transport service providers and professional groups were also invited to specific events. "We also wanted to communicate our findings to industry, local government and policy-makers in a targeted way. That went down very well."



Hands-on experience is another important factor when communicating new technologies. As part of the project, members of the public were able to use innovative means of transport, such as on-demand shuttle services in Ahrensburg, Winsen and Trittau, or an automated shuttle in Bergedorf. These services could be requested via an app and drove on demand.

The last mile – automated and on demand

Widespread use of public transport can take the pressure off roads and cities, while insufficient use of public transport can result in a lack of space, air pollution and heavy traffic that are severely detrimental for cities and the environment. Researchers are looking at how to maximise the appeal of public transport to encourage as many people as possible to opt for it on a regular basis. Could driverless, on-demand shuttle services encourage more people to make the change?

Hamburg-Bergedorf – a district with 36,000 residents – already has good transport connections, but the options for short trips within the district could be improved. To help with this, the researchers deployed on-demand shuttles (free of charge within a defined district) to connect the district to the suburban railway network. Shuttles carried up to five people, using on-board sensors to navigate, determine their position and avoid collisions. They were fully electric and automated and were used to get people from their homes to the nearest public transport stop. The selected residential area to the north-east of Bergedorf station was the ideal test area for the fully electric and automated minibuses.

DLR provided services for dispatching the vehicles and integrating them into the city's surrounding public transport network. Together with the vehicle providers Continental and EasyMile, the project partners created a landscape of digital services that met the needs of both the shuttle operators and the users. The researchers tested the first on-demand transport with virtual stops and automated shuttles in the Bergedorf test field in September and October 2021.

During the citizens' survey, DLR researchers collected hopes and concerns regarding future mobility solutions.



The DLR researchers also looked into what users expect from a flexible, on-demand service with automated shuttles and how they rate the service implemented in this test. "We wanted to get as close as possible to the members of the public who were using these services and find out all about their needs and any potential problems," says Annika Dreßler from the DLR Institute of Transportation Systems. "For example, we asked about the occurrence of unexpected events during the ride, how the users experienced the ride in the shuttle and whether they would use such a service without a vehicle attendant."

© DLR



Automated shuttles on the road at the RealLab Hamburg (left).
On the right, the MATSim traffic simulator shows the distribution of traffic in Hamburg. The thicker the road the more vehicles drove over it.

"We wanted to get as close as possible to the members of the public who were using these services and find out all about their needs and any potential problems."

Annika Dreßler

"More than 1000 passengers used the shuttles during the trial period," explains Anke Sauerländer-Biebl, from the DLR Institute of Transportation Systems. "In general, they felt safe and comfortable on their journeys and described the experience as a pleasant one." The DLR scientists also investigated what could still be improved and what obstacles could currently still prevent potential passengers from using a shuttle.

In a separate activity, the researchers developed a workstation prototype for a remote control centre. New legislation allows autonomous vehicles to operate on public roads without a back-up driver on board as long as they can be monitored and controlled remotely in the event

of an emergency. This represents a new job for control centres. The prototype consisted of several screens showing video displays from the vehicle, forwarding status reports or an overview of error messages, or providing the vehicle with new directions to avoid obstructions.

Well-informed and safe at level crossings

Rail traffic was also studied at the RealLab Hamburg. The 'Digital St Andrew's Cross' project revolved around whether digitalisation could make level crossings more convenient, and whether waiting times at crossings could be shortened by improving the flow of information.

"The idea is that the level crossing sends up-to-date information about upcoming waiting times or the end of a train's passing to nearby navigation systems and smartphones," says Miriam Grünhäuser from the DLR Institute of Transportation Systems. "This allows road users to be more proactive." The researchers believe that digitalised level crossings have a number of benefits. Timely information about closed barriers

improves the flow of traffic around the crossing. It is also easier for road users to wait if they know whether a level crossing will be closed and, if so, for how long it will remain closed. Most of the crashes at level crossings are caused by road users. Providing them with more detailed information about the crossing situation could reduce crashes. The digitalisation of transport infrastructure is also a necessary step for the increased adoption of automated vehicles.

"At the RealLab Hamburg, we worked with two types of level crossings," explains Grünhäuser. "We used a technically secured level crossing in Sieversstücken and one in the harbour area that was not technically secured." All the tests were successful. The DLR team used the V2X standard, which is similar to WLAN, to transmit the messages. "We had to take into account that there is not an established V2X standard for signals from railway infrastructure as there is for traffic lights," says Grünhäuser. "This needs to be improved in the future to allow railway infrastructure to communicate with road users." A proposal has been submitted to the relevant standardisation committee and discussions are ongoing.

Nationwide insights, made in Hamburg

The 'Simulation and Scenarios' sub-project brought together the technologies from the various sub-projects at the RealLab Hamburg, looked at the findings that emerged, the impact that these could have on traffic and the environment in future and how these results can be applied to other cities. "We determined the status of the modes of transport involved before the research, compared this with their status after the measures were introduced and then extrapolated the results to the entire metropolitan area," explains Peter Wagner of the DLR Institute of Transportation Systems. "This gives us a good overview of what could be achieved if the technologies were used throughout the city in the long term." The researchers used a simulation developed at TU Berlin for this purpose.

