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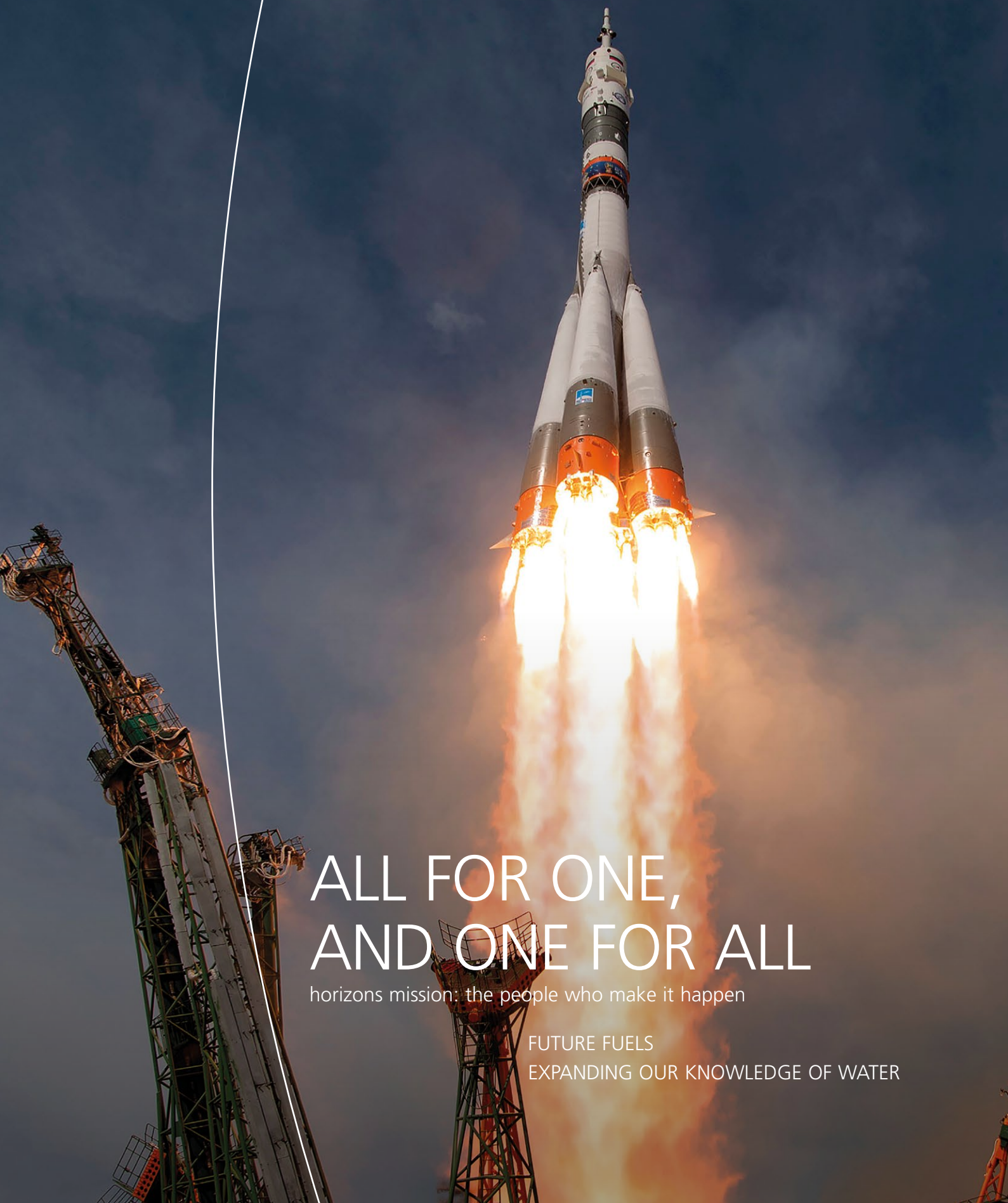

ALL FOR ONE, AND ONE FOR ALL

horizons mission: the people who make it happen

FUTURE FUELS

EXPANDING OUR KNOWLEDGE OF WATER

DLRmagazine 158

Dear readers,

To borrow a phrase from Alexandre Dumas: "All for one, and one for all." This motto helped the Three Musketeers to muster their courage when embarking on special missions. Flying to a space station and serving as its commander is something very special indeed. However, this issue of the magazine is devoted not so much to the heroes who make the headlines as to the people who work behind the scenes to make sure that the mission of Alexander Gerst and his crew runs like clockwork. This is a task that carries the utmost responsibility. Courage may not be the most important requirement here, but meticulousness and a sense of responsibility are absolutely essential – the astronauts bring the courage. Nowadays, people often overlook the fact that leaving planet Earth and, not only living in space under extreme conditions, but also carrying out demanding scientific work there is a real challenge – a word that is somewhat overused but in this case is perfectly apt.

Working together to achieve a common goal is just as important, albeit less outwardly adventurous. In order to meet the challenges (yes, we at DLR are at home with this term) that society is facing in terms of energy supply, climate change and digitalisation, standalone solutions are no longer sufficient. We need to take a broader view and bring together different areas of expertise. That is exactly what DLR's cross-sectoral projects are for. This issue presents one such project, Future Fuels.

Company founders also need a certain amount of courage as they embark on their personal mission. The company EOMAP provides water information based on satellite data. To follow a new path is one thing, but to really assert oneself within the market is something quite different. If one wants to be successful as a founder, one must do both. Thomas Heege, CEO of the company, which was spun off from DLR in 2006 and now has 20 employees, is familiar with this.

If you are looking for ideas for your summer holiday, how about a completely new kind of mountain experience with a trip to the Matterhorn in the Gasometer in Oberhausen; or perhaps a visit to the Rosetta exhibition in Vienna or an excursion to Ars Electronica in Linz? You will come across DLR in all sorts of places.

We wish you a pleasant summer, wherever you may be.

Your Magazine editorial team

Image: Christoph Otto for DLRmagazine

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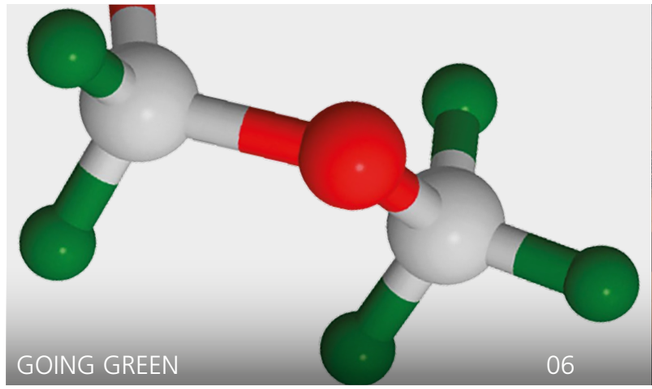
COOL: TINA STÄBLER 40



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WHEN THE FOG ROLLS IN 28

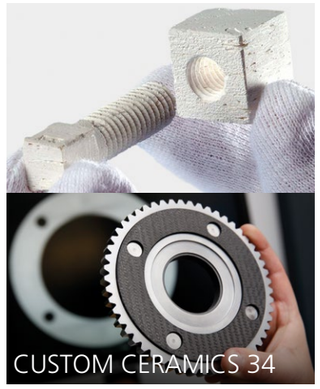

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Image: Ars Electronica

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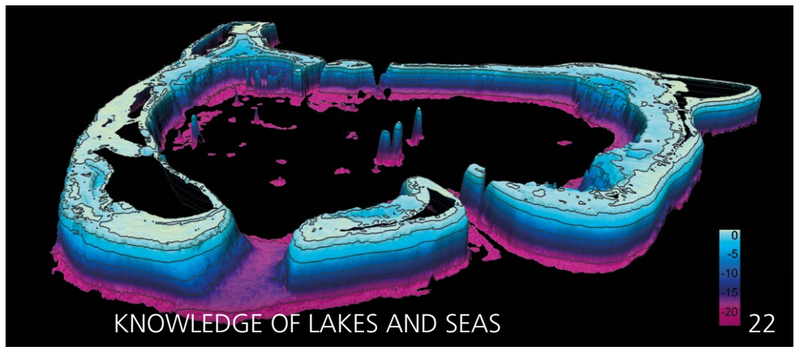

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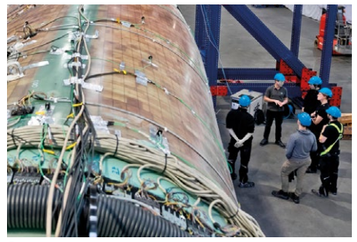
TEST METHOD FROM AVIATION IMPROVES WIND TURBINES

500 sensors measure vibrations directly on the rotor blade



Rotor blade with sensors for measuring vibration behaviour

DLR scientists have fitted 300 acceleration sensors and 200 strain sensors directly onto a wind turbine rotor blade. The data they record enables logging of the deformation in the rotor blade with millimetre precision; this is then compared with a simulation model. This provides them with information about the vibration behaviour of rotor blades to an unprecedented level of accuracy and quality.

The tests were carried out as part of the SmartBlades2 research project at the Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) in Bremerhaven. In the project, which is funded by the German Federal Ministry for Economic Affairs and Energy (BMWi), research institutions are working with industry partners to develop technology for larger and more powerful wind turbines. In the experiment, an electrodynamic vibration exciter pulls and pushes at the 20-metre SmartBlades Demo-Blade with a force of 100 kilograms. The rotor blade oscillates with a deflection of 50 centimetres at the tip. Scientists analyse these movements, taking all material loads within the rotor blade into account. The method comes from the field of aviation and was developed at the DLR Institute of Aeroelasticity in Göttingen for ground vibration tests on prototype aircraft. The structural dynamics are measured there.

The rotor blade from the Center for Lightweight-Production-Technology (ZLP) in Stade stands on the test rig in Bremerhaven. One new feature is the geometric bending torsion coupling. When exposed to wind, the blade not only bends backwards, but also rotates slightly around its axis, allowing the blade to adapt its geometry independently to accommodate the prevailing wind conditions. It does this by turning away from stronger winds and presenting a smaller surface area, automatically reducing the loads acting on the root of the blade.

HEAT STORAGE CONCEPT INCREASES THE RANGE OF ELECTRIC VEHICLES

Test facility for investigating metallic latent heat storage

Using metallic latent heat storage, heat can be stored very efficiently.

With DuoTherm, DLR researchers have developed a concept in which efficient heat storage takes over the heating capacity of an electric vehicle. Fuel-powered vehicles are heated using the waste heat from the engine. Electric cars, conversely, use the battery to both drive and heat the car, which can reduce its range by up to 50 percent. Since electric drives are an important element of a climate-friendly transport system, it is vital to solve the problem presented by this loss of range in winter. The DuoTherm system, which has been developed at the DLR Institute of Vehicle Concepts in Stuttgart and the Institute of Materials Physics in Space in Cologne, in conjunction with Audi AG and ZAE-Bayern, is based on the principle of thermal storage.

Metallic latent heat accumulators, such as aluminium-silicon alloys, have a high energy density and thermal conductivity. They absorb so-called latent or hidden heat during a phase change, for example from solid to liquid, and can release the heat again. One example of this is pocket warmers, which release energy when the liquid inside them solidifies. With a small volume and tiny mass, they store more energy than other types of thermal storage systems and are therefore well suited to space-saving installation in electric cars.

The DuoTherm concept is intended to improve the efficiency of electric vehicles in addition to increasing the range, by absorbing braking energy, reducing charge losses or cooling the battery with an additional high-temperature accumulator. DuoTherm combines high-temperature and low-temperature storage. Thus, waste heat, which is often only generated at low temperatures, can be recovered and stored. This means greater overall efficiency without additional load times. The system is more cost-effective for the producer and end user than a second battery solution.

Image: DLR/Gesine Born

Pascale Ehrenfreund,
Chair of the DLR Executive Board

A NEW WAY OF THINKING IN RESEARCH

By Pascale Ehrenfreund

With its Strategy 2030, DLR has set its sights beyond the consolidation of its traditional areas of expertise, in order to make an even greater contribution towards solving current and future challenges faced by society. These include, for example, digitalisation, the Energy Transition, networked mobility and climate change. What these very different challenges have in common is that they are complex. In addition to scientific and technological issues of various kinds, social, political, economic and ecological aspects must be taken into account.

DLR is in a good position to be able to conduct complex analyses and devise comprehensive solutions. For this reason, we have made a cross-sectoral initiative an integral part of DLR's Strategy 2030. At present, it consists of 10 projects, in which scientists from a wide range of specialised disciplines tackle the aforementioned societal challenges together. The cross-disciplinary area of digitalisation brings together projects relevant to economics, intelligent mobility and cybersecurity, as well as Big and Smart Data.

In the 'Big Data Platform' project we are laying the foundations for analysing the enormous volumes of data generated in almost all areas of research and development, and for deriving knowledge from it as added value. Despite the very different questions being addressed by the specialist disciplines, there are many commonalities between interrelated problems, allowing researchers to support one another in finding solutions. Through its 'Factory of the Future' project, DLR is aiming to make a contribution towards Industry 4.0. Space robotics and cutting-edge robotic manufacturing technologies from the field of aeronautics are being further developed with the help of networks as part of the Internet of Things. This will enable innovative digital production chains in manufacturing, which will also promote safe and efficient collaboration between humans and machines. The 'Transport 5.0' project brings together issues relating to the key challenges of digitalisation and transport. We are conducting intensive research in almost all of the relevant areas – from the technology of individual vehicles to the traffic management of the overall system – all with the aim of creating an automated, highly networked Transport 5.0 system – one that is safe, efficient and environmentally friendly.

In addition to a focus on digitalisation, the cross-sectoral initiative also addresses the topic of energy. Here, too, the strength of our interdisciplinary approach is immediately apparent. The issues being addressed today under the umbrella of the Energy Transition require nothing less than an entirely new way of thinking about our energy system. The energy system of the future will be made up of many decentralised energy producers that do not feed in energy continuously, but rather in a variable manner. This means that the problem of storing energy for use at a later time is gaining in importance. A good example of the new way of thinking that is so urgently needed is the 'GigaStore' project. In tandem with the 'Future Fuels' partner project, 'GigaStore' is concerned with the development of new concepts and types of chemical and thermal energy storage for both the Energy Transition and future mobility. Applying this thinking in a consistent manner with the help of cross-sectoral projects creates invaluable synergies.

Overall, DLR is investing approximately 40 million euro per year in this cross-sectoral initiative. Such interdisciplinary projects are fully supported by the Executive Board, ensuring that they will be implemented and their findings transferred into concrete solutions for the pressing challenges of our time. The boundary between fundamental and applied research is becoming blurred; many projects conduct both at the same time. Space research is an example of this symbiosis – it addresses fundamental and even philosophical questions, such as the existence of life on other planets. Finding answers to these requires the development of numerous technologies: satellites, spacecraft and launchers. Generating knowledge and implementing solutions go hand in hand.

One of DLR's cross-sectoral projects is dedicated to the fuels of tomorrow. An article on this is found in the following pages. It also contains more detailed information about DLR's Cross-sectoral Initiative and a list of all 10 projects.

GOING GREEN

Scientists from 11 DLR institutes are working together as part of the cross-disciplinary Future Fuels project to research the development and application of synthetic fuels. In future, these will replace fossil fuels and play an important role in the sustainable transformation of the energy and mobility sectors.

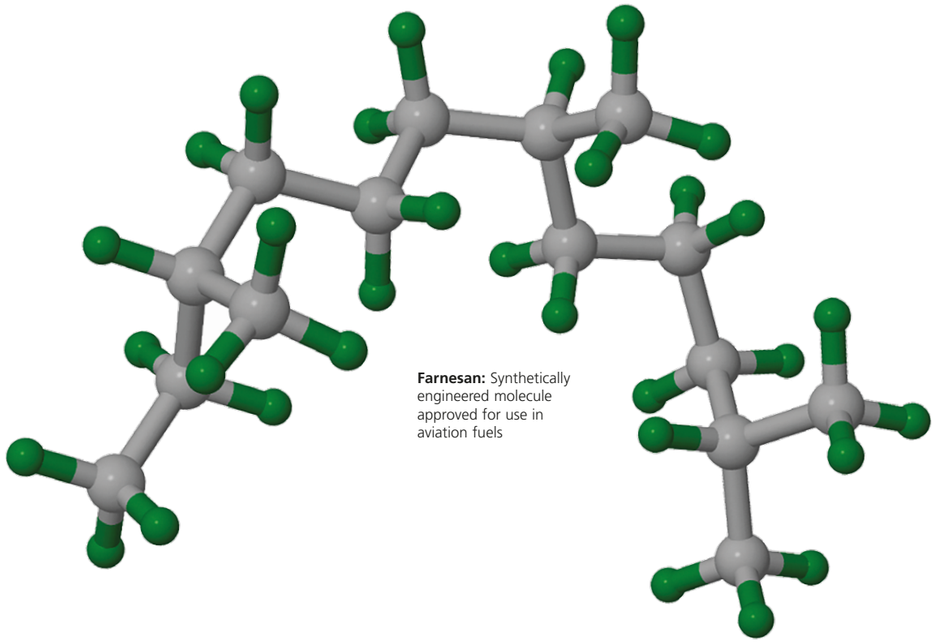
DLR's cross-disciplinary Future Fuels project – 11 institutes work together to create the fuels of tomorrow

By Denise Nüssle

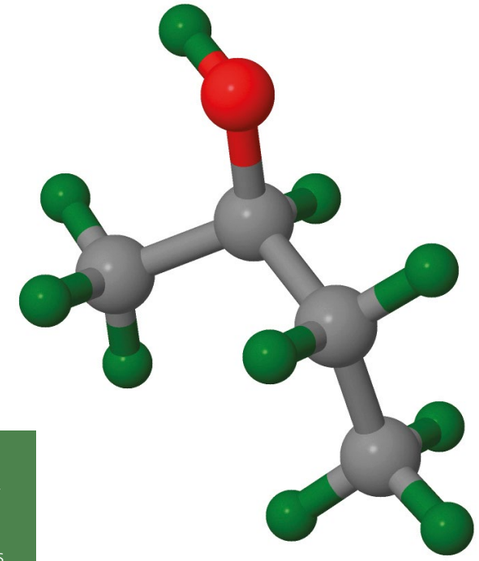
Taking centre stage are C and H – two letters that often appear together. In the periodic table, they are the symbols for the elements carbon and hydrogen – the basic building blocks of all fuels. Both elements are available in essentially unlimited quantities on Earth, in the water, air and biomass. Combining C and H atoms using chemical processes and electrical energy generates liquid hydrocarbons. These form the basis for what are known as future fuels. This term refers to a large number of fuels and propellants that can be used in a wide range of applications and could replace fossil fuels in cars, lorries, trains, ships, aircraft and rockets, as well as for power generation.