They concluded that the technologies investigated at the RealLab Hamburg improve the appeal of public transport and may lead to an increase in the number of people forgoing their own car of around 12 percent. The ideas arising from the RealLab Hamburg can also easily be transferred to other cities of a certain minimum size. Some measures introduced during the project have already proven their worth, such as the shuttle service in Ahrensburg where the municipal authorities have opted to continue with the programme. Nevertheless, Wagner is keen to stress that "even stronger measures, such as a redistribution of urban space in a way that is unfavourable to private cars could lead to as many as 33 percent of people in city centres forgoing private cars to travel by bike or bus instead." This can be achieved

through measures such as increasing parking fees and converting traffic lanes into cycle paths and footpaths. "In the end, what matters most is achieving the right balance of making alternative mobility options more attractive, while reducing the appeal of private vehicles."

Jasmin Begli is Communications Officer for the Hamburg, Braunschweig, Cöchstedt, Stade and Trauen sites.

ABOUT THE PROJECT

Duration:

2020 to 2021

Research sub-projects:

- Mobility platform
- Data interaction and sovereignty
- Mobility budget
- Autonomous driving
- On-demand in rural areas
- Goods mobility microdepot
- Networked vulnerable road users
- Digital St Andrew's Cross
- Dialogue strategy
- Service design and simulation

Partner organisations:

BMW, Continental Automotive GmbH, DB Connect, Deutsche Bahn, DEKRA Automobil GmbH, DLR, EasyMile GmbH, Fraunhofer Institute for Open Communication Systems, Free and Hanseatic City of Hamburg, Hasso Plattner Institute for Digital Engineering gGmbH, Hermes Germany GmbH, ioki GmbH, Kreis Stormarn, KVG Stade GmbH & Co. KG, District of Harburg, SAP AG, S-Bahn Hamburg GmbH, Siemens Mobility GmbH, Sixt GmbH & Co. Autovermietung KG, Stadt Ahrensburg, Süderelbe AG, Swarco Traffic Systems GmbH, Technische Universität Berlin, Technische Universität Hamburg, Technische Universität München, T-Systems International GmbH, Urban Software Institute GmbH, Verkehrsbetriebe Hamburg-Holstein GmbH, Hamburger Hochbahn AG, International Data Spaces Association, Rewe digital GmbH.



In one sub-project, a level crossing was equipped with V2X communication technology – similar to WLAN. This informed road users about possible waiting times.



Hanging Gardens Interactive

The music adventure 'Sonority' is one of 370 funded game developments

GAME ON

370 projects benefit from the German federal government's funding programme for the national games industry

In conversation with Matteo Riatti

Computer games are now an integral part of many people's everyday lives. According to the 2021 annual report of the German Games Industry Association, 58 percent of people aged 6 to 69 now use a PC, console or smartphone to immerse themselves in the digital world, at least occasionally. Like films, books and theatre plays, this medium has evolved into a cultural asset that is recognised in policy. Since 2019, the German Federal Ministry for Economic Affairs and Climate Action (BMWK) has been running a funding stream for computer games, managed by DLR Projektträger. To gain insight into this growing sector, we talked with Matteo Riatti, Head of the Computer Games/Creative Industry Department, part of the Society, Innovation and Technology Division at DLR Projektträger.

Dr Riatti, the German government spends 50 million euros per year to promote the gaming scene. Why?

Germany is the world's fifth-biggest market for digital games, but until recently the domestic computer gaming scene has been somewhat neglected. The country creates just five percent of the new titles that come out every year. The federal government is now trying to correct this imbalance.

What has the funding initiative achieved so far?

It has given the industry an incredible boost. Of the 370 or so games that have received funding from DLR Projektträger, more than 200 are now ready and nearly a dozen are added every week. There is hardly a German game developer out there that has not applied for funding. Many small studios owe their very existence to this funding. It is the reason they have been able to try things out, develop new game mechanisms or reinvent existing ones.

Matteo Riatti

is a media scientist and holds a PhD in computer game aesthetics and narratives. He heads the Computer Games/Creative Industry Department in the Society, Innovation and Technology Division of DLR Projektträger.



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Can you give an example?

Oh, there are loads of them. Take Sonority, for instance: this innovative adventure game designs puzzles based on musical harmonies and has been nominated for the German Computer Game Award two years in a row. In fact, even if studios receive funding, we do not necessarily expect them to create their game entirely on their own. Norwegian developer Funcom is currently working on a multiplayer online game for the science fiction film Dune. Hanover-based studio Nukklear is also involved, so the project benefits from federal government funding via us as the project sponsor. Nukklear's sole task is to design the vehicles and calculate their physical properties. Their findings could be used for the benefit of future titles or even in tie-ins with other industries. In other words, we are investing in the future at the same time.

How do you find working with computer game development companies?

Most applicants are dealing with funding applications for the first time, so it is not always easy for them. As project promoters and advisors, we are happy to help them. After all, we understand the requirements of the games industry, which is very new in many aspects, and the steps required to obtain funding. Our team is made up of employees who all have a real love of computer games, and some of whom have been professionally or academically involved in the games industry. As such, we really enjoy liaising with studios and development teams, especially when they use our consulting services again and again. When the funding measure was first announced, some industry representatives were sceptical about our role in the process, especially as the bureaucratic procedures we need to abide by caused some frustration. Since then, however, we have won them over with our expertise and dedication.

How do you think the industry will position itself over the medium and long term?

I do think that the computer gaming industry will keep growing over the coming years. After all, in its coalition agreement, the new federal government confirmed that it will carry on with the funding, so the studios have some certainty for their planning. There is also a lot going on in the field of eSports at the moment. Digital tournaments attract enough spectators to fill entire arenas and achieve ratings that many Bundesliga clubs could only wish for. Although eSports players in Germany lack the status that they enjoy in Scandinavian or Asian countries, things are looking up. In Berlin, for instance, there is increasingly talk of recognising the non-profit status of eSports. That would mean a huge boost for sports clubs, which could finally incorporate one of the most popular hobbies among young people into their output.

What is the role of DLR Projektträger in all this?

We are currently the only project management agency in Germany that deals with the topic of computer games. That is undeniably a unique selling point. We have the contacts, the expertise and the will-power to strengthen and expand this segment. It could be that we will expand into the education sector, for instance, or promote networking with other sectors, as I mentioned earlier. Most importantly, we can ensure sustainability, both culturally and technically, and we can establish new ways of storytelling and innovative approaches in certain fields such as gameplay mechanics and game design.

This interview was conducted by **Thomas Kölsch**, a freelance writer working in corporate communications on behalf of DLR Projektträger.

ABOUT DLR PROJEKTTÄGER

As one of Germany's largest project management organisations, DLR-PT has been a service provider committed to a strong research, education and innovation location for almost 50 years. Its clients include Federal and State Ministries, the European Commission, science organisations, associations and foundations. It advises on strategies and programmes, manages accompanying dialogue processes, plans and takes over the implementation of funding programmes such as the federal government's computer games funding programme mentioned here, supports knowledge transfer and evaluates the impact of its clients' programmes and initiatives. DLR Projektträger covers the broadest range of topics of all German project management organisations. Their spectrum reaches from education and equal opportunities to health, society, innovation, technology, environment and sustainability, as well as European and international cooperation.

This enables them to offer every service in an interdisciplinary and transdisciplinary manner. The competence centres for science communication, public relations, and analysis and evaluation round off the professional services offered by its divisions. DLR-PT is a central pillar of DLR and complements its scientific orientation.



Expanding focus

The computer game Utopia Tower Endgame is an economic simulation. The goal is to design an ecosystem optimised for Earth and its inhabitants.

FROM THE ARCHIVE

DLR's Central Archive is home to over 50,000 documents, with some real treasures buried among them. This series of articles searches for clues amid the wealth of images, documents, records and articles to root out such gems. In this issue, we are looking at the turbulent history of Germany's DVL aeronautics laboratory, one of DLR's predecessors.



Propeller test stand at the DVL (around the decade 1910)

FROM AIRSHIPS TO AEROPLANES

A new research institute that sought to make German aviation competitive in 1912

by Jessika Wichner

If you pay a visit to DLR's site in Berlin-Adlershof, the walk from the S-Bahn station will take you on a stroll through contemporary history. Nestled among the research institutions, university building and hotels, you are certain to spot two unusual concrete structures. Go back almost a century, and aircraft models were already being tested in the large wind tunnel and aircraft spin tests were being conducted in the vertical wind tunnel known as the 'Trudelturm'. Back then, these research facilities were part of the German Aviation Research Institute (Deutsche Versuchsanstalt für Luftfahrt; DVL), one of DLR's predecessor organisations. The DVL was founded to position Germany at the forefront of aircraft development.



Flight tests for planes – Johannisthal airfield in the immediate vicinity of the DVL.

When the DVL was founded on 12 April 1912, aircraft development was still in its infancy. At that time, Germany was primarily focused on airships, the first of which had been developed by Count Ferdinand von Zeppelin. They had been considered a promising means of transport since the inaugural flight in 1900. Meanwhile, countries like France and the United Kingdom were concentrating on developing aircraft and their engines, leaving Germany trailing behind in this area. German pilots barely featured in international flying competitions.

At a board meeting of the Deutsches Museum in Munich on 28 September 1909, Count Zeppelin suggested setting up a large research institution for the scientific study of both airships and aircraft. He suggested his hometown of Friedrichshafen as a possible location on the grounds that his airship construction yard was already located there, while Lake Constance would provide an excellent training place for airships.

An idea takes shape

His proposal made it all the way to the Reichstag, where it was the subject of intense discussion. The majority of the members believed it necessary to create a higher-level State Research Institute for Aviation, but three experts were asked to give their opinion before the final decision was made. These experts were Hugo Hergesell, Director of the Alsace-Lorraine State Meteorological Institute in Strasbourg, Ludwig Prandtl, who headed the Institute of Model Testing of the Motorised Airship Study Society (MVA) in Göttingen – another of DLR's predecessors – and Friedrich Bendemann, Head of the Aeronautics Technology Office in Lindenberg. All three concluded that establishing

an interregional research institute would expedite making Germany competitive again in aircraft development. Nevertheless, they feared that an institution with state endorsement could restrict academic freedom. As such, they suggested founding a registered association based on the model of the MVA.

The Reichstag agreed with this assessment. Now all that was left was to find a suitable location. While Friedrichshafen had undeniable advantages in terms of airship development, the Reichstag ultimately opted for Berlin-Adlershof, settling on a site adjacent to the Johannisthal airfield. The airfield was set up in 1909. Soon after, all of Germany's major aircraft manufacturers relocated there and Johannisthal became the centre of the German aviation industry.