Driving the Energy Transition while reducing pollutant and carbon dioxide emissions

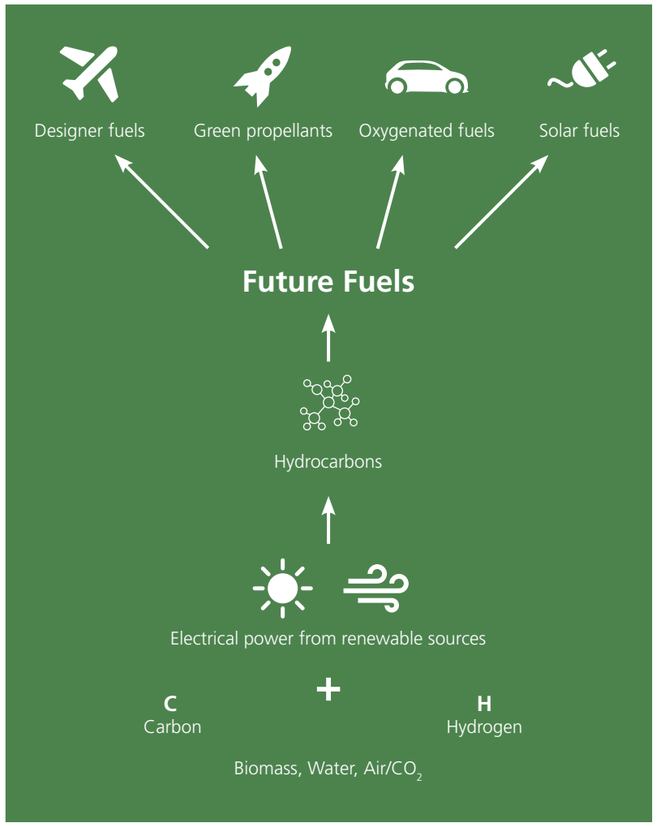
Future fuels store energy easily, flexibly, efficiently and sustainably. With these characteristics, they can make a decisive contribution to successfully implementing the Energy Transition and safeguarding global mobility. "The key challenge is to make future fuels climate-neutral and to design their chemical properties in such a way that they do not produce any – or at least significantly fewer – pollutants such as soot particles and nitrogen oxides," says Manfred Aigner, Coordinator of the Future Fuels cross-disciplinary project and Head of the DLR Institute of Combustion Technology.



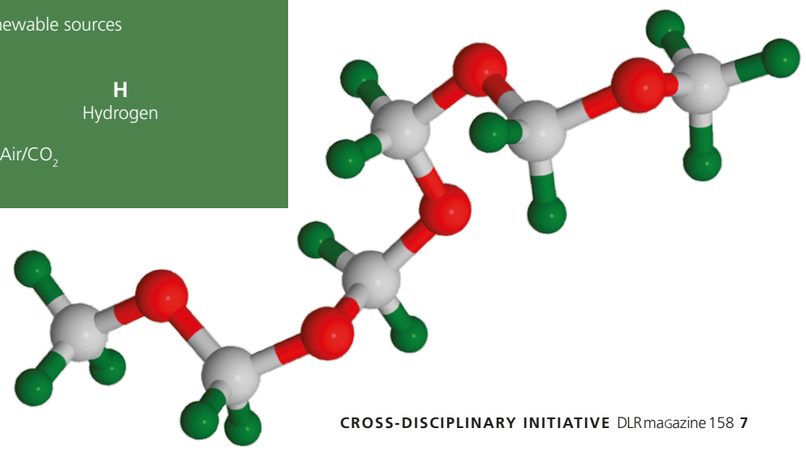
Farnesan: Synthetically engineered molecule approved for use in aviation fuels



2-butanol: Example of an oxygenated fuel; an admixture component for increasing the octane rating of petrol.



Molecular structure of **OME** – a member of the class of polyoxymethylene dimethyl ethers; these can be used as components of diesel fuel or as a complete replacement.



DLR'S CROSS-DISCIPLINARY INITIATIVE

With the implementation of cross-sectoral projects, DLR is exploiting potential synergies and thus generates a technological added value for Germany that goes beyond its existing research areas of aeronautics, space, energy, transport and security as well as digitalisation. The topics of the 10 cross-sectoral projects are:

DIGITALISATION IN THE ECONOMY

- **Global Connectivity**
  Global broadband access via satellite and high-altitude platforms using laser-assisted optical data transfer
- **Factory of the Future**
  Intelligent robotics for digitalised production processes
- **Simulation-based certification**
  Simulation processes as a basis for technical approval/ authorisation

BIG AND SMART DATA / DATA SCIENCE

- **Big Data platform**
  Systematic analysis of large data sets from multiple sources
- **Condition monitoring for safety-relevant structures**
  Novel diagnostics for the secure operation of complex structures

CYBERSECURITY

- **Cybersecurity for autonomous and networked systems** in the areas of aeronautics and aerospace as well as traffic on the ground

INTELLIGENT MOBILITY

- **Transport 5.0**
  Automated and networked transport systems
- **Digital atlas**
  Geodatabase for the transport area of the future

Two additional projects in the area of **ENERGY STORAGE / ENERGY EFFICIENCY** are being developed:

- **Future Fuels**
  Fuels of the future, high-capacity chemical storage
- **GigaStore**
  Cost-effective electricity and heat storage for the energy and transport systems of the future

Future Fuels was initiated in April 2018 as the first of 10 cross-disciplinary projects at DLR. Researchers from 11 institutes are addressing two societal challenges with this project – the development of a sustainable, secure and cost-effective energy supply for Germany as part of the Energy Transition, and a decrease in the temperature increase in Earth's atmosphere through reduced emissions of pollutants and carbon dioxide. At the same time, the performance of the mobility and energy sectors should remain unchanged or even improve in order to reliably meet societal and individual demands.

Synthetic fuels are the most promising solution, especially for mobile applications that require high power over long distances – such as in large passenger aircraft, heavy transport vehicles or container ships. This is because future fuels have a high energy density (energy per unit mass), which will not be achievable using batteries or hybrid solutions in the foreseeable future. "In addition, the great thing about future fuels is that we can design and optimise them for specific applications within certain limits. Furthermore, the existing infrastructure for transport and storage can often be used, with few or no modifications necessary," says Uwe Riedel, DLR Future Fuels Project Manager, who is also based at the Institute of Combustion Technology.

There is also great potential for the application of future fuels in the energy supply industry, as they can be used in gas turbine power plants for low-emission power generation or simply as an easy-to-manage storage medium that enables a flexible, sustainable supply system without shortages, for instance in cases where solar and wind power are not sufficient to meet demand.

Integrated and interdisciplinary research and development

The aim of this interdisciplinary project is to develop future fuels and to apply and demonstrate them in pilot projects while maintaining an integrated approach. Thanks to its expertise in the fields of aeronautics, spaceflight, energy and transport, DLR covers a wide range of topics and can draw upon in-depth expertise relating to all applications of future fuels in the mobility and energy supply sectors. In addition, the approximately 30 scientists involved in this cross-sectoral project are working with a system-oriented, interdisciplinary approach and taking the entire process chain into account – from the raw materials used to produce future fuels, to the production processes and the utilisation of the fuels themselves, and through to the residual emissions that may result. "This means that we are working on two fronts, but with a comprehensive approach. Only DLR is able to carry out a project like this," Aigner says.

Divided into five sub-projects, the DLR researchers are investigating issues such as how to produce synthetic fuels using solar energy (solar fuels) and developing concepts for the reconversion of these fuels. They are working on emission-optimised fuels for transport and aviation (designer fuels) as well as advanced 'green propellants' for spaceflight; these are intended to replace the highly toxic hydrazine that is currently used. In these areas, DLR can draw upon many measurement techniques and methods for analysing and testing the chemical and physical properties of the various future fuels – from laboratory-scale trials to large-scale experiments using specially equipped facilities, vehicles and aircrafts. In addition, the scientists are carrying out systems analyses and technology assessments that examine the topic of future fuels from an integrated perspective and take into account factors such as cost-effectiveness, efficiency, security of supply, and social acceptance.

Special opportunities for Germany as a hub of industry

The development of synthetic fuels has a bearing on many sectors that are important to the German economy, whether it be in the automotive industry, aviation, the energy sector or the chemical industry. "Future fuels represent a special opportunity for Germany as a high technology hub. They can become an important driver of innovation and strengthen the global competitiveness of our industrial base," Aigner says, describing their macroeconomic potential. "Germany is in a strong position in terms of technology and innovation, but has little in the way of natural resources, and is dependent on other countries for the import of fossil fuels. Admittedly, even with the advent of future fuels, it will continue to depend on imports to a certain degree. However, the market for biomass and power generated from renewable resources for the production of synthetic fuels will look very different – much more diversified and with new players, resulting in additional competition and more flexible pricing."

Four exciting years await the team of researchers working on the cross-disciplinary project as they move towards a single, comprehensive solution concept. Some of them were previously involved in the earlier project involving eight DLR institutes. "The groundwork and the development of methods were the priority there," says Project Manager Riedel. The Future Fuels cross-sectoral project offers the scientists scope for new approaches and creative solutions; no ideas are ruled out from the start. Project Coordinator Aigner expects the first pilot plants for producing future fuels on a larger scale to start operating in 10 years. This will also allow dependable cost calculations to be made. "Until then, we are dependent on reliable framework conditions and the support of our political and business partners to explore future fuels as a future-oriented technology and to prepare for their launch in commercial applications," Aigner says.

Denise Nüssle is responsible for corporate communications at the DLR site in Stuttgart.

Manfred Aigner heads the DLR Institute of Combustion Technology and coordinates the DLR cross-sectoral project Future Fuels

"Future Fuels can become an important innovation driver."

"The good thing about Future Fuels is that we can design them for specific applications."

Uwe Riedel from the DLR Institute of Combustion Technology leads the cross-sectoral Future Fuels project

DLR'S CROSS-SECTORAL FUTURE FUELS PROJECT

Institutes involved
Institute of Structures and Design
Institute of Vehicle Concepts
DLR Flight Experiments
Institute of Air Transportation Systems
Institute of Atmospheric Physics
Institute of Space Propulsion
Institute of Solar Research
Institute of Engineering Thermodynamics
Institute of Transport Research
Institute of Combustion Technology
Institute of Networked Energy Systems

Duration: four years (2018–2021)
Funding volume: 13 million euro

Systems analysis and technology assessment
Institute of Networked Energy Systems
Institute of Vehicle Concepts
Institute of Air Transport Systems
Institute of Engineering Thermodynamics
Institute of Transport Research

ENERGY

Solar fuels and reconversion
Institute of Networked Energy Systems
Institute of Solar Research
Institute of Engineering Thermodynamics
Institute of Combustion Technology

TRANSPORT

Oxygenated Fuels
Institute of Vehicle Concepts
Institute of Combustion Technology
Institute of Transport Research

AERONAUTICS

Designer fuels
DLR Flight Experiments facility
Institute of Atmospheric Physics
Institute of Combustion Technology

SPACE

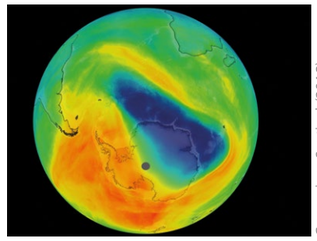
Liquid methane and 'green' propellants
Institute of Structures and Design
Institute of Space Propulsion
Institute of Combustion Technology

GROUND VIBRATION TESTS ON THE BELUGA XL CARGO AIRCRAFT

Ground vibration tests have been carried out on the new Airbus cargo aircraft – the Beluga XL – in Toulouse. Together with the French aerospace research centre ONERA, researchers from DLR studied the structural behaviour of the freighter. Ground vibration tests are a key element of the test programme required for any new aircraft to attain its certification of airworthiness. The test data serve to adapt and improve the mathematical structural model of the aircraft, to predict vibration amplitudes during operation, and to exclude flutter risks from the flight characteristics.

In just eight days, the researchers recorded data from tests using two experimental set-ups – one with an empty fuselage and one with an adjustable, heavy load. For the experiments, engineers installed more than 600 sensors, 7000 metres of cable and 300 metres of optical fibre on the fuselage, empennage, engines and wings. State-of-the-art exciter technology was used to generate the vibrations.

ACCURATE AIR POLLUTON MEASUREMENTS

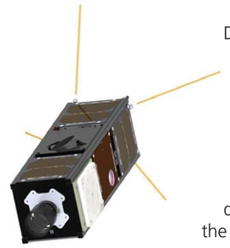


Copernicus-Sentinel (2018), DLR/BIRA/ESA.

Air pollution is one of the biggest threats to health worldwide; approximately seven million people die every year as a result. A special service is now available that can pinpoint sources of pollution precisely and analyse pollutant distributions from space. The Sentinel-5 Precursor Earth observation satellite provides daily global measurements of ozone, nitrogen dioxide, carbon monoxide, and aerosol and cloud properties. The data acquired by the TROPOspheric Monitoring Instrument (TROPOMI) are now freely available.

DLR is responsible for the mission's payload data ground segment and, together with the Royal Netherlands Meteorological Institute (KNMI), processes the satellite data. The DLR Earth Observation Center (EOC) and KNMI developed the data processing system. The EOC is also responsible for the long-term archiving of the mission data. The European Space Agency and the Netherlands Space Office developed the Sentinel-5P mission and TROPOMI as part of the European Copernicus Earth observation programme.

MINI LASER TERMINAL FOR SMALL SATELLITES



DLR researchers have teamed up with Tesat-Spacecom to develop a system that can transmit large amounts of data from small satellites using laser light. The miniaturised and extremely powerful laser terminal passed its 'Critical Design Review' and is now being manufactured ready for its first launch on a CubeSat at the end of 2018.

Optical communications – the transmission of data via laser – enables very high data rates and can be thought of as a 'wireless fibre-optic connection'. In the Optical Space Infrared Downlink System (OSIRIS) project, the DLR Institute of Communications and Navigation is applying this key technology to satellites. The OSIRIS payload occupies an area of 10 by 10 centimetres, is three centimetres high and weighs 300 grams. The laser communication system transmits data at a rate of 100 megabits per second – more than 100 times the data rate of conventional radio-based systems.

The laser terminal is optimised for use on CubeSats, cuboid microsatellites that are cost-effective and can be equipped with high-resolution cameras and measurement devices. Until now, the data that these acquire has been transmitted by radio, but Earth observation missions generate large volumes of data. Now, a powerful optical communications system is available, which makes it easier to fully utilise the capabilities of the cameras.

MEET DLR AT ...

'CONTACT WITH AN ASTEROID'
10 July - 14 October 2018 • Bremen, Germany
DLR is staging a newly designed exhibition on the current Hayabusa2 and MASCOT mission in the Untere Rathaushalle (ground floor) of Bremen's town hall. The exhibit shows how scientists are studying the characteristics and composition of asteroid Ryugu. It also explains the significance of asteroids as primordial matter from the early Solar System, and even demonstrates the threat posed to our planet by asteroids crossing Earth's orbit. Six sections provide information in both German and English on the diversity of asteroids and their role in the Solar System – the scientific objectives of the mission; the stages of the mission; and the sometimes highly complex manoeuvres on the asteroid Ryugu. Full-size models of the spacecraft, videos, large monitors and a photo wall for 'selfies' are further components of the exhibition.

11TH INTERNATIONAL SYMPOSIUM ON SPECIAL TOPICS IN CHEMICAL PROPULSION & ENERGETIC MATERIALS
9 - 14 September 2018 • Stuttgart, Germany
This renowned scientific conference series focuses on research and technology development in the complete range of propellants and energetic materials. It is a platform for communication and networking between the participants regarding state-of-the-art approaches in the field of energetic materials, the discussion of new and improved safety techniques in the combustion and handling of energetic materials, as well as the discussion and recommendation of future directions for research in combustion, propulsion and chemical reaction systems.

INTERNATIONAL ASTRONAUTICAL CONGRESS 2018
1 - 5 October 2018 • Berlin, Germany
The International Astronautical Congress (IAC) consists of a scientific conference programme and a space exhibition. It is the one time of the year opportunity when about 4000 space actors from all over the world come together. Global, multidisciplinary, and covering all space sectors and topics, it offers everyone the latest space information, and above all the opportunity to establish new contacts and potential partnerships. This year, the host is Bremen – Germany's main space city and one of Europe's major space centres. With its outstanding and extensive space sector encompassing global players in industry and internationally renowned research institutes, Bremen offers an exceptionally fruitful environment for bringing together the global space community.

DLR EXHIBITION IN VIENNA: 'COMETS – THE ROSETTA MISSION'

The Natural History Museum in Vienna is hosting the special exhibition 'Comets – The Rosetta Mission: Journey to the Origins of the Solar System' until 12 September 2018. Rosetta is one of the most complex European space missions and came to an end two years ago. The exhibition, which has been organised in collaboration with the Max Planck Society, shows a 1:4 scale model of the Rosetta spacecraft, as well as a full-scale model of the Philae lander and some instruments. The star of the show is an approximately 4.3 by 2.6 metre 1:1000 scale reproduction of Comet 67P/Churyumov-Gerasimenko with all of its surface details. The exhibition made its debut in 2016 at the Natural History Museum in Berlin, where it attracted over 700,000 visitors.

If you are not able to visit the exhibition in Vienna, you can take a virtual tour of the exhibition on the DLR app 'DLR COMETS', which can be downloaded free of charge from the App Store or the Google Play Store (optimised for tablets). It is also available on the 'Virtual tour' page (for Firefox, Chrome and Safari).

Image: NHM/Kurt Kracher

FIRSTS IN PARABOLIC FLIGHTS

When the parabolic flight aircraft Airbus A310 ZERO-G took off from Bordeaux-Mérignac Airport on 5 June 2018, there were three 'firsts'. For the first time, it was carrying only life-science experiments on board – for a campaign conducted by DLR, the European Space Agency (ESA) and the French space agency CNES. These experiments were also exposed to three different levels of gravity, another 'first'. In addition, the US space agency NASA was involved for the first time.

After climbs in which the occupants experienced forces of up to 1.8G, three special types of parabola were flown instead of the normal 22-second microgravity phases – weightlessness. A quarter, a half and three-quarters of Earth's gravity were achieved. This provided the researchers with a unique opportunity to observe biological and physiological systems, and to understand how the underlying mechanisms function under different gravity conditions. The three German experiments on board addressed the following questions: How does partial gravity affect muscle control? How does human mental capability fare under these conditions? What do the thresholds for experiencing gravity mean for plants?

E-MOBILITY IN EVERYDAY LIFE

What expectations do users have of electric vehicles and how do they stand the test of everyday life? DLR scientists answered this question by means of a study. To this end, they monitored the commercial use of electric vehicles in the 'electrically mobile' pilot project.

Over a period of three years, the mobile nursing services and assistance facilities of the Archdiocese of Freiburg tested 15 electric vehicles in practical use. At the same time, the researchers investigated the energy requirements and the costs of acquisition, use and the necessary infrastructure. They calculated the carbon dioxide emissions from power generation and battery production, and collected data on users' expectations and experiences. The study found that the users were satisfied with their electric vehicles, despite range limitations and occasional technical or logistical issues, such as charging. They were pleased with the low noise, the pleasant driving experience and the rapid acceleration. The environmental effects were also perceived positively. However, the installation of the charging infrastructure proved to be expensive and, without subsidies, the overall costs are still higher than with comparable conventional vehicles.

Image: RogerKoeppe/ErzbistumFreiburg

Electric cars have proved themselves for short trips to patients

THE DLR EVENTS PORTAL

Here you will find information on events that are organised by DLR or in which DLR participates, including trade fairs, exhibitions, workshops or conferences – in Germany and worldwide.

event.DLR.de/en/

Image: Christoph Otto for the DLRmagazine

Alexander Gerst – here standing on firm ground –
in the training module during the last exercises for his second flight to the International Space Station ISS.