A state prize provides an incentive

On 27 January 1912, the birthday of Kaiser Wilhelm II, a contest to award the Kaiser Prize for the best German aircraft engine was announced to promote advances in German aviation. Three months later, the DVL was founded and tasked with organising the contest. The winners were to be decided upon before the Kaiser's next birthday. This was the catalyst, and by October 1912, five engine test stands had been set up in Berlin-Adlershof to assess the aircraft engines submitted for the contest. The winning entry was a four-cylinder Benz FX engine from Mannheim-based company Benz & Cie., today known as Mercedes-Benz Group, which came away with 50,000 Deutschmarks in prize money.

By the end of the Second World War, the DVL had developed into the largest aviation research institute in Germany. After the end of the war, it was closed by the Russian occupation forces. Most of the research facility was dismantled and shipped to the Soviet Union, but parts had been relocated from Berlin to southern Germany during the war, so these were in the American occupation zone. In 1949, the occupying power released them from US control. As the Allies had not liquidated the DVL as a registered association, there was nothing to stop it being reconstructed in West Germany. Its new lease of life began in Essen-Mülheim in the 1950s.

So today, a trip to the DLR site in Adlershof is not only associated with research for tomorrow, but also with yesterday's knowledge.

Jessika Wichner heads the DLR Central Archive in Göttingen.



The DVL site in Berlin-Adlershof (around the decade 1910).



Even the façade of Futurium is futuristic. The DLR Systems and Control Innovation Lab calculated the maximum wind load of the individual elements on the dynamic sculpture at the entrance.



Inside, it is all about the future and how we want to live; outside, the Berlin of the present awaits.

HOW DO WE WANT TO LIVE?

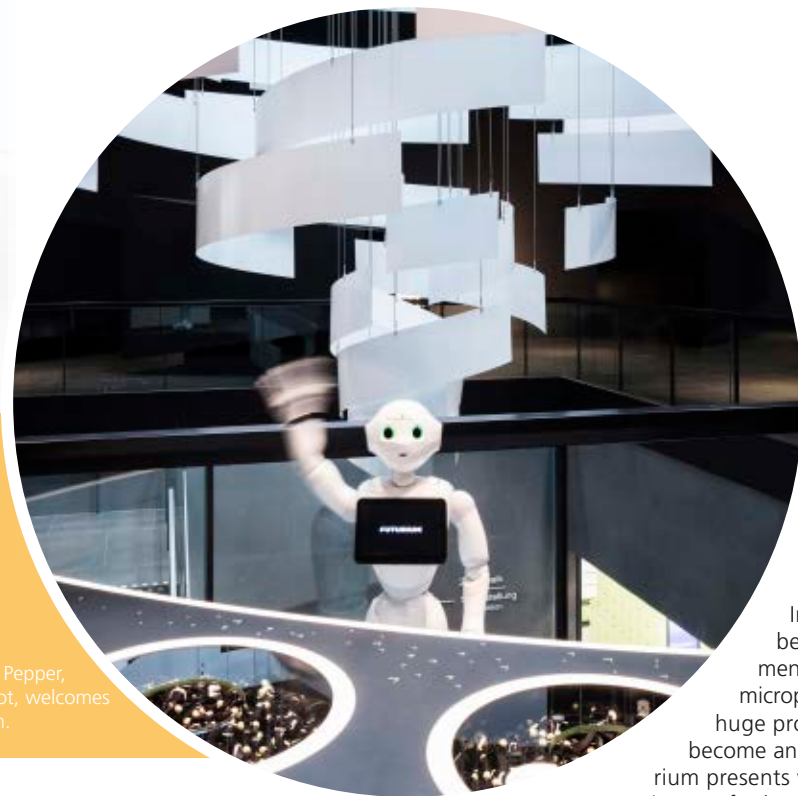
A visit to Futurium

by Anja Philipp

Anyone visiting Futurium and expecting to see Emmett Lathrop Brown – ‘Doc’ – tinkering with his DeLorean so that he can travel back to the future will be disappointed. Similarly, if what you are looking for are predictions of your own future, you will not find them here. Futurium is much more: Berlin’s ‘House of Futures’ shows us different scenarios of what tomorrow’s world could look like.

Sitting on the banks of the Spree just a stone’s throw from the Government District and Berlin’s main railway station, Futurium makes a striking first impression, with huge panoramic windows that connect the present-day life unfolding on the street with the potential futures that lie within. The eye-catching façade comprises 9000 cassette

panels made of folded stainless steel reflectors and ceramic-printed cast glass that change with the light and merge the building with the outside world. As you step inside, a futuristic backlit metal grid on the ceiling sets the stage for your visit as you embark on a fascinating tour of what the future might bring.



A warm welcome: Pepper, the humanoid robot, welcomes visitors to Futurium.

We begin with the ‘Great acceleration’. Thought-provoking from the outset, this space shows how we have reached our present-day prosperity and living conditions. Yet relentless consumption, digitalisation and globalisation have also delivered negative results such as climate change. People want to protect their living standards and are increasingly interfering with nature. But will this continue in the future?

Living with nature

In the ‘Nature’ thinking space, it quickly becomes clear that the focus is on environmentally friendly alternatives. Plastic waste and microplastics are now widely acknowledged as a huge problem for the environment. Plastics have become an indispensable part of our lives, but Futurium presents ways of meeting people’s needs without causing any further harm to nature.

Ready, set, go

Right at the start, visitors are greeted by Pepper, a friendly humanoid robot who explains how to navigate the exhibition: simply hold up a special wristband to exhibits as you tour the museum and learn about the topics presented. Back at home, you can use the code on the band to log into the Futurium website and access articles with detailed graphics and videos.

Then it is time to decide where to start. The three rooms are individually designed, and there is no set path through the exhibition.

Fishing nets made from algae could prevent plastic ghost nets from floating in the oceans, getting tangled up with sea life. New flip-flops could be made from biodegradable foam, heat-resistant material from orange peel. In fact, all these supposedly futuristic technologies could be possible today and are being researched right now. The question inevitably arises as to why these promising alternatives are not already being used. “They are too expensive to produce,” suggests one visitor. “Perhaps they are not durable enough,” adds another. There is no single answer to this. Left with food for thought, we continue on our way.

Images in this article: David von Becker (unless otherwise stated)

Students at the Technical University of Munich designed the Hyperloop, a transport system that can reach high speeds thanks to its contactless levitation and propulsion system.



berlin-event-foto.de

We do not just need new alternatives for plastics. Sustainability is also about durability. Who hasn't experienced a device breaking down just after the warranty expires? Do we really need to constantly buy new devices and appliances, or can their longevity also be improved? Several factors play a role here too. A Futurium guide notes the role of political will: legal requirements could be introduced to ensure devices have a long life.

The 'Natural talents' section shows where nature can act as a model. For example, the tubular inner structure of bone could be applied to aircraft construction to create more robust components; 3D printing could be used to produce components, provided larger and faster printers are developed.

Further along, the museum examines how we will live and what we will eat. Among the exhibits are (unusual) materials that could be used to construct new buildings – bamboo or even certain types of fungi could be used as alternatives to concrete or steel. In visions of an urban world, people and nature coexist, without cars and with sophisticated public transport systems. Vegetables could be grown on rooftops, and life could be greener if grey concrete surfaces were rethought. Confronted with the question of whether we could imagine eating insects instead of meat, our tour group reacts cautiously. Opinions

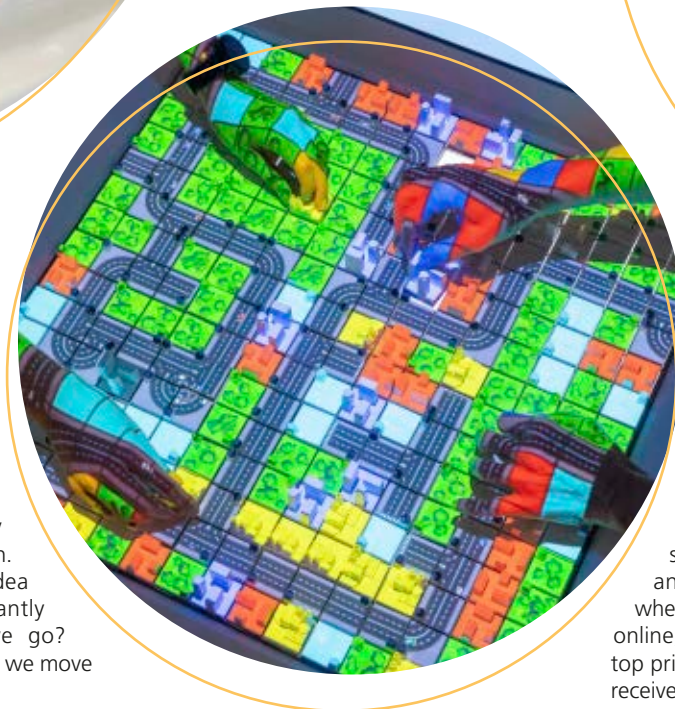
are divided, although insect consumption is not uncommon in many parts of the world. Breeding and eating them would be much more climate friendly for the growing world population. Why do we struggle with this idea and cling to our habit of constantly consuming meat wherever we go? Reflecting on our own behaviour, we move on to the next room.

What impact do modern technologies have?

Films often shape our idea of the future, whether it's Marty McFly's hoverboard or Scotty beaming the crew to a planet. Of course, these technologies belong to the realm of science fiction, but life is speeding up inexorably, and technology is playing its part.

It is hard to deny that machines are taking over a growing number of tasks from humans. They assemble cars and perform operations. However, this progress has also encountered criticism; it is not always foreseeable how great the effects on our lives will be. The world of work, in particular, is in a constant state of flux due to digital technologies; yet digitalisation also offers considerable potential, especially in the care sector, as the 'Technology' thinking space in Futurium shows. Robots could fill the gap between the needs of an ageing society and the insufficient supply of care caused by a shortage of skilled workers. They could carry out activities to facilitate people's everyday lives where assistance is needed. The only question is to what extent personal contact can be substituted. Will we also replace humans in relationships at some point and love a humanoid robot, as portrayed in the film 'I'm Your Man' by Maria Schrader? Here again, the group is divided.

The sculpture Noosphere reacts to movement with sounds, light and vibration.



In the world of tomorrow, ever more data will be collated and processed. Online shopping is part of present-day life. Products that might interest us are suggested to us. Huge volumes of data are processed to encourage us to consume. But where do we draw the line? What personal information should artificial intelligence be allowed to access in order to analyse our behaviour? We now have the first supermarkets where cameras and sensors document purchases – payment is made online; cash registers are superfluous. Even if data protection is the top priority, the cameras constantly observe shoppers who will then receive a digital receipt, expanding our digital footprints still further.

People and their consumption

The space where our tour ends is set up like a village. Twelve small houses are dedicated to different themes, and the village square provides visitors with the opportunity to exchange ideas or go on the swings – the latter is extremely popular, of course.