ALL FOR ONE, AND ONE FOR ALL

horizons

horizons mission:
Alexander Gerst has two teams – one in space and one on Earth

During the six months that Alexander Gerst spends living and working in microgravity conditions, he says that he will be standing on the shoulders of the many others who have helped make it happen. His team on Earth will ensure that he is able to perform his duties effectively on the International Space Station (ISS). All over the world – in the United States, Russia, Japan and Germany – people are sitting in control centres, supporting his 'horizons' mission in round-the-clock shifts. Experiments have been planned, selected, prepared and transported to the ISS over a period of years. Trainers have prepared Gerst for almost every move that he will have to make during the launch, his time on the ISS and the landing. Entire teams of people make sure that the astronaut gets plenty of food in his celestial home, while also receiving the news and even his favourite TV series. These terrestrial helpers number in the hundreds or even thousands. Some work with Gerst personally, while others will never meet him in person. But they all have one thing in common – their behind-the-scenes work is a vital part of the mission. Without them, Gerst would not be able to perform his duties. Here, we introduce six of the men and women working 'backstage' and their tasks.

THE TRAINER

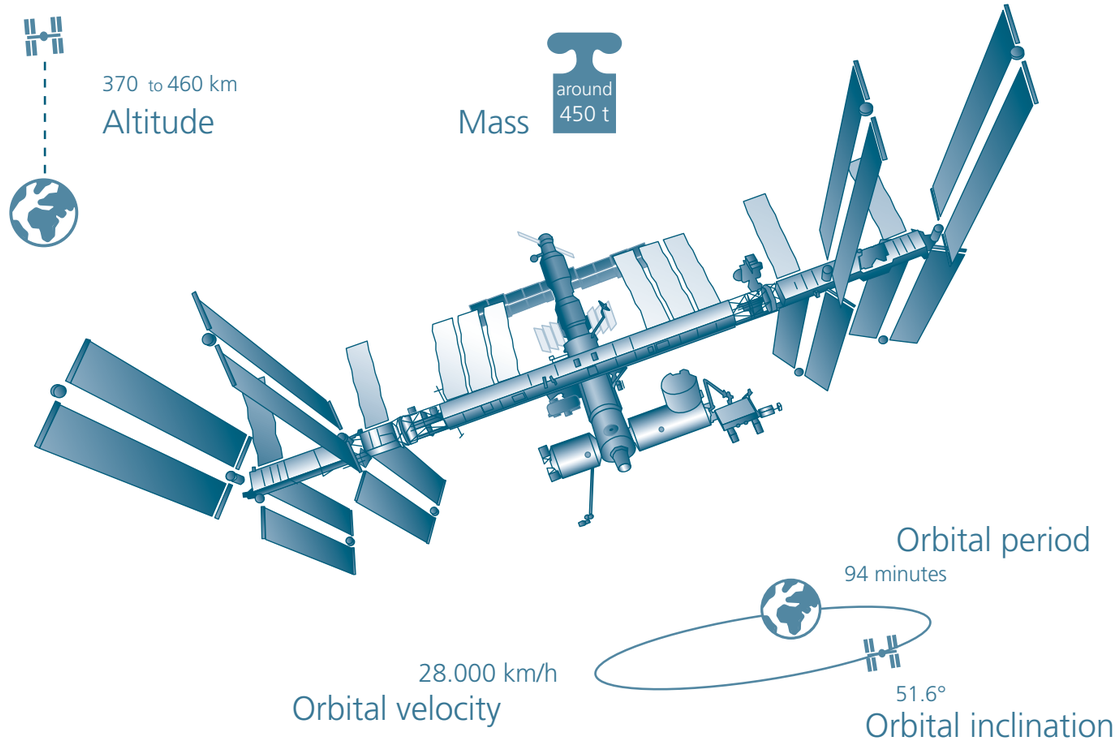
A man who knows the Columbus space laboratory inside out – Norbert Illmer, 'Eurocom' from the very start.

Norbert Illmer

Training, training and more training – that has mainly been Alexander Gerst's life over the last few years. In Russia, he learned how to fly the Soyuz spacecraft, and in Houston he trained for extravehicular activities in the neutral buoyancy pool. In Cologne, Norbert Illmer makes sure that the German astronaut knows the European Columbus research laboratory like the back of his hand. Indeed, he is the 'guinea pig' whenever new training content is introduced. "The instructors keep the training sessions up to date, and I have to go through each lesson one final time before we add it to the astronauts' timetable," Illmer says. From time to time, there are changes to the communication system used by the scientists on the ground to send commands to their payloads in space. "The astronaut must understand the system in order to pull the plug or enter a command if required." New experimental equipment is also added at times. Only someone who has regularly studied and trained with the systems can understand and master them.

But DLR's Norbert Illmer continues to be heavily involved in the 'horizons' mission, even once Alexander Gerst is well and truly settled on the ISS and the Columbus systems are working well. Every other week, he sits at the console in the European Astronaut Centre and works with the astronaut for several days. Gerst might be on the ISS, and Illmer on the ground, but they are a team nonetheless. 'Eurocom' is the position that allows Illmer to engage with the global network of control centres, all supporting the work being carried out in the Columbus module. This makes him the direct point of contact for all astronauts conducting the various experiments under the responsibility of the European teams. English is usually the operational language, but when all is going according to plan in space and everyone is feeling relaxed, Gerst and his German fellow crewmembers on the ground might chat a little in their native tongue. "It is good for all those involved to not just slave away on the experiments, but also take time to connect on a personal level and share a joke every now and then."

Illmer joined DLR at the time of the D 2 (STS 55) mission, and has been involved to some extent in every single mission since then. Illmer supported Thomas Reiter during Euromir 95, and Reinhold Ewald on MIR 97. When the Columbus module was launched in 2008, bound for the ISS, Illmer was sitting at the console. Now, he is working with Alexander Gerst on the 'horizons' mission. "In this team, I am the last Eurocom who has been here since the very start." Everything happens in real time on the console. In the event of a problem, it is important to respond quickly. "Adrenaline certainly plays its part," he says. Complex actions have to be prepared with great precision and detail. "It is a fantastic feeling when this all goes smoothly."



THE SUPPORT TEAM

The fine line between the astronaut's wishes and strict regulations – Antonio Fortunato from the crew operations team.

Antonio Fortunato knows exactly how Alexander Gerst spent the final days before his launch to the ISS. He knows which personal belongings the German astronaut took with him on his journey into space, and he helped to pack the clothing that Gerst will need immediately upon returning from the ISS. Fortunato is part of the DLR team responsible for supporting astronauts at ESA's European Astronaut Centre in Cologne.

Over the last decade, Fortunato has worked on six astronaut launches. On several occasions, he has been among the team members aboard the helicopter that flies to the landing site on the Kazakh steppe to welcome a European astronaut back from space. Three times, he and 'his' astronaut have spent several weeks of quarantine in Baikonur, where the astronauts prepare for the launch and have as little contact with the outside world as possible. He spent three weeks there in May with Alexander Gerst. Fortunato was examined by a doctor on a daily basis to ensure that he would not infect the German astronaut with influenza or another illness shortly before the launch.

However, his work began long before that. He has a range of responsibilities, but they all have the same ultimate goal – to ensure that conditions are right for the astronaut to carry out his work. The six members of the Crew Operations Team provide this support. Andreas Orth and Susanne Altenburger worked with Fortunato this time around. On a mission to the ISS, astronauts are provided with a certain

Antonio Fortunato

amount of food that they have chosen themselves. Alexander Gerst selected cheese noodles, Swabian ravioli with spinach, and Indian butter chicken. The team had to secure the services of a chef who would prepare some test dishes for Gerst and arrange to have them transported with him. Every personal object that an astronaut wants to bring to the ISS must be checked to ensure that it does not contravene NASA's strict rules. To give astronauts something to look at on the crew's web connection in their free time, some favourite TV shows, magazines, music and news sites are regularly uploaded to the ISS during the mission. A private video call between the astronauts and their family takes place once a week.

Fortunato's work is invariably a tightrope walk between the rules and requirements of the mission's US and Russian partners, as well as the personal wishes of Gerst himself. "And that is exactly what makes it so challenging and exciting," says the deputy head of the Crew Operations Team. All of the team members see it as a point of honour to ensure that what the astronaut takes with him to the ISS, how he spends his free time during the mission and what he discusses from space with his family on the ground are all private matters and remain hidden from public view.

THE CONDUCTOR

Planning, talking, coordinating – as Lead Flight Director, Marius Bach checks compliance with plans and resolves scheduling conflicts.

Meetings, meetings and more meetings. Things were quite different back when Marius Bach was the one sitting at the console in the Columbus Control Centre, overseeing the technology of the microgravity research laboratory. Since March 2018, the DLR staff member has been the Lead Flight Director, and until September 2018 he will be responsible for ensuring that the ground team makes every effort to ensure that astronaut Alexander Gerst has a smooth stay aboard the International Space Station. "The staff who now sit at the consoles rely on me to arrange everything effectively and with precision." As such, Bach spends most of his working day in discussions with the various mission partners at NASA and ESA, reaching agreements on how Gerst's work time should be allotted.

The astronaut's timetable includes 6.5 hours of work every day. The first rough plan of the tasks that Gerst should perform, and when, is drawn up six months in advance. "And then real-time planning comes into play," Bach says. If, for instance, an experiment requires more effort, or time has to be factored in for unexpected repairs, the plan has to be reworked. This has a knock-on effect on the breakdown of weekly and daily activities. Bach is like a conductor who oversees and directs the different instruments in this 'orchestra'. "One person is responsible for ensuring that everything is coordinated, that problems are solved and that all those involved have a point of contact – and

Marius Bach

that is my role." Every minute of the astronaut's working time is precious and must be used effectively. As the team member in space, Alexander Gerst relies on receiving precise information during the daily conferences in the morning and evening. "A lot of processes are at play in the background to ensure that a mission in space runs exactly as the astronauts and scientists want it to," Bach says.

He has already worked for three years as a planner for the Columbus Control Centre, and spent two years working shifts on the console as a Flight Director. As Lead Flight Director, Bach no longer has to do any shift work, having swapped the console for a conventional office desk. Up until Gerst's launch, work was relatively calm. But since Gerst's arrival at the ISS, the pace has picked up again for the team on the ground. "Our team can only cross off a task once the data from the experiment has been downloaded and received by the scientist involved." Above all, two things are crucial to Bach's work: good planning and a great deal of discussion with the many partners.

THE HEALTH MONITOR

A constant picture of the astronaut's fitness – as a biomedical engineer at the EAC, Beate Fischer will monitor Alexander Gerst's health until he returns to Earth.

"Among other things, we see ourselves as the team behind Alexander Gerst." Scientists want to make the most of the astronaut's precious time on board to conduct their experiments up until the very last moment, and there is also a tendency for astronauts on the ISS to overexert themselves and carry on working beyond the hours appointed for such tasks. DLR staff member Beate Fischer is a member of the Biomedical Engineering team at the European Astronaut Centre (EAC) and works on the console in shifts. "We make sure that the rules are adhered to and that Alexander gets the rest he needs." Fischer also ensures that Gerst completes the mandatory microgravity exercise sessions put together by a team of sports scientists on the ground. Not only does the astronaut need to fly into space safely, but he also needs to be fit to carry out his mission and return to Earth in a healthy state. "In the control room, we are the eyes, ears and long arm of the certified doctors who oversee astronaut training."

The medical team at EAC includes doctors, sports scientists, nutritionists, psychologists and a total of 10 biomedical engineers – all on a mission to ensure that Alexander Gerst receives excellent care. A medical conference takes place between the doctor and astronaut every week for this purpose. Beate Fischer makes sure that the technical side of this discussion runs smoothly and that neither the flight directors nor other console staff can access the sensitive data that emerges from these private conferences.

Beate Fischer

In the control room, it is not simply a matter of sitting back and watching the astronaut 'do his thing': "As far as we are concerned, the astronaut's surroundings are also hugely important," Fischer stresses. Real-time data is transmitted from the ISS, including temperature, humidity, oxygen content, as well as the amount of carbon dioxide. All of these conditions may have an impact on Alexander Gerst's health and performance, and must therefore be taken into consideration. "In critical situations, we inform the doctors directly." And then the biomedical engineers work through the many electronic documents provided on the console – schedules, procedures, everything is checked to determine whether it could affect the astronaut's health. Beate Fischer has been doing this for more than 18 years. She claims that she would have made a poor scientist, as she simply lacks the patience. "As a biomedical engineer, however, my job is quite varied – there is very little routine involved."

THE CONTROLLER

Planning and checking experiments – as Mission Director for the European Space Agency in Oberpfaffenhofen, Berti Meisinger is in close contact with the astronaut.

Berti Meisinger

When Berti Meisinger's mobile phone rings, there is every chance that the person on the other end of the line could be orbiting Earth at 28,000 kilometres per hour. She confirms that Alexander Gerst does indeed put in the occasional call or sends her an email to say when he will call her at the office. Berti Meisinger is the Mission Director for Gerst's 'horizons' mission and is thus his point of contact for matters relating to experiments and schedules. Previously, she was in charge of the ground team for the Space Shuttle mission of astronaut Gerhard Thiele, and was a flight director working at the console in the control room for Thomas Reiter's mission. For 11 years now, she has been responsible for missions in the Columbus module and has worked for ESA at DLR's site in Oberpfaffenhofen.

Months before Gerst embarked on his space mission, Berti Meisinger was focused on obtaining the 'certificates of flight readiness' – the final certification that an experiment has everything required for a flight to the ISS – successful functional tests, detailed procedures that set out how the experiment is to be conducted, and confirmation that it represents no danger to astronauts on board the ISS, due to gas emissions or sharp edges, for example. Meisinger is both motivating and strict in her regular meetings with the scientists involved in the experiments and her colleagues from the DLR Space Administration. "Only when everything has been properly arranged can we transfer the experiments to the respective launcher," the Mission Director says.

The Orbital 9 and SpaceX CRS 15 – experiments are carried to the ISS on almost every transporter, to be conducted and monitored by Alexander Gerst during his time in space. Regular telephone conferences with the various teams in Europe and at NASA provide an opportunity to determine the current status, determine whether experiments or timetables need to be adapted, and identify how much working time the astronauts have to carry out experiments.

"What makes the work so exciting for me is working with a large, international team that includes lots of different viewpoints, but with everyone striving towards a common goal," Meisinger says. She allows a year for preparation and half a year for the execution of the mission: "Sometimes it is pretty intense." As such, she is in close contact with the astronauts. Videoconferences with Alexander Gerst take place on a weekly basis, with Meisinger and her team sitting in a conference room while the astronaut floats around in front of the camera on the ISS as it orbits the Earth. And if it is an urgent matter, Gerst can simply call Meisinger's mobile phone. "He knows that he can call me at any time."

THE DIPLOMAT

The mission's architect – as Mission Manager, Volker Schmid researches what is appropriate, feasible and affordable.

Volker Schmid

Volker Schmid once visited the International Space Station himself, in the form of a photo that the German astronaut Alexander Gerst took with him on his 'Blue Dot' mission and returned to Schmid when he came back to Earth. That is the closest that Schmid has ever come to the flying space laboratory. But his association with the ISS and Alexander Gerst goes back many years – Schmid is Mission Manager at the German Aerospace Center and, with the help of his team, ensures that the astronaut can carry out the experiments for German research institutions and industry partners in microgravity conditions during his mission. "We see the astronaut as the top of the pyramid in the chain of action – the operative hand in space," he says.

Schmid's team began working on the mission years before it began, precisely to ensure that Gerst would be able to fulfil this function. By the time the astronaut embarked on his 'Blue Dot' mission in May 2014 and was recorded floating through the Space Station, the Mission Manager had been working since autumn 2011 to make sure that the experiments and technology demonstrations developed under the DLR Space Administration's national programme – with the support of the German Federal Ministry for Economic Affairs and Energy – would receive sufficient funding. Likewise, Schmid has been preparing for Gerst's second mission, 'horizons', since September 2015.

Having planned out the scientific portfolio and focus of the mission in detail, he must then identify which ideas are appropriate and feasible, and how these might be funded. Once funding has been secured, he has to wear a number of different hats: "We become coordinators, string pullers, problem solvers, therapists, diplomats, politicians, motivators, project managers and sometimes even campaigners, all rolled into one," he explains. This is what really fascinates him about his job. Scientists and industry partners need to be looked after, the necessary documents have to be obtained and checked, and the close interaction with the European Space Agency must be maintained. If everything goes smoothly, the work is easily manageable, but there is nothing routine about the experiments being conducted on board the ISS. For one, Schmid's team is introducing the first artificial intelligence system to the Space Station, in the form of the flying astronaut assistant 'CIMON'. DLR's 'Research under Space Conditions' division has also provided FLUMIAS, a high-resolution fluorescence microscope that can examine the behaviour of cells in the human body under microgravity conditions, among other things.

Schmid's desk is normally hidden beneath documents and notes. While Alexander Gerst lives and works on the ISS for more than six months, he will carry out 41 German experiments. A successful experiment in space will mean that all of Schmid's hard work has paid off. "At the end of the day, our team does not want to miss a single second of this," he explains. "We can set some great things in motion and break new ground." He admits that this brings a certain amount of stress and pressure with it. "These kinds of feats are never easy."

KEY FACTS

Mission:	horizons – Knowledge for Tomorrow
Number of German experiments:	approx. 41
Astronaut:	Alexander Gerst (*3 May 1976 in Künzelsau)
Launch to ISS:	6 June 2018 from Baikonur Cosmodrome in Kazakhstan
Mission duration:	expected to be 187 days
Docking:	8 June 2018

Crew Expedition 56

- Andrew Jay Feustel, Commander
- Oleg Germanovich Artemyev
- Richard R. Arnold

Crew Expedition 57

- Alexander Gerst, Commander
- Serena Maria Auñón-Chancellor
- Sergei Prokopiev
- Alexey Ovchinin
- Nikolai Tikhonov
- Tyler Nicholas Hague

Return to Earth: planned for 13 December 2018

The latest information on the horizons mission can be found on DLR's dedicated site

www.DLR.de/en/horizons

Here you will find videos, an image gallery and details about the experiments carried out on board the ISS.

Manuela Braun is responsible for the communication of spaceflight-related themes in the Programme Strategy department of the DLR Space Research and Technology division.

Ready for the mission: Alexander Gerst's team is more than just his crewmembers – it includes a reliable team back on Earth.

SCIENCE BY CITIZENS

Scientists collect, analyse and evaluate information, but they cannot be everywhere, and they cannot gather and review all the data. Nor can they know all of the scientific questions posed by society. 'Citizen science' provides researchers with strong, far-reaching support. Here, both sides benefit from the collaboration. Researchers obtain alternative information that complements their scientific data and offers a new perspective. Meanwhile, the laypersons are as close to research as is seldom possible, and contribute towards the expansion of knowledge.

Teamwork between scientists and citizens

By Manuela Braun

Ferns like to have moist roots, so they thrive in places where the soil moisture is high. In turn, this has a bearing on the data recorded by radar satellites performing Earth observation tasks from space. At present, however, it is not possible to be more precise about this. "We assume that the soil moisture affects how the radar signals are reflected back to the satellite," says Friederike Klan. "But determining just how this effect is observable would require more research and measurement data." This would be essential to better assess and evaluate the biomass data collected by the satellites. And this is where citizens, who have rarely been involved in scientific research until now, come into play.

Measurements for climate models

With the founding of the DLR Institute of Data Science in August 2017, these potential on-the-ground partners are set to play a much bigger role. Friederike Klan heads the 'Citizen Science' working group at the Institute. The connection between ferns growing on Earth and the satellite view from space is one of the first areas of study that she is looking to implement with the help of citizens. The cooperation partner is the Friedrich Schiller University in Jena. The principle behind the project is simple – citizens conduct on-site measurements in places where the satellites cannot look into the finer detail that is thought to be affected by the soil moisture. Students take photographs of the measurement points as well as predefined trees, and measure the average height of the ferns in a test area at Trockenborn-Wolfersdorf, approximately 20 kilometres south of Jena. In accordance with the plan, both values will then be entered in an 'app' specially designed by DLR, and then the data will be sent through DLR to Friedrich Schiller University for processing. The information derived from this data will then be fed into the analysis of radar images from space and ultimately improve the models for biomass change, carbon balance and climate change that are calculated using the satellite data.