In one of the houses, everything revolves around our increasing consumption. Many products have travelled a long way – clothes from India, shoes from China or bags from Bangladesh. This is not very environmentally friendly, not to mention the often-precarious working conditions of those who produce these goods. If you want to protect the climate, you can opt for fair trade clothing, which is also better quality and more durable. Appliances and devices can also be repaired instead of thrown away. This is one way in which we can reduce consumption and protect the climate.

Meanwhile, a series of pictures on the wall of the neighbouring house prompts us to think about what



Even the youngest visitors can try out all kinds of activities at Futurium

Visitors are presented with different perspectives that encourage them to think about and discuss the possibilities of the future.

THE FUTURIUM IN BERLIN

Alexanderufer 2, 10117 Berlin

Admission:
Free

Opening hours:
Mon, Wed, Fri, Sat, Sun: 10:00–18:00;
Thur: 10:00–20:00

[Futurium.de/en](https://www.futurium.de/en)

we could do without in order to live in a more environmentally friendly way. With yellow sticky dots, visitors can mark the things they don't need in their everyday lives. Do I really have to travel by air? Do I actually need a car? Or a mobile phone? And how important is fast food? Ultimately, these all are luxuries that are not essential to life.

Futurium invites you to take a journey of discovery, experimenting and discussing your ideas. "How do we want to live?" is the guiding question running through the exhibition. The museum showcases the potential of research and innovation in order to stimulate thought and discussion, inviting us to reflect on our own behaviour and question the bigger picture. Climate change, the unsustainable consumption of resources and the growing population are central themes. While these topics are frequently the subject of media coverage, Futurium shows visitors a range of alternatives that can be used to overcome these enormous challenges. Time will tell which future scenarios become our present. As Emmett Brown 'Doc' said, "The future isn't written. It can be changed." And he is right!

Anja Philipp works in communications for the DLR sites in Berlin, Neustrelitz, Jena, Dresden, Cottbus and Zittau.



AIR ON THE MOVE

How does air flow around an aircraft? And how can we investigate what is happening? This is difficult to do on a flying object, of course. But what if it is not the object that is moving through the air, but the air around the object? This is the basic idea behind a wind tunnel.

Early aerodynamic investigations are thought to have been conducted back in the 15th century. These led to the realisation that the shape of a body has an effect on its drag, regardless of whether it is moving through air or water. In the mid-17th century, hydrodynamic studies provided a sounder scientific footing for such findings, but it took until the second half of the 19th century for the first usable wind tunnel to be built, in Great Britain. Aviation was the driving force behind this development, but aerodynamic properties also played an increasingly important role in the development of rail, road and water vehicles and the design of bridges and buildings. Countless wind tunnels were built in many places around the world prior to World War I. Such systems were constructed in ever greater dimensions up until the 1950s and 60s, when they reached their performance limits.

Since then, more and more high-speed wind tunnels and specialist facilities have been created for purposes such as examining the effect of airflow on the acoustic or climatic properties of bodies. In addition, measurement technologies are becoming increasingly sophisticated, while digital models of the flow properties of bodies are being developed. Despite digitally acquired knowledge, however, testing in wind tunnels is still an essential part of the development of all manner of vehicles, structures and even sports equipment.

Although wind tunnels are among the most vital research tools out there, such facilities are usually enormous, and their purpose is not evident from the outside. Nonetheless, the superb team of authors behind the book **Windkanäle – Der Orkan in der Röhre** ('Wind Tunnels: The Hurricane in the Tube') (German only) manages to pique our interest with the cover photograph and title alone. Following a brief historical overview of developments on the international stage, it delves into aerodynamic research in Germany, before another chapter on wind tunnel designs and components. Specific facilities and research projects in Germany up to 1945 are presented in detail in the main section.

The final chapter focuses on developments in Germany during the post-war period. Besides the facilities at well-known locations in West Germany, the book also covers the only wind tunnel in the former East Germany, which was built during a brief phase of aircraft construction from 1955 to 1961. It concludes with a brief outline of expectations for the future. The well-researched text is perfectly complemented by the excellent historical photographs. My only criticism would be the quality of some of the more recent photos, which are no match for the historical ones.

Heiko Triesch



MAKING IT TO THE MOON

In light of NASA's plan to send the first woman to the Moon in the 21st century, it's important to remember that this could already have happened.



The documentary **'Mercury 13'** (2018) tells the inspiring story of 13 female pilots who underwent rigorous astronaut screening tests in the late 1950s / early 1960s in tandem with the first astronauts of NASA's space programme.

William Randolph Lovelace II, the physician and NASA advisor who devised the astronaut tests for the men, conducted an independent study with women to prove they could be considered for spaceflight as well. This group of smart and savvy pilots were poked and prodded just as the men. Dr Lovelace discovered that 13 of the 26 participants fit the criteria and in certain cases even surpassed the men, for example when spending time in the sensory deprivation tank.

The study was shut down as soon as NASA got wind of it and despite presenting the case to Congress, the programme was not allowed to continue. "A woman astronaut – how ridiculous." Undeniably, these women, who were just as, if not more capable than the men, were unjustly denied access to space.

Despite this sad truth, the documentary shines a deserved spotlight on these incredible women, most of which had remarkable careers as pilots and continued to be trailblazers and an inspiration to women around the globe. When the first woman finally walks on the Moon, we should all raise a glass to them – the Mercury 13.