The project is still in its early stages. Many things that sound simple require new methods and techniques. Specifying trees as measuring points does not pose a problem, but how can citizens find these measurement points when the forest does not have sufficiently good GPS reception to locate such a tree? Data that scientists cannot pinpoint to a precise measurement point is worthless. "You could attach a QR code to the tree for scanning, but then you would have to be very close to the measuring point in order to spot it," Friederike Klan says. "One solution might be to install a Bluetooth transmitter that a mobile phone could detect from a distance." The quality of the reported data must also be guaranteed. And most crucially, how do you motivate citizens to engage with the project, so that they carefully measure and report the heights of ferns?

Citizen science techniques

The newly established working group will look into these questions, not only for individual projects, but also for the use of citizen science in a number of different areas. "Among other things, we are researching how the data gathered by citizens is gaining in importance." For instance, computers have to learn to understand this data and automatically evaluate it. The methods used by citizens to collect data and, in some cases, evaluate it, is also an area of research at the DLR Institute of Data Science.

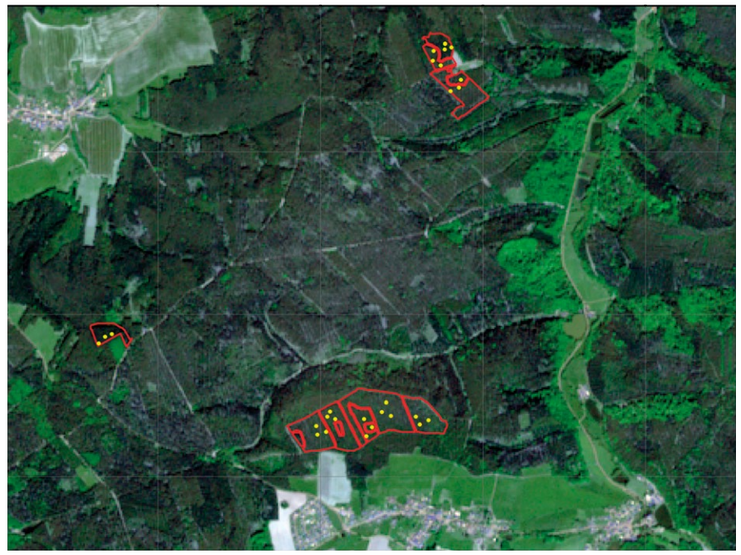
The possible fields of application for data science are manifold, and such projects require a rather creative approach. For example, measuring noise is easy, but the subjective perception of the level of sound can only be determined by citizens. Social media data can enable an assessment of the situation on the ground in the event of a disaster, once the unreliable information has been filtered out. Farmers and students could add to an understanding of the growth stages of crops on agricultural land. "Every project is different," Klan stresses. The one thing they have in common is that they have to draw upon fundamental concepts and methods.

Step by step, Klan and her working group are aiming to ensure that citizens and scientists can operate as an effective team. "At the moment, citizens have little in the way of direct contact with researchers and the results of their studies," the data scientist says. "But they are the very people whose lives will be directly affected by the results of such work." Some initial projects are already under way. The DLR Institute has also set itself a goal for the future: "We are planning a 'citizens' laboratory' that interested persons can visit to contribute their ideas and work with researchers to realise their own scientific projects."

DLR Institute of Data Science

Number of employees: 65 (planned)
Founding director: Robert Axmann
Address: Mälzerstraße 3, 07745 Jena
Tel: +49 2203 601 3139
Website: DLR.de/DW/en

For more information about citizen science please contact
friederike.klan@dlr.de



The Trockenborn-Wolfersdorf forest south of Jena, as seen from a satellite. In the test area, citizens' ground measurements help to ensure that more accurate conclusions can be drawn on the basis of satellite data.

How high is the fern under the trees? Citizens complement the scientific work with important on-site data.

Thomas Heege
Thomas Heege was born in Bonn in 1966. He grew up in Bonn and Kiel. Married with two children, he has a degree in physics (from universities in Kiel and Konstanz), majoring in environmental physics. He completed his undergraduate thesis at the Institute of Environmental Physics in Heidelberg and at the Institute of Aquatic Biology in Konstanz. Heege then followed up with a doctorate at the Institute for Space Sciences at the Freie Universität Berlin. From 1996 to 2006, he was a researcher and project manager at DLR.

EXPANDING OUR KNOWLEDGE OF LAKES AND SEAS

It all began in 1996 with a collaborative research project studying Lake Constance, in which DLR participated. With his doctoral thesis on 'Remote sensing of water on Lake Constance', Thomas Heege – at that time a researcher at DLR's Earth Observation Center – laid the foundations for EOMAP, a company whose services are now in global demand. In 2006, EOMAP was established as a spin-off from DLR. In the early years, its work focused on mapping the seafloor using airborne sensors. At first, the mapping of water depth was just a by-product of these efforts. Today, the company – which employs 20 people – plays a key role in the field of remote water sensing. Miriam Poetter, responsible for communications and public relations at the DLR site in Oberpfaffenhofen, spoke to the company's founder, Thomas Heege.

Dr Heege, the company that you founded in 2006 provides information about bodies of water, based on global data derived from space. What kind of information do you provide, and for whom is it intended?

: Earth observation has a strong social impact. The need for information from satellites is growing at an ever-increasing rate. For instance, satellite data can be used to create and improve early-warning systems for severe weather and extreme events. and data on specific climate indicators gives us a better understanding of our changing climate. EOMAP maps and monitors aquatic environments worldwide. We generate and market satellite-based mapping and software products such as water depth, seafloor and water quality, and offer online solutions for environmental monitoring of coastal and inland waters, for example in Arabia, Africa, Australia, Vietnam, Indonesia and Germany. Our customers include environmental agencies, the maritime industry and space agencies across the globe. In addition, our services include the daily monitoring of sediment distribution for offshore construction projects. We also devise new mapping techniques for offshore areas, develop operational atmospheric correction procedures and coordinate scientific projects at various international research institutions.

Approximately 70 percent of Earth's surface is covered with water. But fresh water, which is vital to life on Earth, makes up less than three percent of global water reserves. Many of these are in imminent danger, primarily as a result of human activities. The main threat is posed by pollutants entering the water systems, as the quality of the water is affected and the organisms living there endangered.

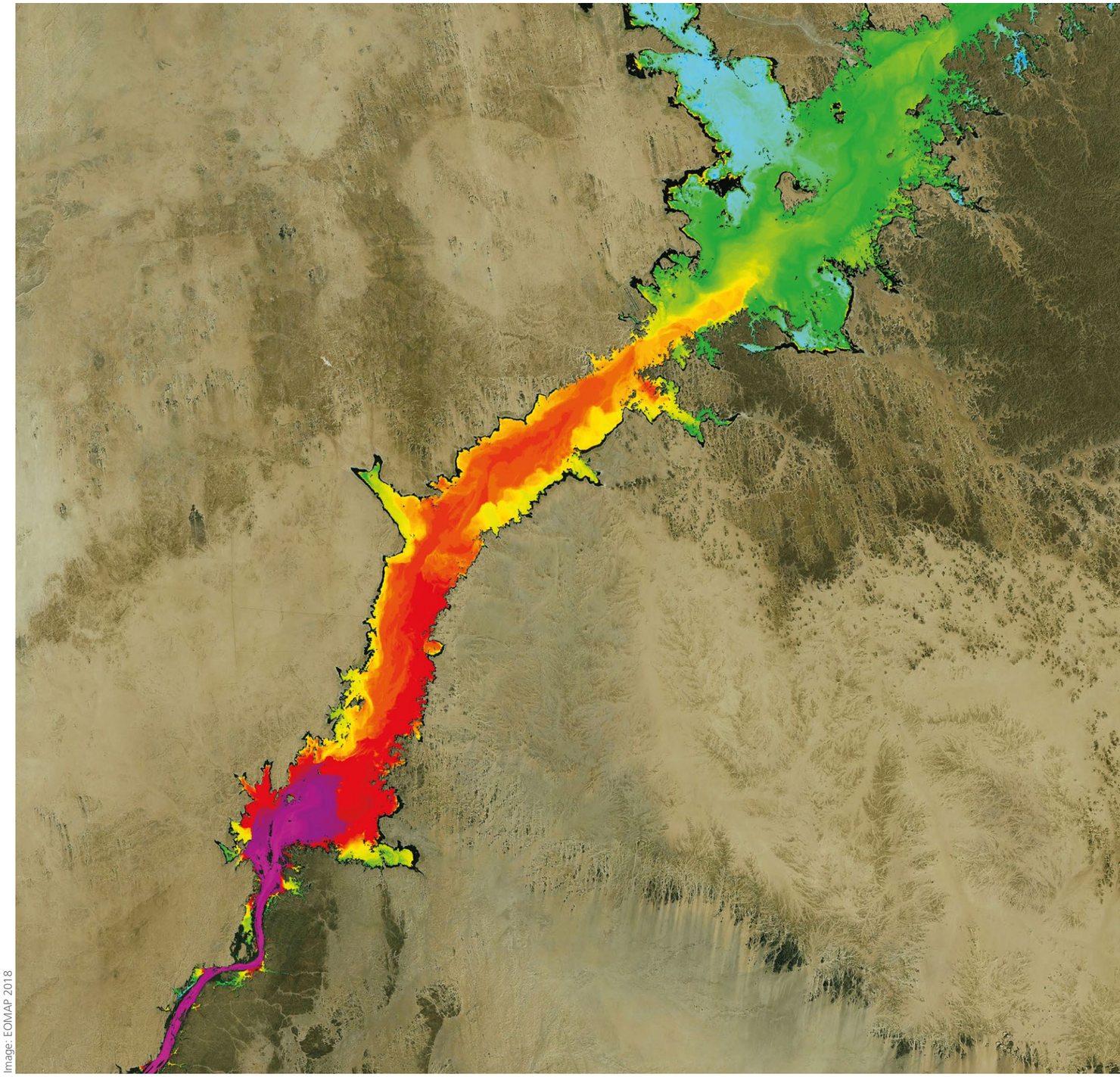


Image: EOMAP 2018

The River Nile in Egypt and Sudan in August 2016, showing sediment concentrations in the Nile and the Aswan Dam reservoir during the rainy season. Red and purple show extremely high quantities of particulate matter in the river, which was washed in by rainfall.

EOMAP maps bodies of water. Do you serve other market segments?

: The exploration of areas with shallow water is of interest to many disciplines – from ecology and flood prevention to the maritime industry. Port authorities, organisations responsible for shipping lane and fisheries management, the offshore industry and environmental authorities all need detailed topographical data from coastal waters, artificial reservoirs and coastal areas covering a depth of up to approximately 30 metres. Remote water sensing remains our core area of expertise, as we have led the market in this field for the past 10 years. Since the very beginning, we have been committed to building robust operational process chains when creating our digital products. Therefore, we also offer 'Big Data' services – in other words, large amounts of Earth observation data. This includes automated pre-processing and web-based visualisation solutions. In addition, some of our larger clients, such as the Dutch company Van Oord, are interested in demand-driven, real-time broadband information services. Van Oord is one of the world's leading companies within the marine construction industry and specialises in dredging, land reclamation, hydraulic engineering and coastal building. For this, we offer stand-alone EOMAP software solutions and professional online interfaces to put this new information to use.

What are your particular strengths?

: We excel through our quality-controlled services, which are based on high-tech data analysis processes. In addition, the automation of complex processes, as well as automated access to Earth observation data are part of our trademark service. To meet our clients' needs, we also acquire a wide array of other information products to provide solutions and environmental consulting, and then integrate them into appropriate project management systems. This again sets us apart from our competitors.

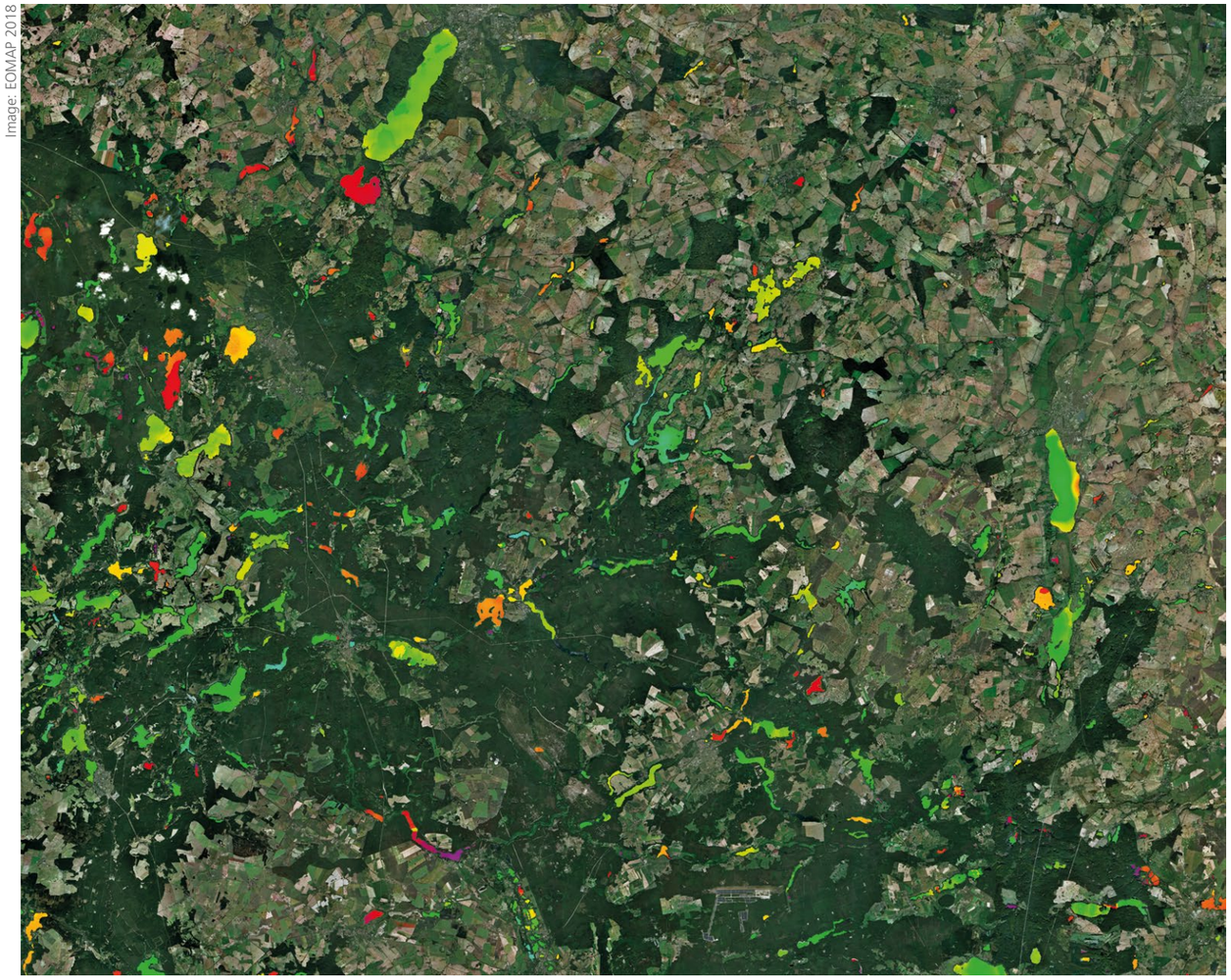
Can you give an example of an application?

: The agricultural sector – we have, for instance, counted fruit trees for the German Ministry of the Environment. To do this, we processed high-resolution airborne lidar data for one German federal state. We have also created transnational terrain models by analysing and combining land and water elevation models. Just recently, the United Kingdom Hydrographic Office – one of our regular clients – commissioned us to conduct satellite-based bathymetry for seven atolls in the Maldives. We are currently providing satellite-supported bathymetric data to assist with the mapping of the Great Barrier Reef. We also have some interesting commercial projects relating to satellite-based water quality monitoring. We have been requested to provide seasonal turbidity and sediment parameter data for Georgia's river system in order to assist with the decision-making process related to the planned development of a hydroelectric plant there.

How do you think the market will develop in this area?

: The strengths of satellite-based environmental data have been evident for some years. The order situation is developing very positively, in particular due to growing market acceptance over the last two years. Thanks to better satellite data availability, as well as more accurate sensors and advanced evaluation methods – allowing routine monitoring of environmental impacts in highly industrialised areas, for instance – our information services have reached a high level of maturity, making them exceptionally well suited to operational use.

Image: EOMAP 2018



The Mecklenburg Lake District in June 2016 with Lake Tollensesee. The concentration of algae differs significantly from lake to lake.

What plans do you have for EOMAP's future, bearing in mind that more and more suppliers are entering the market?

: There is certainly competition, but we see this as a positive. Not only does it serve as a catalyst for our own further development, but it is also a sign that remote water sensing is subject to ever-growing demand. Clients are prepared to pay for high-quality services in areas ranging from the maritime industry and the security sector through to official bodies and international institutions. Therefore, our first priority is to consolidate our status as a leading technology provider within this sector and to continue focusing on quality products that are delivered reliably. Without giving away too much about our technology development plans, we certainly see an opportunity to integrate technology from other disciplines into our areas of application. Our market experience has shown us that close collaboration with various complementary industries is important. One good example of this is our partnership with Fugro, the world's largest provider of geotechnical and survey services.

EOMAP at a glance

Founded: 2006
Number of employees: 20
Areas of focus: Earth observation, remote water sensing, Big Data processing, sustainability, environment monitoring, environmental protection, climate, software products, online tools, map products
Headquarters: Seefeld; branch office: Queensland, Australia
Management team: Thomas Heege, CEO; Knut Hartmann, COO; Magnus Wettle, Managing Director of EOMAP Australia Pty Ltd

www.eomap.com

What are the current challenges facing the Earth observation industry from EOMAP's perspective?

: The real strength of remote sensing is the comprehensive provision of independent information with ever-greater temporal and spatial coverage – and this is also its greatest challenge. Clients must be able to use this information effectively, which means we have to provide this data reliably, while offering a predictable level of quality. This is far from simple. After all, a range of different factors affect satellite images. For instance, we need to ensure that disruptive effects, such as atmospheric disturbances, can be reliably corrected. Our customers expect constantly improving high-tech methods and quality-assured production processes. In addition, Earth observation services often provide only part of the information needed, so integration and information reduction in response to customer requirements represents another challenge. Against the backdrop of Big Data, government agencies often play a role in Earth observation technology. The increasing amounts of data acquired by European satellites must therefore be made available in a reliable fashion – for instance, by allowing commercial service providers like us to have full access to it. However, this can also lead to a situation whereby technologies that are already in use receive an injection of public financing, are further developed and ultimately offered freely on the market.

Regarding sales performance, where does EOMAP's geographical focus lie, and where do you see the greatest potential for development?