Sara Kehrer

RETURN TO SPACE

SpaceX has quickly become a key player in space launches, a role further cemented as they've stepped up to replace Soyuz as a launch vehicle for private and public organisations in 2022. So, the new documentary film **Return to Space** seems to be released at a particularly opportune time. It tracks the development of SpaceX's Dragon spacecraft, with a particular emphasis on its first successful crewed mission to the International Space Station in 2020.



Return to Space is fundamentally a human film. Its narrative is focused on people, with discussion of the scientific or engineering challenges of space launches as background support. It features a variety of key SpaceX staff, including CEO Elon Musk, as well as astronauts, current and former NASA administrators, and YouTuber Tim Dodd (better known as the Everyday Astronaut). These interviewees are, without exception, passionate about human spaceflight. They are sincere while discussing the future of humanity as a spacefaring, interplanetary species and joyful while geeking out looking at historical spacecraft. Watching key events alongside them and sharing their hopes and fears brings the story to life.

Where the film is somewhat lacking though, is in its almost myopic focus on SpaceX. Despite the goal of returning to the Moon and journeying on to Mars, NASA's Artemis programme is never discussed by any of the interviewees. Instead, the focus is on the past, especially the Apollo and Space Shuttle programmes. While those examples provide useful context on both the risks and rewards of crewed spaceflight, it does nothing to place SpaceX within the larger aerospace field. All this said, an authentic behind-the-scenes experience with the people behind SpaceX is valuable. That, combined with the refreshingly optimistic tone makes it an enjoyable watch, even if it is a bit incomplete.

Sarah Leach

RECOMMENDED LINKS

KURZGESAGT – IN A NUTSHELL

[youtube.com/user/Kurzgesagt](https://www.youtube.com/user/Kurzgesagt)

This great science YouTube channel explores many aspects of science and technology in its attempt to "explain the Universe and our existence, one video at a time." The subjects are incredibly varied. The videos are very educational and fun. Be warned however, that once you watch one, you might want to watch them all!

PEOPLE-POWERED RESEARCH

www.zooniverse.org

Welcome to the Zooniverse, a place where you can discover, teach and learn! Here, everyone is able to take part in actual groundbreaking research projects. The Zooniverse creates opportunities for you to unlock answers and contribute to real discoveries in many fields across the sciences, humanities, and more. If you want to help further science, from wherever you are, become a volunteer today!

THE WORLD AWAITS

arvr.google.com/earth/

Could you imagine going for a stroll in Paris, Tokyo and New York, all on the same day? It's now possible thanks to Google Earth VR. It lets you explore the world from totally new perspectives. The entire planet is now within your reach. What will your first destination be? Put on your headset and go! This app is available on Vive and Oculus.

STAY CONNECTED

www.esa.int/ESA_Multimedia/ESA_Web_TV

From a selection of dazzling imagery from space, to the launch of an astronaut to the International Space Station, or a return to Earth, ESA Web TV has it all. The 24 hour European Space Agency stream offers programmes on European space activities in a variety of languages. The ESA programming schedule on Web TV is updated periodically.

PIONEERING AEROSPACE #ILA2022

www.ila-berlin.de/en

ILA Berlin showcases Aerospace as a key sector in the EU and its strategic importance for Europe's security, sustainability and competitiveness. At ILA Berlin, the focus is the future. The international trade fair brings together the global space community, and provides a platform for the defence industry and military to show how they protect countries. Take a look at what this year's International Berlin Airshow will bring!

LEARNING FROM REAL SPACE MISSIONS

www.jpl.nasa.gov/edu/

Want to learn while having fun? Fancy building a Mars rover or playing a space board game? The JPL education page offers great activities for schoolteachers and parents alike. These hands-on lessons approximate the work of NASA scientists, engineers and astronauts and make use of actual NASA satellite data.

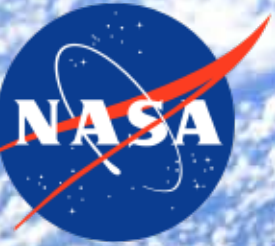
Cover image

Engines are the heart of aircraft propulsion systems. At DLR, they are put through their paces – digitally on a computer and in real life on test rigs such as the Multistage Two Shaft Compressor Test Facility (M2VP) at the Institute of Propulsion Technology in Cologne. As in many areas, the importance of simulations is also increasing in research. In aviation, for example, DLR researchers are developing a platform on which they are testing new concepts and ideas for virtual engines.



DLR

Deutsches Zentrum
für Luft- und Raumfahrt
German Aerospace Center



MEHR ALS 20 JAHRE FORSCHUNG IM FREIEN FALL | MORE THAN 20 YEARS OF RESEARCH IN MICROGRAVITY

Die Internationale Raumstation ISS ist ein fliegendes Labor mit exzellenten Möglichkeiten für anwendungsnahe und Grundlagen-Forschung. In Schwerelosigkeit gewinnen wir einzigartige Erkenntnisse von Astrophysik über Materialforschung bis hin zu Psychologie und Medizin. Auch astronautische Explorationsmissionen werden hier vorbereitet. Nicht zuletzt ist die ISS ein Innovationsmotor für neue Technologien wie Laserkommunikation, Robotik oder Sensorik. Seit dem Jahr 1998 umrundet sie unsere Erde in 400 Kilometern Höhe mit einer Geschwindigkeit von etwa 28.000 Kilometern pro Stunde. Aktuell hat sie eine Masse von rund 420 Tonnen. Die Crew an Bord hat mit rund 1.000 Kubikmetern etwa so viel Platz wie in einer Boeing 747.