: Two factors that have a major impact on this are economic and the ecological demand, as well as clients' awareness and the understanding of Earth observation solutions. This varies considerably across the globe. For instance, the level of knowledge about the possible applications of satellite-based monitoring is high in Australia – just think of the Great Barrier Reef and its economic and environmental requirements. The same applies to countries like the Netherlands, which has a strong project management and exploration industry and employs our services for projects all over the world. We are also seeing this kind of demand in South America and Africa. In this context, we greatly appreciate the work done by UNESCO in supporting emerging countries with capacity building, in other words

developing capacity and skills that relate to a technical and administrative infrastructure. EOMAP has developed the 'World Water Quality Portal'– comprising water quality data for all inland and coastal waters worldwide – for UNESCO's International Initiative on Water Quality. This online portal makes crucial information about water quality available to an extensive range of government institutions, state environmental agencies, the maritime industry and higher education institutions.

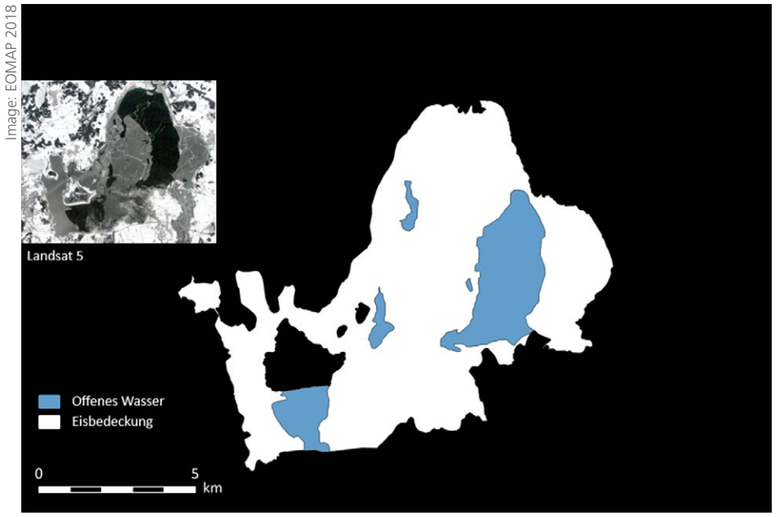
How was EOMAP's last year, and where are you headed in future?

: 2017 was a great year for us. Nonetheless, we will have to continue to invest in capacity building and in developing our service concepts over the next few years, until Earth observation solutions become commonplace worldwide. The coming years will be shaped by two different developments – the systematic expansion of international business in our core segments, coupled with the growth of information services. In technological terms, we are keen to expand and link our various operational processes in a modular fashion to form diverse customer information and decision-making platforms.

What do you believe to be particularly important in managing EOMAP's business affairs?

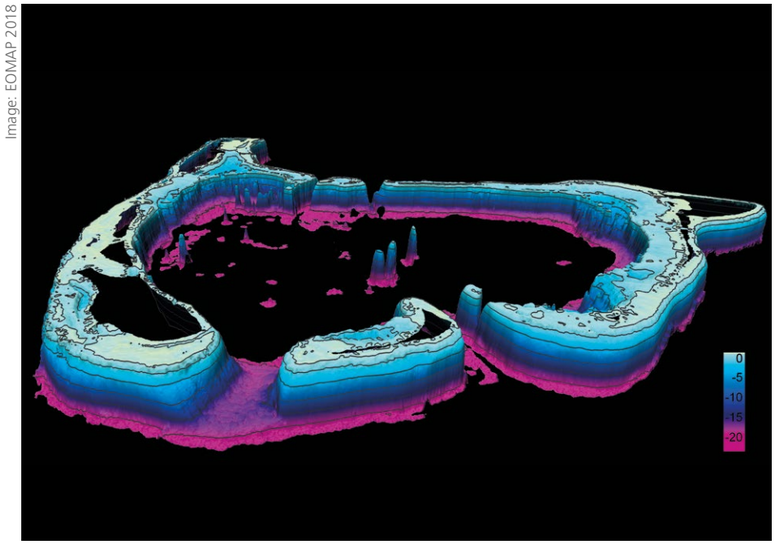
: There are three things. Firstly, flat hierarchies with a working atmosphere of mutual respect, so that we can utilise the superb skills of every single staff member for the benefit of the entire cross-disciplinary team. Secondly, developing cutting-edge operational technology. And thirdly, a customer-oriented service approach, so that our international customers have confidence in and understand the value of high-tech services as an efficient part of their business. We are very proud to have achieved several world firsts with this strategy. In 2014, we digitally mapped out the entire Great Barrier Reef in high resolution using satellite-derived bathymetry. In 2018, we monitored the water quality of rivers as well as inland and coastal waters all over the world with complete coverage and, of course, using satellite data. DLR Technology Marketing has proved a strong and extremely important partner in all of this, having helped EOMAP in numerous ways since its foundation.

Image: EOMAP 2018



In the context of a study commissioned by the Bavarian State Office for the Environment, the ice cover of three Bavarian lakes (Ammersee, Starnberger See and Chiemsee) over the last 25 years (1992 to 2017) was reconstructed on the basis of satellite data. Data sources used were both satellite optical imagery (Landsat 5/7/8, Sentinel 2) and radar data (ERS 1/2, ASAR, Sentinel 1). This example shows the mapped ice cover (in white) of Lake Chiemsee on 27 January 2006, based on Landsat 5 data.

Image: EOMAP 2018

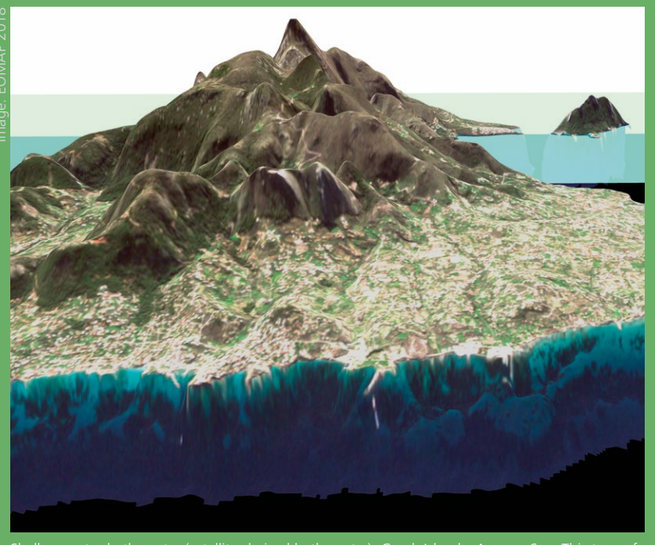


Through the use of shallow water bathymetry (satellite-derived bathymetry), Shell Qatar, for example, achieved cost savings of 1,000,000 US dollars – savings that are not possible with traditional bathymetric processes. Shallow water bathymetry enables depth mapping without the need for costly and time-consuming on-site measurements.

Image: EOMAP 2017

The colours show sediment distribution in the River Enguri, Georgia in June 2016. EOMAP has analysed the water parameters turbidity and sediment content for the river system in Georgia. The data provided guidance to Stucky Ltd, which is strategically assessing the Georgian government's renewable energy sector.

Image: EOMAP 2018



Shallow water bathymetry (satellite-derived bathymetry), Greek Islands, Aegean Sea. This type of data was delivered to the EMODnet Bathymetry Portal.

GLOSSARY

SPECIAL RESEARCH AREA LAKE CONSTANCE

The German Federal Government has been supporting long-term (up to 12 years) crossdisciplinary projects for 50 years to promote particularly demanding research projects. The Bodensee Collaborative Research Centre is dedicated to interdisciplinary basic research in the fields of sediment circulation and sedimentation in the littoral zone. For DLR and remote sensing, this long-term project was the entry into the application-oriented development of processes and it was the basis for the technologies that led to the founding of EOMAP.

SEDIMENT / SEDIMENT DISTRIBUTION

Sediments in the geoscientific sense are various organic and/or mineral particles that are transported in the water or deposited or accumulated at the bottom of a body of water. The spatial measurement of sediments in water makes it possible to deduce their origin and transport routes.

OFFSHORE CONSTRUCTION

This includes, for example, the construction of offshore wind farms (typically below the water surface, near the coast or on the open sea), submarine cable laying, dredging to deepen shipping channels and associated works.

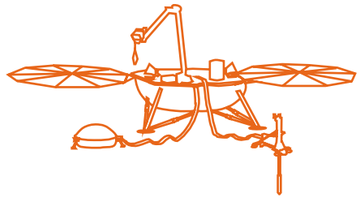
ATMOSPHERIC CORRECTION PROCEDURE

Computational methods for minimising the influence of atmospheric conditions on satellite image data.

BATHYMETRY

Measuring techniques and methods for determining water depths. Maps of the depth profile of oceans are created, among other things, from surveying the topographical geometry of riverbeds, seabeds and lakebeds.

WHEN THE FOG ROLLS IN



On 5 May 2018 at 04:05 local time, the InSight mission embarked on its journey to Mars. Scientists will, for the first time, explore the interior of the Red Planet using a seismometer and a penetrometer to measure temperature and other physical properties. The lander is expected to touch down on the surface of Mars on 26 November 2018. The launch was a thrilling moment for scientists, the media, and the residents of the Californian town of Lompoc alike.

The Mars InSight lander is on its way to the Red Planet

By Manuela Braun

The drawing on the cover of the Santa Barbara News-Press shows a series of concentric circles indicating the areas from which the Atlas V rocket can be seen, with the small town of Lompoc right at the centre. Lompoc takes its name from the language of the native American Chumash people, who called this region 'The Land of Many Lakes'. Today, this small town in California's Santa Barbara Valley is dubbed 'The City of Arts and Flowers'. Home to 42,000 people, it lies directly on Highway 1, surrounded by a landscape of gently rolling hills. The coast and its beaches are nearby. The main roads are lined with fast food chain restaurants, car dealerships and shopping malls. The town centre is small, with the Heritage Walk wending its way through the area around H Street and Cypress Avenue. Covering a mile-long route, it takes in historic houses and passes beneath large trees along the way, punctuated by sites dating back to 1870. The illuminated panel above the old Lompoc Theater has long ceased to advertise any films. Just a few steps away from the historic buildings, we come across the first mural, showing a rocket with powerful engines producing a glowing cloud of orange flames. The Titan II, which lifted off from Vandenberg Air Force Base near Lompoc in 2003, has been immortalised on the wall of a building.

A small town with space fever

This little spot has a long-standing connection with the space industry – Vandenberg Air Force Base has hosted satellite launches since 1958. One of the first was the Discoverer 1 satellite. In 1984, the base was even equipped as a launch site for Space Shuttles, but the Challenger tragedy in 1986 ended plans to conduct shuttle launches from the Californian base. It continues to serve as a spaceport, with a total of 2000 launches having taken place from the site to date. Another tradition began at 04:05 PST on 5 May, when an Atlas V 504 launcher lifted off with the InSight Mars lander, bound for the Red Planet. This is the first time a mission to another planet has flown from the Air Force Base.

Lompoc is preparing for the big day. The Santa Barbara News-Press reports that thousands of spectators will be there to attend the launch. On Friday night, the town's airport will open at around 02:30, and viewers can also watch the launch from St. Mary's Episcopal Church to the north of the town centre. Both locations should offer good views of the Atlas V's trajectory. Two new murals at Allan Hancock College in Lompoc have been created in honour of the space flight. One of the paintings shows a satellite and a celestial body, while the other – several metres high – depicts a female student looking at a rocket as it lifts off. It is called 'Looking to the Future'.

The 57-metre-tall Atlas V launcher ready for lift-off at Space Launch Complex 3 in the midst of the coastal fog near Lompoc. At the top is the Mars InSight lander.

Lompoc, near the Californian coast, is a space city – the numerous murals reveal this. More than 2000 launches have taken place at Vandenberg Air Force Base since 1958.

Two days before the launch, however, First Lieutenant Kristina Williams puts a bit of a dampener on things at a press conference. As a weather officer at Vandenberg Air Force Base, she has good and bad news to deliver. While the prospects of a successful launch remain high, visibility is likely to be only 20 percent. Every morning, mist billows from the ocean onto the land, and there is a strong likelihood that the sea fog will be particularly dense on 5 May as it surges over Vandenberg Air Force Base.

Mars – inner values

The Atlas V rocket has precious cargo on board in the form of the U.S. InSight lander, which is devoted to exploring the interior of Mars, as indicated by the full mission title – 'Interior Exploration using Seismic Investigations, Geodesy and Heat Transport'. European organisations have contributed the two most important instruments on the NASA lander. An international, French-led consortium has developed and built the mission's SEIS seismometer, which is set to record waves triggered by 'marsquakes' and meteorite impacts directly on the planet's surface for the very first time. The German Aerospace Center is also sending a 'mole' to Mars – the HP³ (Heat Flow and Physical Properties Package) penetrometer that will hammer up to five metres into the Martian soil, pulling a flat ribbon cable fitted with 14 sensitive temperature sensors behind it underground.

"On Earth, we have plate tectonics, where slabs of rock collide with one another and are constantly being formed anew or swallowed up – but this is not the case on Mars," says Tilman Spohn, the Principal Investigator for the HP³ project, who is visiting California for the launch. "Mars is covered by an immovable, solid outer layer, pierced here and there by volcanoes. So far, we have not been able to ascertain why Earth is different from Mars and all other Earth-like planets in this respect." While Earth has undergone many changes due to its plate tectonics, Mars has changed less dramatically over the 4.5 billion years since its formation. The mole and the sensors on the flat ribbon cable are intended to measure how much heat flows from the deep interior of Mars. These findings can be used to estimate the temperature within the interior, thus providing a better understanding of the 'Mars thermal engine'. "Just as an engineer can surmise the power of an engine from its temperature, so can we get a picture of Mars as a thermal engine, using the heat flow. How does it compare to a thermal engine? Well, all earthquakes, mountains, volcanoes and ground movements are caused by the workings of this thermal engine. And we can learn a lot from the comparison – what we find out about Mars will help us to better understand Earth and its formation."

Depth record in the Solar System

This is the first time that a fully automatic penetrometer – which will work its way down to a depth of five metres, avoiding small rocks and realigning itself along the way – will be used for planetary research. In the past, astronauts have performed these kinds of measurements on the Moon. During the Apollo 17 mission in 1972, Eugene Cernan and Jack Schmitt used a hand-operated drill to perform heat flow measurements at a depth of 2.3 metres. The previous record for Mars is somewhat lower; using the U.S. Phoenix Mars lander, researchers managed to burrow only 18 centimetres into the ground.

One last look at the launcher

The lander and its instruments are concealed inside the fairing at the top of the Atlas V launcher, which is poised for take-off. On Friday evening, just after 23:00, the time has finally come. Centimetre by centimetre, the Mobile Service Tower – which had previously hidden the launcher from view – rolls back. The workers in their safety helmets are dwarfed by the 60-metre-high structure. A crowd of onlookers gathers at a safe distance. Film cameras are shooting, mobile phones are pulled out, and cameras click away. This is the last chance to see the Atlas V launcher before InSight embarks on its six-month trip to Mars. The temperature in California, which is usually rather warm, has dropped considerably after nightfall. The cold rises from the ground and seeps into your bones. The white launcher towers a majestic 57 metres high on Space Launch Complex 3. Thick layers of fog are now billowing across the land from the sea. Bright floodlights shine through the dark night like fingers of light pointing at the launcher. Just above the ground, the launcher is now flooded by the light beams, which shred the fog around the InSight logo at the top. It is not looking good for a clear view of the launch. If all goes to plan, in just five hours the button will be pressed in the control room, launching the mission on its way to Mars.

Up until 8 June, the relative positions of Earth and Mars are particularly favourable, so the flight to the Red Planet will only take six months. If InSight has to be delayed until after that date, a new launch attempt will not be possible for another two years. The mission had already been set back two years, as the French SEIS instrument developed a vacuum leak, resulting in the cancellation of the launch planned for March 2016. Back then, the scientists feared that the whole mission was in jeopardy. The InSight mission is part of the Discovery programme and is subject to strict rules that dictate a short development time, a timely launch and a tight budget. NASA made the decision to waive these stringent requirements for InSight. The mission was given a reprieve, SEIS was repaired, and the HP³ team made the most of this time to optimise the reliability of their instrument.

Waiting in the dark

Overnight, viewers assemble under cover of darkness to wait for the InSight launch. Cars line the access roads to Vandenberg Air Force Base. Those unable to make it all the way to the launch site park on the side streets, stand around at Lompoc Airport, or drive to the church, which offers a slightly elevated vantage point. The Air Force has allowed the press and scientists onto the base. The places that the army has prepared for watching the launch have been dubbed 'Hawk's Nest' and 'Gravel Pit'. As the name suggests, the latter is a large gravel pit with an almost lunar barrenness, and it is ice-cold there. Beyond this lies the place where InSight is set to lift off into the sky. Camera lenses point towards it through the gloom. The loudspeaker booms with voices from the control room. Just before 04:00, one "Go" after another echoes across the site. Every part of the launch system must give green light. At the end of the procedure, the voice of the Launch Director is heard: "We're GO for InSight!" Tilman Spohn briefly clenches his fist in triumph. "Excellent news!" he declares. The launch is now tantalisingly close, and the excitement reaches fever pitch in the 'Gravel Pit'.

A rumbling launch to Mars

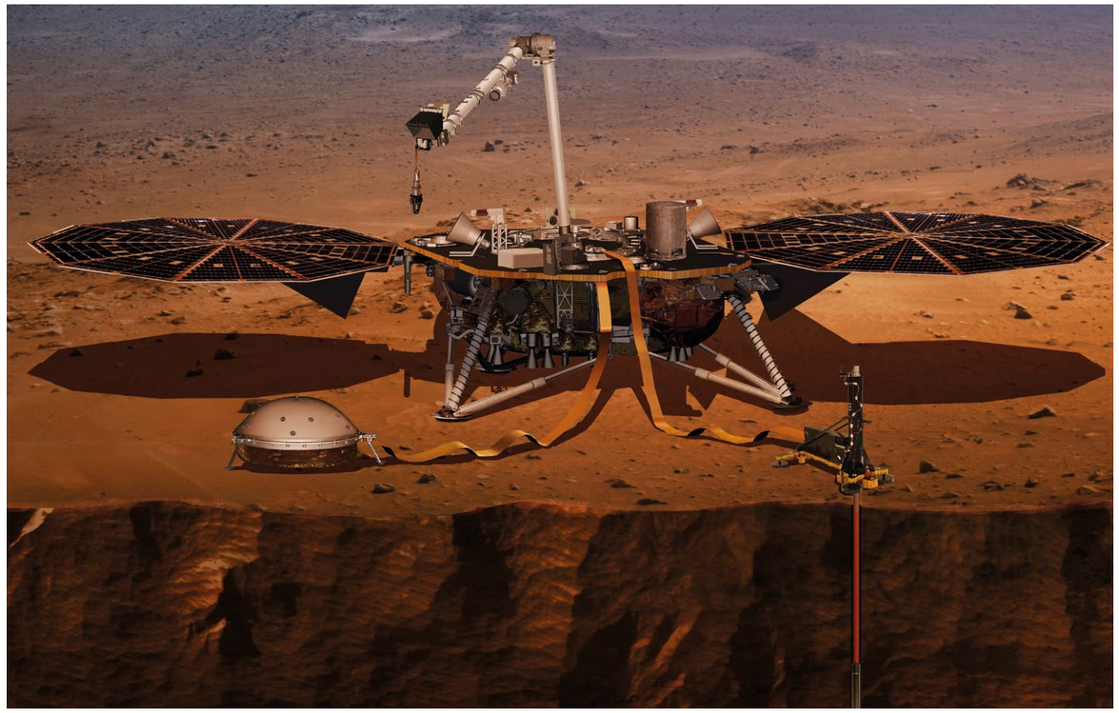
The countdown begins right on time. "Six, five, four …" Everyone holds their breath and scans the darkness for a first glimpse of engine ignition. "Three, two, one …" After a wait that feels like an eternity, a muffled rumbling rolls across the gravel-covered ground. On the launch platform, the Atlas V rocket ignites in a brilliant wave of fire and lifts off, carrying InSight on its way to Mars – right on schedule at 04:05. The orange glow is reflected by the clouds of fog that envelop the launcher. However, this is only captured by the cameras that are positioned at the launch complex itself. All remains dark in the 'Gravel Pit', the 'Hawk's Nest' and on the access roads. The growl of the launcher can be heard for 30 seconds, and then silence fills the air. For a moment, everyone remains quiet. The InSight mission is now under way. Everyone heard it happen, but no one saw it in the coastal fog. Only those watching from a long way south of Lompoc would have been able to see a small, glowing point of light rising into the sky.

The tension starts to abate. At Lompoc Airport, people break into applause, mixed with sighs of disappointment. Many of them are, however, impressed by the mere sound of the Atlas V launcher. InSight now has to travel 485 million kilometres before it arrives at the Red Planet's Elysium Planitia on 26 November 2018. A robotic arm will pick up the SEIS and HP³ instruments and set them down on the Martian surface. "And then we will begin our measurements," says Tilman Spohn. Standing in the 'Gravel Pit', he is freezing cold, but happy that 'his' Mole is on its way to Mars.

The headline of the Lompoc Record on 6 May says it all: "Launch makes history." It has indeed.

www.DLR.de/en/InSight

The HP³ penetrometer will hammer its way into the Martian surface to a depth of five metres



ON THE RIGHT TRACK

Trains powered by fuel cells are emission-free and do not require overhead power lines. Travelling along non-electrified routes, they offer a sustainable alternative to diesel vehicles. Of the almost 40,000 kilometres covered by Germany's rail network, around 60 percent is electrified with overhead lines. These provide the train's electric motors with power. If this electricity comes from renewable sources, this means that rail transport on electrified main and high-speed routes can be carbon dioxide and pollutant free. The situation is different on regional and branch lines, which often have no overhead lines due to the expense of electrification; trains with diesel engines are required to run along these sections of track. As with road transport, this causes climate-damaging and environmentally harmful emissions in the form of carbon dioxide, nitrogen oxides and soot particles.

Research at the interface between energy and transport

By Denise Nüssle

The future of rail transport – fuel cells instead of diesel

In the quest for an efficient and sustainable alternative to diesel vehicles, the DLR Institute of Vehicle Concepts in Stuttgart is working together with industry on research into fuel-cell-powered trains specially designed to meet the requirements of rail transport. On board the train is the fuel-cell system itself, together with hydrogen tanks, a battery and electric motors. A chemical reaction takes place in the fuel cell, where hydrogen reacts with oxygen and electricity is generated. This drives the electric motors. The battery stores energy recovered during braking, helps with peak loads and ensures that the fuel-cell system can be operated under optimum conditions – meaning efficiently and at constant power. "The high power outputs and compact design that are possible today mean that fuel cells have massive potential as low-emission, flexible and efficient technology for the rail sector," says Joachim Winter, a train researcher and Head of DLR's Next Generation Train (NGT) project. With its range of up to 1000 kilometres, Winter sees regional and freight transport as the prime area of application for this technology. Purely battery-based concepts can cover short non-electrified routes. However, the much higher weight and long charging times involved are drawbacks.

Comprehensive DLR expertise for industry and policymakers

From the conception of the fuel-cell power unit to realistic component tests on special test benches, the installation of a new powertrain in demonstration trains and the monitoring of the first test journeys, DLR has already contributed its expertise in technological development to support rail vehicle manufacturers in several projects. It also advises decision-makers from the fields of politics and industry about these matters. There is major interest from industry players and regional public transport authorities; most railway companies wish to convert their trains from diesel power to fuel-cell propulsion. The state of Lower Saxony has already ordered 14 fuel-cell-powered trains, while Baden-Württemberg, Hesse and Schleswig-Holstein are currently preparing the necessary calls for tender. Two fuel-cell-driven trains manufactured as part of the National Innovation Programme Hydrogen and Fuel Cell Technology (NIP), which received scientific support from DLR, have already been given green light. These regional trains have been undergoing testing since autumn 2016 and are scheduled to start running passenger services from Cuxhaven and Buxtehude to Bremerhaven in summer 2018 – a world first. "A fuel-cell-powered drive train is currently about twice as expensive as a conventional diesel system. Prices are set to fall considerably as we get closer to series production. At the same time, we have to bear in mind that fossil fuels are becoming more expensive," says Winter. When it comes to the technology, the train expert sees huge potential: "New combinations of materials will enable improvements in capacity and cycle stability, the systems are becoming smaller and the packaging more efficient."

Image: Alstom/Michael Wittwer

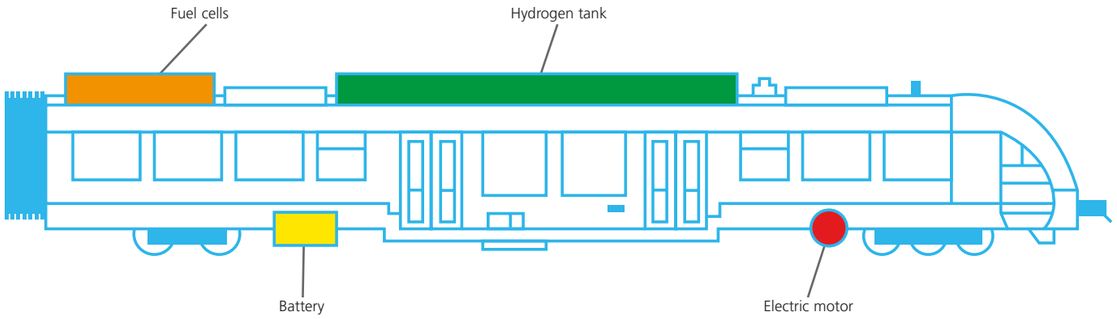
Ready for its first fuel-cell-powered trip – the Coradia iLint from Alstom.

Hydrogen infrastructure – avoiding bottlenecks?

Whether for cars or trains, fuel cell technology requires its own hydrogen infrastructure. Rail transport has a decisive advantage in this respect because routes, train timings and refuelling points can be planned with great precision and well in advance. At the same time, train transport reliably consumes large quantities of hydrogen – around 200 kilograms per unit and day of use, as a rough estimate. While road transport requires a network of hydrogen refuelling stations that are as closely spaced as possible, rail transport can cope with a few, centrally located refuelling hubs. These would also be ideal sites for establishing electrolysis plants to generate hydrogen. As part of their work, the DLR researchers are developing simulation models in order to determine the size of such facilities. "Such infrastructure hubs could also be located near business parks, which often already have a hydrogen infrastructure in place or generate hydrogen as a by-product, for instance as part of the chemical processing industry," Winter says. At the same time, he explains, these hubs and the hydrogen infrastructure created there for rail transport could also be used by fuel-cell-powered cars and buses, resulting in another interesting interface.

Sector coupling – green hydrogen – storage plus fuel

The way in which hydrogen is produced is key to sustainable, climate-friendly mobility that makes an important contribution towards implementing the Energy Transition. Only 'green hydrogen', produced using electricity from renewable sources such as wind or solar power, makes the complete process emission-free. Germany and its federal states have been working on solutions for storing renewable energy in the form of hydrogen for some time now. "Against this backdrop, fuel-cell-powered trains can serve as an example of the successful coupling of the energy and transport sectors," Winter says. At present, green hydrogen is not competitive due to high taxes and duties. One solution would be to exempt fuel-cell-powered trains from the track pricing that generally applies to the use of railway infrastructure.



Source: Wolfram Schwab, Alstom Transport Deutschland GmbH, 15th International Rolling Stock Conference, Dresden, 1-3 March 2017 – the Coradia iLint.

Martin Schmücker
is a qualified lecturer in materials science, an associate professor at Clausthal University of Technology and an honorary professor at Koblenz University of Applied Sciences. He has been a researcher at DLR since 1992 and Acting Head of the Structural and Functional Ceramics Department at the DLR Institute of Materials Research since 2017.

A TALE OF BLACK AND WHITE

The many facets of ceramic materials

Ceramics are part of our daily lives, and they come in many forms. But we hardly pay any attention to them unless they break. This drawback has been an inherent property of these materials ever since people first decided to use them thousands of years ago. But what do we actually know about the properties of these non-metallic materials? What possibilities do modern, high-tech composite ceramics offer? Do they help devise solutions to global challenges? And what about black and white ceramics? Martin Schmücker from the Institute of Materials Research at the DLR site in Cologne and Dietmar Koch from the Institute of Structures and Design at DLR in Stuttgart provide some answers.

You are both researching materials that are far more common than one would generally think. Where do we find fibre-reinforced ceramics?

: Koch Twenty years ago, car brakes became the first commercial product made of fibre-composite ceramics to be introduced in Germany. The efficiency of high-temperature furnace equipment can also be greatly improved by using these composites. Nowadays, wherever one needs high temperatures and has to combat corrosion, or wants to build with greater complexity, one tries to use fibre-reinforced ceramics.

: Schmücker Fibre-reinforced ceramics are a comparatively new material. They were developed to take advantage of the positive properties of ceramics, such as resistance to high temperatures, corrosion and oxidation – while mitigating their major shortcoming, which is brittleness.

You are dealing with two types of ceramics – black and white. What are the differences?

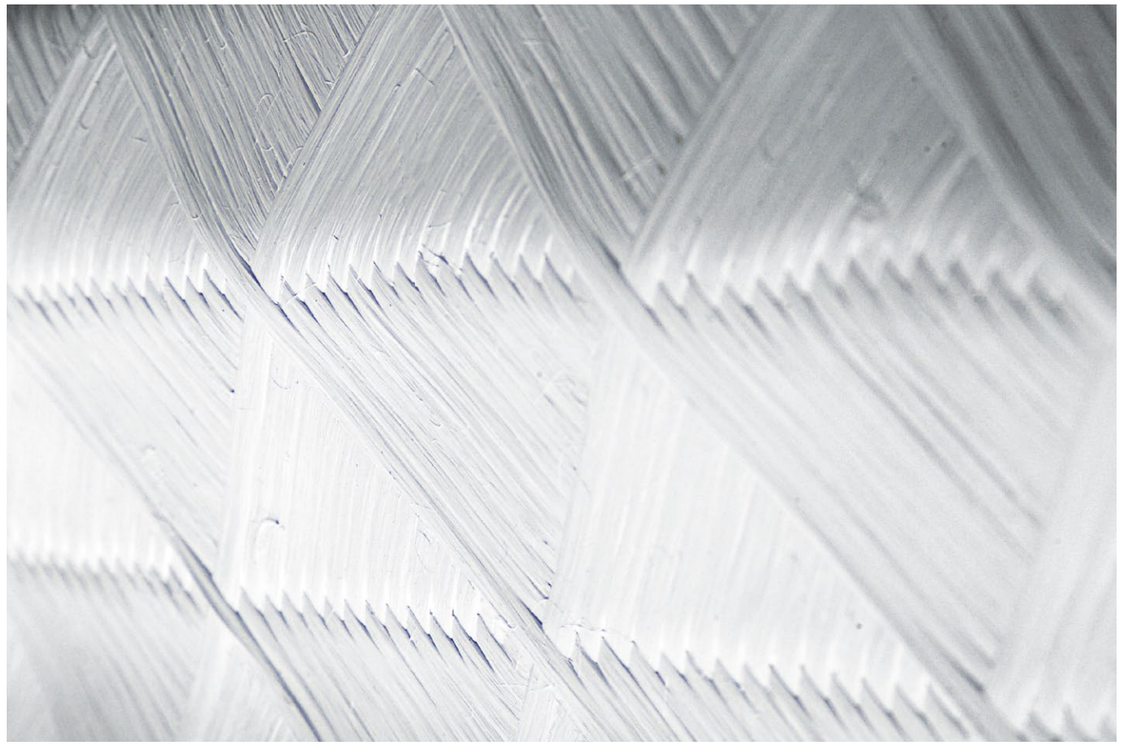
: Schmücker White ceramics are referred to as oxide ceramics. Their advantage is that they cannot oxidise further, meaning that they are stable in air- and oxygen-rich atmospheres. One drawback is that the chemical bond strength of these oxide materials is somewhat weaker, which, among other things, negatively impacts their high-temperature strength. Black ceramics consist of carbon, silicon carbide or related compounds. Both groups of ceramics have advantages and disadvantages. White oxide ceramics are ahead in long-term use under oxidising conditions; black non-oxide ceramics have the lead at very high temperatures …

: Koch … for us, very high means from 1100 degrees Celsius upwards. If we look at aircraft gas turbines, which are an absolutely key topic at present, a great deal of effort is currently being expended to make use of fibre-reinforced ceramics there as well. People are taking a close look at which oxide materials can be installed and where non-oxides need to be used. Whenever I am working above 1100 degrees Celsius, I try to use black – meaning non-oxide – fibre-reinforced ceramics. However, these need to be coated to protect the material from oxidation.

What challenges arise in the manufacturing processes? Professor Schmücker, for example, you are developing special winding techniques.

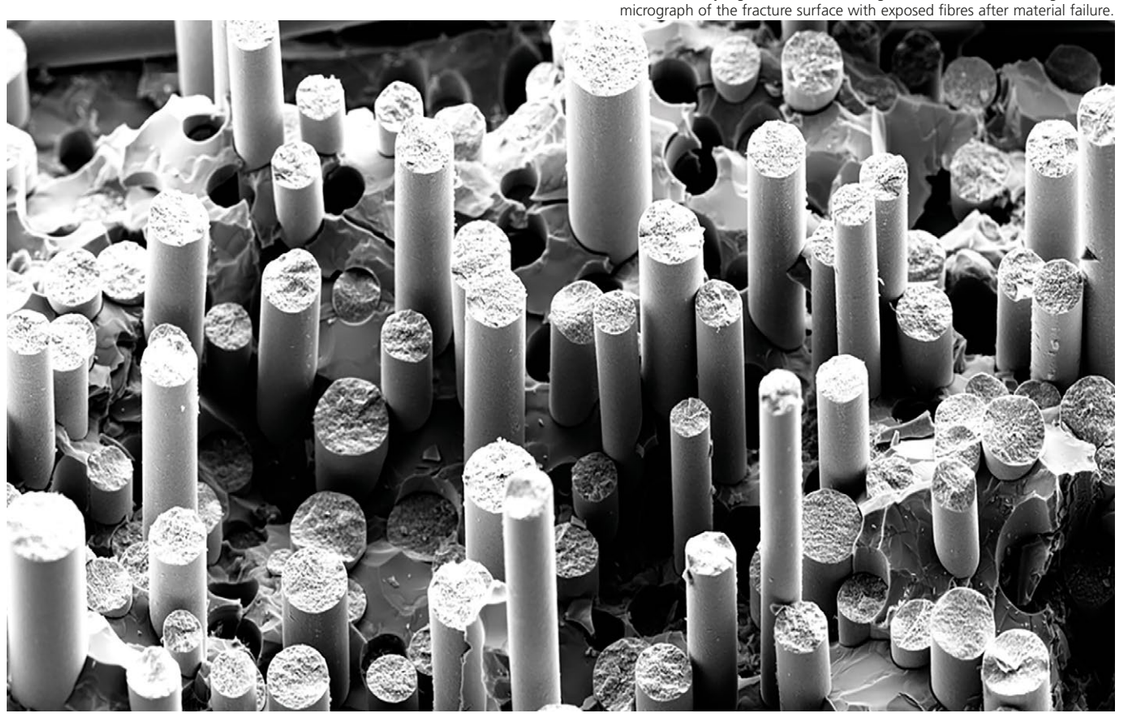
: Schmücker The winding technique is a process to produce fibre-reinforced ceramics. The principle behind it is that we guide a fibre bundle through a ceramic emulsion known as a slurry. The challenge is to have the slurry impregnate the fibre bundle homogeneously. This is not easy, because a fibre bundle of this type consists of up to 1200 individual fibres and each fibre has to be surrounded by ceramic

Dietmar Koch
has headed the Department of Ceramic Composites and Structures at the DLR Institute of Structures and Design in Stuttgart since 2011 and has been Deputy Director of the Institute since 2015.

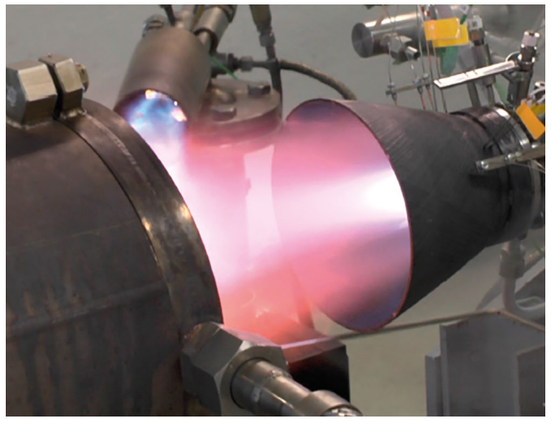


White ceramic structure using a winding technique

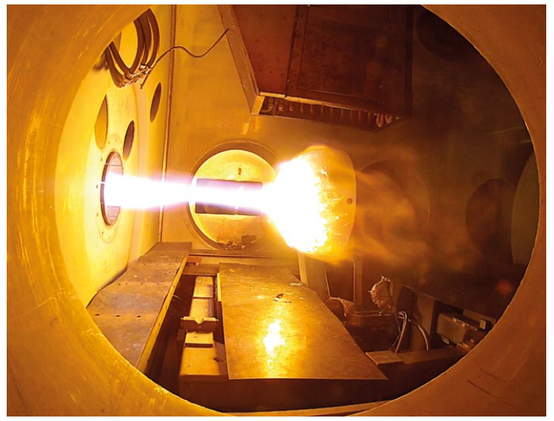
Black ceramics exhibit a very high tolerance to damage. Shown here, a scanning electron micrograph of the fracture surface with exposed fibres after material failure.



Propeller brake disc for the Airbus 400 M; the friction lining is made of black fibre-reinforced ceramic.



Nozzle produced using winding technology undergoing a hot gas test



A re-entry capsule made of fibre-reinforced oxide ceramic undergoing testing in a plasma tunnel

System for winding fibre-reinforced oxide ceramics at the DLR site in Cologne

particles once the infiltration process is complete. Once the fibre bundles have been impregnated, they are wound onto a mandrel. The winding program allows us to adjust the fibre orientation; this has to correspond with the expected mechanical loads. The winding is performed while the fibre bundle is wet. When the wound form is completed, it is dried and then subjected to a sintering process at temperatures of up to 1300 degrees Celsius, resulting in a solid ceramic material.

Does this also apply to black ceramics?

: Koch In the development of fibre-reinforced ceramics, we have been using the technologies developed for producing fibre-reinforced polymers. In both worlds, you have to work with fibres that you want to somehow give a targeted form. We are now very intensively involved with various textile technologies. We are also borrowing from the processing of natural fibres to produce spacer fabrics or other complex fibre forms. We then impregnate these with the matrix material and apply our high-temperature processes, to end up with the fibre-composite ceramic component. This issue of fibre preforming is currently also a very important one because you always want to achieve the final geometry of the fibre-composite materials directly. As finishing should be minimised as far as possible, the correct geometry must already be created during the fibre preforming stage.

That means you have a kind of predetermined shape, a kind of model of the later workpiece over which you then lay the fibres.