The International Space Station ISS is an orbiting laboratory that offers excellent opportunities to conduct fundamental and applied research. In microgravity, we gain unique insights, from astrophysics and materials research to psychology and medicine. In addition, preparations for future crewed exploration missions are conducted here. The ISS also drives innovation for new technologies such as laser communications, robotics and sensor systems. The ISS has been orbiting Earth since 1998 at an altitude of 400 kilometres at a speed of about 28,000 kilometres per hour. In its current form it has a total mass of around 420 tonnes. Its residents live in a space of around 1000 cubic metres, about as much room as on a Boeing 747.



Aufbau der ISS | Development of the ISS

Stand März 2022 | As of March 2022

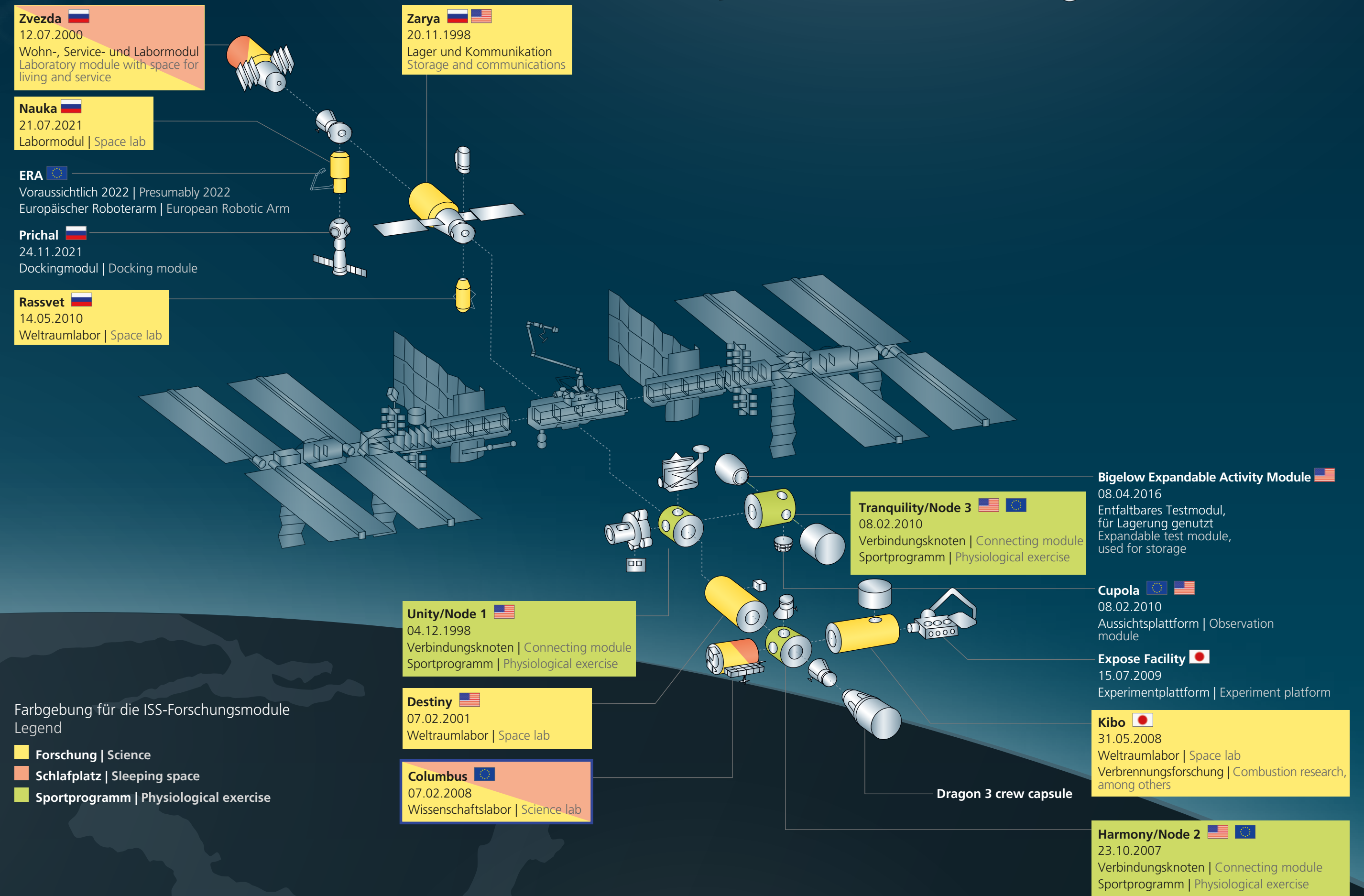


Bild Vorderseite: Der deutsche ESA-Astronaut Matthias Maurer bei seinem Außeninsatz am 23. März 2022. Zusammen mit seinem NASA-Kollegen Raja Chari reparierte er das Kühlsystem der Raumstation. Zudem tauschte Maurer eine Kamera an der großen Auslegerstruktur der Station. Abschließend machte er die kommerzielle Außenplattform Bartolomeo am Columbus-Modul der ESA betriebsbereit.

Front image: German ESA astronaut Matthias Maurer during his extravehicular activity on 23 March 2022. Together with his NASA colleague Raja Chari he repaired the space station's cooling system. Maurer also replaced a camera on the station's large boom structure. Finally, he made the Bartolomeo commercial external platform on ESA's Columbus module ready for operation.