: Koch Not necessarily. We do not always need a negative form. They may also be freestanding preforms, which are then impregnated by dipping processes or other methods. Or, as my colleague Professor Schmücker said of white ceramics, during the winding process you take already impregnated fibre bundles, which are then processed into a three-dimensional geometry. But before manufacturing, the design step is absolutely necessary. I need to know what my component will look like and what the loads will be. I have to be able to calculate everything in advance. Then I begin production.

: Schmücker The winding process is ideal if you want to achieve cylindrical shapes. If we need differently shaped components, we currently proceed by cutting the wound layups while they are damp and then shaping them. However, there is a risk that the fibres will lose their original orientation. That is why we are developing special fibre-laying processes in order to produce even more complex components.

It sounds as if the manufacturing methods still require a great deal of manual labour. How are you moving your work towards automated processes?

: Koch Of course, this is an important topic at the moment. How can you automate everything? We are trying to accelerate fibre-composite ceramic development by focusing strongly on fibre-reinforced polymers and by directly using new automation processes.

Production automation will be the key to widespread use of ceramic fibre products ....

: Koch ... absolutely, yes, reproducibility is a very important issue. The same goes for quality assurance. If you want to use components in aircraft gas turbines, they must meet the relevant specifications, and this is of course much more difficult with manual production methods. It is therefore very helpful if the production line is machine-assisted and therefore more reproducible.

Where is the use of such expensively produced components worthwhile?

: Koch Engineering ceramics are already relatively expensive materials. Fibre-reinforced ceramics are even more expensive. In practical terms, fibre-reinforced ceramics will really only be used where they offer functional improvement. We can take a large chemical plant as an example, where there are high temperature gases and a corrosive environment. This system has to be shut down every four weeks to replace a metal component. This is a very costly procedure, but the component itself is inexpensive. If this component is replaced by one made of fibre-composite ceramic, the maintenance intervals can be significantly extended. The ceramic component may be considerably more expensive than the metal one, but the overall performance compensates for this. These fibre-reinforced ceramics will always be used where other materials are not able to survive.

The two examples you mentioned are from aviation, but you are also active in the space sector ...

: Koch These were actually the first steps we took when fibre-composite ceramics were developed at DLR. For example, many years ago we developed the nosecap for the then planned successor to the Space Shuttle. This nosecap was for NASA, so it needed to be capable of flying in space. This topic has, or course, been on our agenda over the years. Nowadays we are working with completely new matrices that are stable at ultra-high temperatures. These materials are still functional at 2000 degrees Celsius and are very interesting for new applications, such as hypersonic propulsion systems. Of course, the spectrum of applications in spaceflight is wide, especially with regard to thermal protection, control surfaces and other components that are subject to extreme thermal stress. We are working intensively in these areas.

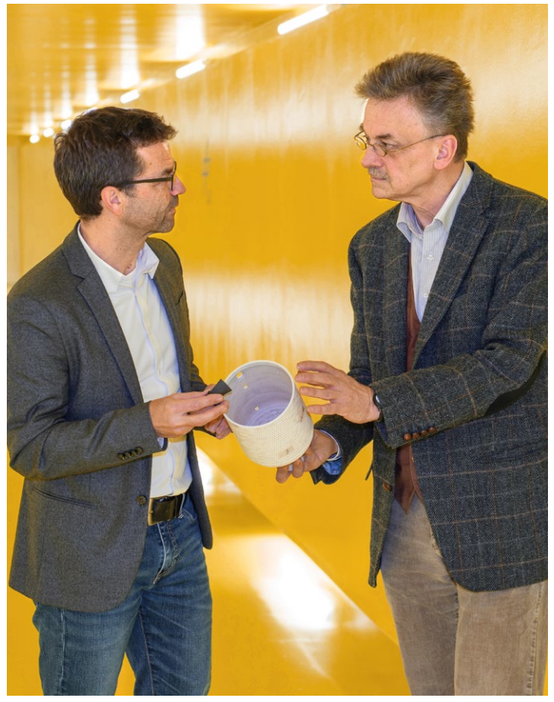
: Schmücker Although non-oxide ceramics basically offer better performance at extremely high temperatures, there are individual applications where oxide ceramics have advantages. We recently developed a re-entry capsule, which in addition to satisfying thermal and thermodynamic requirements, had to be transparent for radio waves. This is only possible with oxide ceramics.

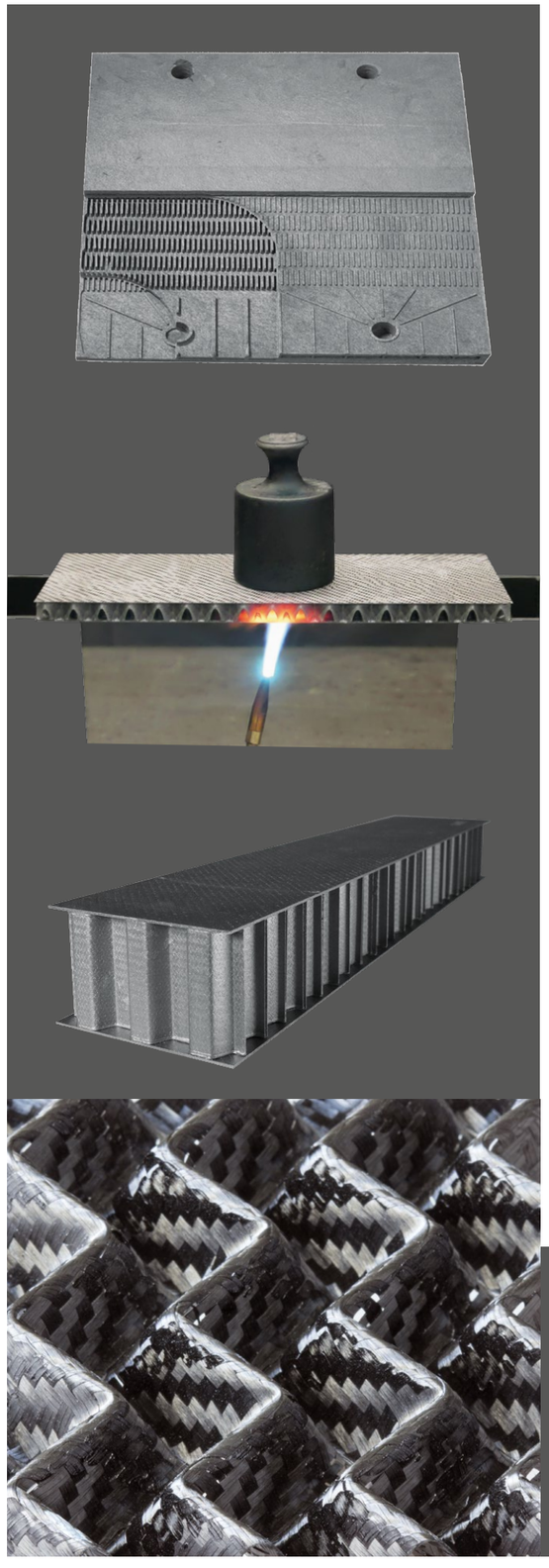
We have discussed aviation and spaceflight, so what about energy technology? For example, are there further applications in stationary gas-fired power plants?

: Schmücker The key term ‘gas turbine’ is an essential point. Generally speaking, whatever is advantageous for aircraft gas turbines can also be useful for stationary gas turbines. Therefore, we have also been working in the field of smaller gas turbines for some years, for example in the field of combined heat and power plants. There, you can achieve higher efficiencies with components made of fibre-reinforced ceramics. Other activities of our ceramics research are being pursued in cooperation with DLR’s Institute of Solar Research and Institute of Engineering Thermodynamics. Solar thermal energy is an area associated with high temperatures, where relevant material issues are the focus. Complex monolithic ceramics are used in solar absorbers. Here, we are examining durability and stability under desert conditions. Another area is functional ceramic materials, for example redox materials, which can be used to produce hydrogen from water and solar thermal energy, to be used as a synthetic fuel. In this area, we operate as part of a virtual Helmholtz Association institute. We have been researching these redox materials for five years together with two DLR institutes and three university institutes.

What is happening in Stuttgart?

: Koch We are also active in the field of micro gas turbines. We are attempting to use fibre-composite technologies to develop components that can increase the efficiency of micro gas turbines. Our focus is clearly on the design and construction of complex structures.





Functions such as redox play a subordinate role with us, as non-oxide ceramics are not appropriate. In the field of solar energy, highly porous structures are also interesting, where large internal surfaces are produced to use them as a material for solar absorbers. Although we have not yet succeeded in gaining a foothold in cooperation with other DLR institutes, we are working on it.

Isn't predicting the lifespan of such a new material a big challenge? We have decades or centuries of experience with other materials, how they degrade and how durable they are.

: Koch Yes, that is absolutely right. This is a huge challenge. But that also makes it so exciting, to attempt to comply with regulations. It must also be noted that we are not alone in the world. Together, the two departments here in Cologne and in Stuttgart make up the largest research group in the field of fibre-reinforced ceramics in Germany. But there are many others. Various research institutions, universities and companies are addressing these issues. Of course, everyone is striving to tackle the complex issue of lifespan. And what I find very exciting is that we are also trying to move forward together. That is actually working quite well. I have been leading the working group 'Fibre Reinforced Ceramics' supported by DGM, DKG and CCeV, for some years now. Everyone in this community meets twice a year to discuss how fibre-composite ceramics can be introduced into use as quickly as possible. Here, critical issues such as lifetime, design of components and more are addressed.

We have now talked a lot about materials and the differences between the Cologne and Stuttgart locations, but how exactly are you working together?

: Koch This is easy to summarise. We do not work together on colour, but we do on everything else – for example, when we talk about coating systems and calculation methods. Earlier, we already discussed how the macroscopic properties of fibre-composite ceramic components are based on micromechanical changes. This means that knowing the whole scale from micro to macro is necessary, so you have to understand how the fibre behaves within the matrix, at the fibre-matrix interface, what is going on there at an atomic level, how cracks propagate, and how these cracks develop. This simulation chain is an example of a very important issue that we are tackling together. We only have the clear distinction between the colours because it makes sense technologically. Besides this, we do not have any boundaries. On the contrary, we are trying to collaborate as much as possible in order to understand the mechanisms that make composite materials more stable and to jointly characterise the materials.

In power technology, ceramic structures enable longer service lives at higher operating temperatures. The upper image shows a modular, high-temperature heat exchanger with a complex channel structure.

Sandwich structures for use in satellites. Sandwich construction is a widely used design principle for producing thin-walled structures with low mass but very high stiffness.

: Schmücker ... very roughly speaking, the tendency is that our colleagues in Stuttgart might be somewhat more involved in engineering, whereas we are more concerned with materials science fundamentals.

: Koch That may be an important aspect. We are at home in design methods and structural technology; these are part of the mission of our Institute. We think about design methods, we think about bonding concepts, we think about lifetime. And if I then have questions about microstructure, I go to Cologne with my black material and Cologne solves these microstructural issues. In return, we solve the bonding questions for our colleagues in Cologne. That is how it fits together.

In which direction would you like to advance your work in future?

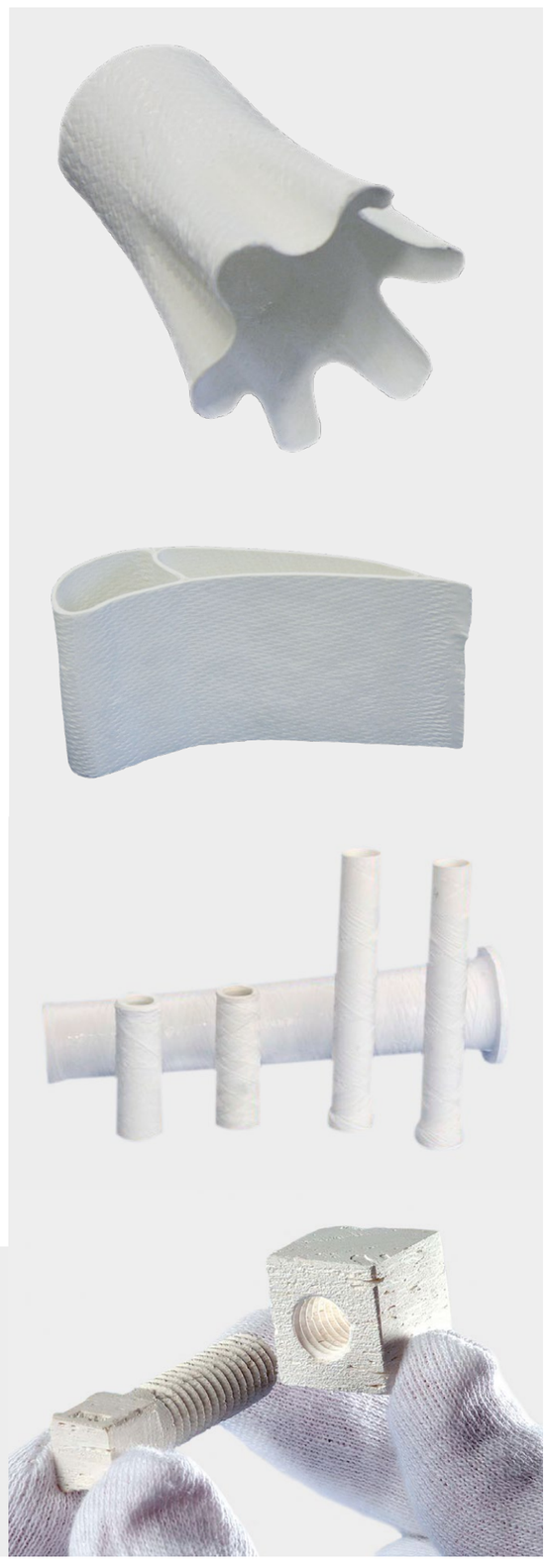
: Schmücker I would be interested in the microscopic aspects. This is actually my original area of expertise. In cooperation with colleagues from our Institute, as well as from Stuttgart and other DLR institutes, we then look at how our materials and equipment find their way into practical applications.

: Koch I studied mechanical engineering, so I come from the components side. If I had the freedom to arbitrarily define the targets, I would like to be able to design the components and then, based on this design, make my material really perfect. That means I would calculate the component, taking into account all the lifetime aspects. Then I would decide on a specific manufacturing process – for example a tried-and-tested one from the textile industry – and I would make my component using this. I would find it very appealing to follow this sequence.

With textiles, I think of a tailor-made suit.

: Koch Exactly. A tailor-made suit for an aircraft gas turbine … that sounds great.

The interview was conducted by **Michel Winand**, who works in the Department of Public Affairs and Communications at the DLR site in Cologne.



Prototype components made of fibre-reinforced oxide ceramics

Above: Two design studies for engine components, produced by the lamination process.

In between: burner tubes, manufactured by the fibre winding process.

Below: From a feasibility study on the post-processing capability of the ceramic composite.

Image: DLR/Frank Eppler

Tina Stäbler
was born in 1986, grew up in Ditzingen, near Stuttgart, and studied aerospace engineering at the University of Stuttgart. She successfully completed her degree in 2014 and has since worked in the 'Space System Integration' department of the DLR Institute of Structures and Design in Stuttgart. Within the framework of the Helmholtz Young Investigators Group 'High temperature management in hypersonic flight', she is obtaining her doctorate on the topic 'Electrical health monitoring system for thermal protection systems in space'. In January 2018, Stäbler was awarded an Amelia Earhart Fellowship.

BEATING THE HEAT

Whether on the climbing wall or in the laboratory, extremes are Tina Stäbler's thing. She enjoys conquering an apparently unscalable precipice. At the DLR Institute of Structures and Design in Stuttgart, the doctoral student is developing a structural health monitoring system for ceramic matrix composite (CMC) heat shields. This system makes it possible to identify damage to materials on space vehicles during atmospheric re-entry. The scientist was recently rewarded for her work: She was awarded the prestigious Amelia Earhart Fellowship.

Tina Stäbler is flying high with extremely durable heat shields

By Nicole Waibel

Flight experiments, stabilisation fins, rocket motors – Tina Stäbler walks past numerous aerospace structures as she makes her way across the Technology Hall. On this particular day, she is working at the Indutherm, a facility that enables the mechanical testing of materials at temperatures exceeding 1000 degrees Celsius. A porthole provides a good view of the interior. Clamped inside is a rectangular panel made of fibre ceramics, glowing with a light orange colour. Stäbler's eyes also light up when she talks about her research work. At the DLR Institute of Structures and Design in Stuttgart, the 32-year-old scientist is investigating the behaviour of ceramic matrix composite structures upon re-entry into Earth's atmosphere and the detection of damage to the material in the process.

A monitoring system could save lives in extreme cases

"Atmospheric re-entry is one of the most critical phases of a space mission. With intense heat and high mechanical stress, spacecraft are subjected to extreme conditions. An intact heat shield is essential for a safe re-entry," Stäbler explains. The importance of identifying damage in time was tragically demonstrated in the Columbia space shuttle accident of 2003. A damaged heat shield caused the United States space shuttle to break apart while re-entering Earth's atmosphere. It burned up and all seven crewmembers perished.

Stäbler is devoting her doctorate to developing a method for monitoring the condition of heat shields to be able to replace critical components of future heat shields before failure, or to prevent further damage through adjustment of the flight path. The doctoral candidate has been awarded with an Amelia Earhart Fellowship. These are given in memory of the eponymous female aviation pioneer and are granted each year to as many as 30 female scientists worldwide who are undertaking doctorates in the aerospace field.

In her studies, the engineer is primarily examining the electrical properties of ceramic matrix composites in detail, measuring the electrical resistance from which conclusions about changes in the material can be drawn. In this way, she can detect mechanical stress that can lead to dangerous cracks. The glowing sample, visible through the window of the thermionic test facility, consists of CMC. This class of material is highly resilient to stress and is characterised by a high resistance to cracks; resistance to corrosion, abrasion and oxidation; as well as a high tolerance for temperature and damage. It is also electrically conductive.

Image: DLR/Frank Eppler

Tina Stäbler in the workshop of the Institute of Structures Design in Stuttgart: The attachment of contacts on the sample plate is based on a carefully considered system. The network of measuring paths should be as precise as possible.

The panel, which is the size of a small chopping board, has 12 contacts on each side to measure electrical resistance. Stäbler explains how it works: "All contacts of the sample are connected to a test stand. Two contacts on opposite sides are always activated and impressed with current. The electrical resistance between the contacts on the one side and those on the other side is measured one after another. With 12 contacts on each side, one normal sample has 12 times 12 – that is 144 – measurements per cycle. The current test stand makes it possible to connect up to 32 contacts per side, resulting in 1024 individual measurements per cycle. Since resistance and voltage are always measured, the measurements per cycle double to 288 and 2048, respectively." The network of measurement paths with 32 contacts per side is more finely meshed, and the accuracy significantly increased.

The sample is heated in a vacuum to 1100 degrees Celsius and in other experiments up to 1750 degrees Celsius. As in a spacecraft, the contacts are in a less hot area. Cyclic tensile tests are carried out while the sample cools down. This means: strain, release, wait. What happens with the first strain? How does the sample behave with the xth strain? "In this way, I can determine whether a critical load condition has occurred. If that is the case, the tile must be replaced." The advantages of the new test procedure are that it prevents structures from failing unexpectedly and lengthens the maintenance intervals of the heat shields.

"When measuring, we have to be fast," Stäbler explains. "It is important that damage is detected swiftly." At present, the data must be evaluated after each experiment. In future, they are to be examined in real time using a special algorithm, and the critical changes are to be reported. Stäbler aims to have her measuring procedure eventually used in actual flight operation: "You could also use it in aviation." The prerequisite is that the material to be monitored is electrically conductive.

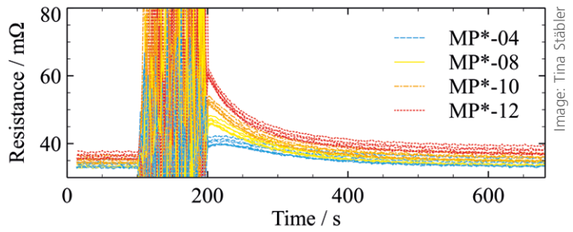


Image: Tina Stäbler

Effect of an incidence of damage, which was incorporated from second 100 - 200, shown schematically in the graph on the individual paths of the measuring paths from second 200.

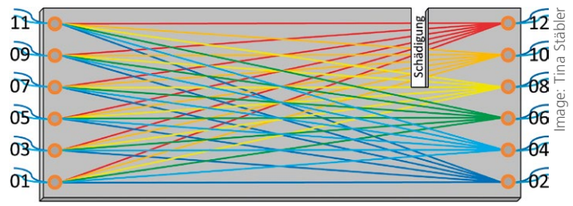
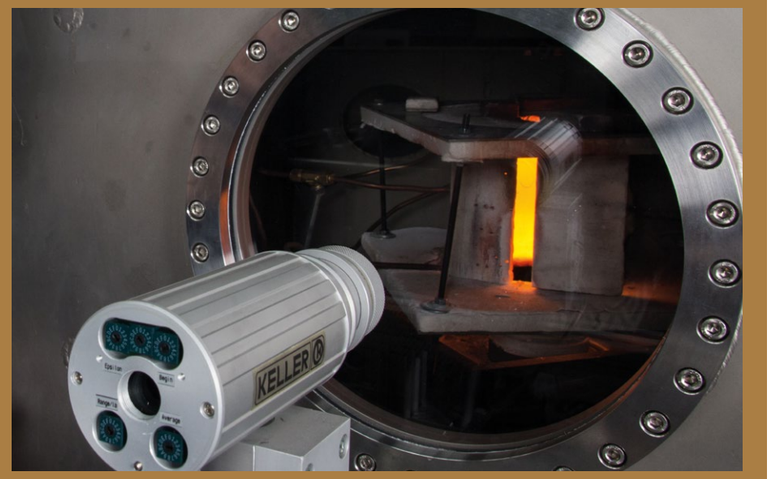


Image: Tina Stäbler

Schematic representation of a sample with damage and 12 contacts as well as colour grouping of their virtual current paths

A look into the interior of the Indutherm plant: At very high temperatures far above 1000 degrees Celsius, the sample can be mechanically tested here.



Spaceflight – a childhood dream

Spaceflight is Stäbler's passion. Ever since she was a small child, it has wielded a particular fascination. It might be a coincidence that the scientist's middle name is Ariane. "Ariane – like the European launcher," she laughs. The name says it all. "The question of whether there is life beyond Earth has intrigued me for a long time." As a schoolgirl, Stäbler took part in the Berkeley University SETI@home project, which deals with the search for extraterrestrial intelligent life. For this purpose, a telescope scans the heavens for radio signals; the processing load is distributed to PCs worldwide for the evaluation of the large amounts of data. It also went to the computer in the Stäbler household. The prerequisite was simply an Internet connection and the installation of free SETI@home client software. "The computer ran the whole day trawling through the data packets. I found it exciting to browse through the statistics," Stäbler recounts. Does she still believe in extraterrestrials today? – "I think that there is life somewhere. But will we ever catch sight of it?" However, why roam in faraway galaxies when there are also interesting things to discover so 'close' to home. "A crewed mission to Mars would naturally be terrific!" Has Stäbler, with all her enthusiasm for space travel, thought about becoming an astronaut? – "Definitely! But the next objective is first and foremost the dissertation," she says with a wink. So, although there is no going to space just now, she can certainly climb higher: Stäbler can be regularly seen in the climbing gym and at the cliff face. And when she is not working on her doctorate, she is very involved with young scientific talent. For several years, she has actively participated in Girls' Day to pass on her enthusiasm. "The book and film 'Hidden Figures', has raised awareness of women's significant contribution to spaceflight. That should remain so and will hopefully continue to increase."

Doctorate in a Helmholtz Young Investigators Group

When Stäbler joined DLR in May 2014, she had just earned her degree in aerospace engineering. "What convinced me about DLR was the opportunity to work on my project from start to finish – from the first thoughts on how the system should work, through the tests, and up to the prototypes of the test stand. The production of samples, the evaluation of data, the development and improvement, and right up to the functioning system. At DLR, you do not just see a small part of your project – you see the whole, and that is truly fantastic!"

She is still enrolled at Stuttgart University – now as a doctoral candidate. What is the challenge with getting a doctorate? "If you get your doctorate, you become the greatest expert in your field at some point. No one has devoted themselves to this more than you yourself. So beyond a certain depth, the points of contact are few and far between." Such a focal point for Stäbler is Hannah Böhrk, the deputy head of the department 'Space System Integration'. Böhrk also leads the Helmholtz Young Investigators Group 'High temperature management in hypersonic flight', where she investigates modern heat shields in simulations and experiments, with the help of Stäbler and other young scientists. They wish to better understand the thermal behaviour of structures during re-entry and hypersonic flight. "In the Helmholtz junior research group, we research a comprehensive matter intensively in a small team," Böhrk says. "As a result, we are in constant communication with each other." Stäbler will be the first graduate of the group and is now really inspired to complete her work and then to further develop her topic in new directions. In addition to the high-temperature applications from spaceflight, she sees the detection and localisation of damage in aircraft structures as an area of application. "It is fun to engage in excellent research with such focused doctoral students!"

With so much hard work, it is good to take things easy once in a while. Almost excitedly, she reports on her latest achievement, called 'Terraforming Mars' – a board game that involves transforming Mars into an Earth-like planet. Who knows, perhaps Stäbler will one day fly to the Red Planet… You need intact heat shields for this, too.

Nicole Waibel is responsible for marketing and public relations at the Institute for Structures and Design in Stuttgart and Augsburg.

Women in astronautics

Until 14 October 2018, the Universum® Bremen will be showing the photo exhibition

'Space Girls Space Women'

in which women from aerospace are portrayed.

www.universum-bremen.de/space-girls-space-women

Amelia Earhart Fellowship

Amelia Earhart Fellowships are awarded each year to as many as 30 female scientists worldwide in the field of aerospace engineering in order to strengthen the position of women in aerospace-related sciences or aerospace-related engineering. The US$10,000 fellowship is in memory of the aviation pioneer Amelia Earhart, who in 1932 became the first woman (and the second person after Charles Lindbergh) to fly across the Atlantic. The fellowship is awarded by Zonta International, an association of professional women in responsible positions who help improve conditions for women with respect to legal, political, economic, occupational and health matters. The first fellowship award dates from 1938.

DLR researcher Tina Stäbler at the award ceremony on 26 January 2018 in Stuttgart. The award was presented to her by Sigrid Duden, Governor of Zonta District 30 (right).

High-precision measuring instruments in the air: the Channel Sounder in the hangar at the DLR site in Oberpfaffenhoffen before its installation in the Falcon research aircraft.

TRACKING RADIO WAVES

When information is transmitted by radio – whether for communications, position determination or authentication – it must reach its destination reliably and be received correctly. Also, in view of increasing levels of automation, ever-increasing importance is attached to having reliable communications links between various systems. To open up new frequency bands or make better use of existing ones, DLR researchers are surveying radio channels with a special instrument that covers all areas of research – the Channel Sounder. Work on the use and development of this indispensable measuring instrument began 15 years ago.

The Channel Sounder analyses the propagation of radio signals – for the best reception

Uwe-Carsten Fiebig and Thomas Jost

Everyone has experienced hearing their voice reflected from the face of a nearby mountain, with the typically long echo. The mountain scenario is an expanded version of what we hear in an empty room. Why is that? Nature provides the answer; these sound waves are reflected off of the walls. These types of reflections are greatly dependent on the wall characteristics – including their dimensions, the material they are made of and the roughness of their surfaces. If there are strong echoes, anyone listening to a spoken voice will have difficulty understanding what is being said.

Similar effects are experienced with the transmission of radio waves. In most cases, electromagnetic waves reach the receiver not only through the direct path of propagation – meaning the line-of-sight connection between the transmitter and the receiver – but also via reflections or echoes. At the receiver, the direct signal has the reflected signals superimposed on it; this causes distortions of the direct signal and, in turn, an erroneous reception of the transmitted information bits. The quality of reception is determined by the transmission channel, which defines the characteristics of propagation between the transmitter and the receiver.

When new radio systems are being developed, it is important to have precise knowledge of the transmission channel – that is, the propagation conditions. These conditions are dependent on many parameters, such as the frequency and bandwidth of the transmitted signal; the physical environment in which the radio system is operated; and the relative speed and separation distance between the transmitter and the receiver.

Researchers examine the transmission channel characteristics through the use of a ‘Channel Sounder’. This measuring instrument consists of a transmitter that sends out a known test signal, and a receiver that records the signal in a highly accurate way. The evaluation of the data acquired makes it possible to achieve a precise mathematical definition of the transmission channel. The researchers construct a model of the propagation characteristics – the ‘channel model’. This model provides the basis for designing and optimising radio systems, as well as for computer simulations of their transmission quality.

The Channel Sounder in operation – transmitter (left) and receiver unit (right).

In the first satellite Channel Sounder campaign, the receiving unit moved through Munich city centre in a measurement bus.

During the first measurement campaign, the transmitting unit was on an airship.

The Channel Sounder in DLR's Dornier Do 228-101 (D-CODE) research aircraft

Travelling across land, sea and air

Whether investigations are needed for satellite navigation, aircraft radio, maritime communications, vehicle-to-vehicle communications, or radio systems on trains, the Channel Sounder has an extremely diverse range of applications. Researchers at the DLR Institute of Communications and Navigation have already carried out numerous measurement campaigns to record the propagation characteristics of many different transmission channels. Modifications had to be made to the Channel Sounder to open up new frequencies. The Channel Sounder was originally designed only for the measurement of transmission channels with a carrier frequency of 1.51 GHz (L band), with a bandwidth of 100 MHz. With time, its range of capabilities has been expanded to include several carrier frequencies in the VHF frequency range, and in the S band and C band sections of the spectrum. Aviation, satellite navigation, as well as road, rail and maritime transport are all areas of research in which regular breakthroughs have been made in the field of radio transmission thanks to the researchers' campaigns.

In the Channel Sounder's first practical application in 2002, DLR researchers surveyed the propagation conditions affecting satellite navigation. The accuracy of GPS receivers is greatly dependent on the transmission channel because the signals have to travel over a long distance, and can – in cities, for example – experience strong reflections off of buildings. The transmission system sent the test signals not from a satellite but from an airship that was parked in a position several hundred metres above, while the measurement bus carrying the receiver unit drove through the streets of Munich and recorded the signal. Working on the basis of the measurements gathered, researchers were able to achieve an unprecedented level of detail in defining the propagation phenomena that satellite navigation signals are subjected to. The researchers noticed strong signal echoes in streets with a lot of building development; these echoes had a remarkably long duration. In such cases, a navigation receiver's position error may lead to a deviation of more than 50 metres from the true location.

At the Institute, new methods were subsequently developed to significantly reduce the effects of multiple-path propagation affecting a navigation receiver – with the result of providing far more accurate position determination. The channel model that was developed has been standardised in the Radiocommunication Sector of the International Telecommunication Union (ITU-R), a special organisation within the United Nations dedicated to the technical aspects of telecommunications.

From 2008 to 2010, in a range of different measurement programmes, DLR researchers expanded the use of the Channel Sounder to investigate the propagation conditions for signals reaching a mobile receiver within a building – either from a satellite or from a mobile radio base station. Measurements confirmed that signals would pass through windows (if not metal-coated), walls and even concrete ceilings to reach the interior of the building. But within the building, the signals become greatly attenuated and reflect off walls, doors and fixtures. Navigation is extremely difficult in such a multipath environment. Deeper inside the building, the received signals become so weak that it is impossible to achieve reliable position determination on the basis of satellite signals.

In a subsequent measurement programme, researchers showed that C band signals experience much greater attenuation as they enter a building than signals in L band. Accordingly, the advantages of potential broadband navigation signals in C band can only be exploited outdoors, and not inside buildings. Indoor applications tend to require lower-frequency signals. A comparison between transmission channels in L band and C band is necessary to decide whether the next generation of Galileo signals should be broadcast at different frequency ranges.

In 2003, the Channel Sounder was used in an aviation application to survey the transmission channels within an aircraft cabin. These transmission channels are important for aircraft manufacturers when they wish to replace cable-based communications with radio links. It was possible to determine which areas of the cabin could easily receive radio signals, learning in the process that there are many points (typically surrounded by metal) where the radio signal experiences severe attenuation or is not received at all. In 2007, the scientists investigated the transmission channel between the apron control tower and aircraft at Munich Airport. What they used was not an aircraft but a measurement bus, with which they tested various scenarios on the runway – both during the day and at night. A typical airport architecture – with its wide-open spaces and large buildings – is a recipe for changing behaviour in the transmission channels. This channel exhibits very strong, long-lasting echoes, together with signal shadowing near the positions where aircraft are parked. The channel model, as developed, takes these characteristics into account, with the result that DLR was able to adapt the new AeroMACS radio standard, which is designed for transmission between control towers and aircraft or vehicles on the ground, to these conditions.

The Channel Sounder's travels included airborne operations, as in a 2009 measurement campaign conducted in order to investigate the radio channel between two different aircraft using a carrier frequency of 250 MHz. The aircraft flew over a range of land surfaces, such as bodies of water, fields, forests and conurbations. The signal reflected from the ground proved to be exceptionally strong – to such an extent that it equalled the intensity of the direct signal. The direction in which the antenna was pointed was sufficient to make the reflected signal even more powerful than the direct signal in the case of some aircraft banking manoeuvres. The disruptive effect caused by the reflected signal can be markedly reduced by employing an equaliser.

Traffic applications

Rail transport is another area of application for the measuring instrument. In addition to a measurement campaign conducted on two trains (DLR Magazine 151/152 presented an article on this topic), the DLR measurement team investigated the transmission channel between two vehicles while both the transmitter and the receiver of the Channel Sounder were in motion. On the basis of the results achieved, the researchers were able to develop a model that incorporated the constantly changing transmission characteristics arising between moving vehicles. This model will be used to optimise vehicle-to-vehicle communications technology.

Future for good reception

Many new questions will await future scientists at the Institute of Communications and Navigation. These questions may include investigating higher bandwidths and other frequency ranges, as well as whether it is necessary to survey channel characteristics that were not previously relevant or even impossible to examine. Using a new Channel Sounder that is scheduled to go into operation in 2018, it will be possible to rely on ultra-wideband signals with a bandwidth of up to 1 GHz to improve the resolution of echoes. In addition, the researchers will be able to increase the measurement rate in order to capture higher-frequency Doppler effects. Composite antennas for both the transmitter and the receiver will also be supported by the new Channel Sounder. As a result, the foundations for good reception and reliable transmission technology have been laid.

Uwe-Carsten Fiebig heads the Communications Systems Department. One of the department's core competencies is the analysis and modelling of the propagation characteristics of radio signals for space, aeronautics, transport and maritime security applications. **Thomas Jost** has been a leading scientist in the field of radio wave propagation for many years and has been responsible for the Channel Sounder in almost all measurement campaigns.

During a measurement campaign in 2014, during which the researchers examined the radio link between a ship and the mainland, the receiving antenna was installed on the Warnemünde lighthouse. In 2016, one team recorded the transmission channel between two ships (DLRmagazine 148/149 reported about this).

In two moving high-speed trains, DLR experts investigated the propagation of radio waves for train-to-train communication in Italy.

THE MATTERHORN IN THE GASOMETER – A TEST OBJECT FOR DATA VISUALISATION

Soaring through the sky at 250 kilometres per hour, the twin-engine DO-228 approaches a restricted military area. Its final destination can be seen from afar: the snow-covered pyramid of the Matterhorn, gleaming in the sunshine. The DLR pilots let the aircraft descend to the predefined flyover height. Their goal is to fly just 400 metres above the peak. Meanwhile, a camera is set up by a DLR staff member to take photographs from the aircraft cabin. A breathing mask provides him with oxygen at an altitude of almost 5000 metres. The 3K camera keeps an eye on the Matterhorn through an opening in the floor.

Almost 3000 images, or 60 billion pixels, are brought back to DLR's Earth Observation Center (EOC) in Oberpfaffenhofen. There, Pablo d'Angelo computes a high-precision ground model from the pairs of images. He considers the Matterhorn to be a tough test. With precipitous slopes exceeding 2000 metres and extreme exposure differences between expanses of snow and shade, it places high demands on the aerial camera and the algorithm, both of which were developed at DLR.

The aerial camera is based on three high-precision professional digital cameras. These are significantly less expensive than specialist airborne sensors, and can be replaced quickly by more up-to-date models. As such, the 3K camera benefits from the fast-moving nature of the digital camera market. The system is particularly notable for its speed, with the images selected and processed on board. For example, in the event of a disaster, the images and terrain models can be transmitted almost instantaneously and directly from the aircraft via laser or microwave to a mobile ground station up to 70 kilometres away. The system has passed the test, and Pablo d'Angelo is pleased. Details of the summit can be made out down to a centimetre scale. The scientist has also managed to spot various mountain routes and the odd climber in the pictures.

The data from the images comes into play again a few weeks later. Hundreds of virtual cameras float above the mountain terrain model displayed on the screens of Gregor Hochleitner and Alvaro Chignola. The DLR scientists have further developed their visualisation methods to allow a seamless texture to be projected onto the model. The virtual model of the Matterhorn is thus transformed into a realistic sculpture. The body of the mountain had to be greatly simplified in order to allow this structure to take shape. The surface then acquires details and a lifelike appearance through an animation created at the Earth Observation Center using aircraft and satellite images. Ultimately, it contains 67 million pixels – eight times that of a high-definition cinema production. Thanks to the scientific visualisation experts at the EOC, such scales no longer present any problem. That said, the DLR staff are still delighted that they have managed to pull it all off. They, too, have proven themselves capable of rising to the challenge presented by the Matterhorn.

Nils Sparwasser

At 43 metres deep, 30 metres wide, 17 metres high and weighing eight tons, the Matterhorn sculpture floats in the Gasometer.

Thanks to the virtual copy of the Matterhorn, it was possible to define the ideal size and precise cut-out for the subsequent sculpture in the Gasometer.

The installation and overlay of the 17 projectors were tested weeks before construction using a specially-made 1:8.5 scale polystyrene model

The sculpture was assembled bit by bit from aluminium girders, a structure of iron bars and panels, and lifted up by heavy duty engines. The screen for the animations of the DLR Earth Observation Center measures over 2000 square metres.

HOUSE OF THOUGHT

Can we see thoughts? And hear ideas? Can these be touched? What do we really mean by 'reality'? Do we feel anything when we find ourselves immersed in an 'augmented reality'? Can the physical and digital worlds merge? How do we form our image of all this, and how do we recognise it? Do we use science, technology, or art? Can a museum help us with this task? Hang on – what? A museum?

Ars Electronica Linz – A tour around the museum of the future

By Peter Zarth

The Ars Electronica Center (AEC) is located on the banks of the Danube in the proud city of Linz, which was a European 'Capital of Culture' some time ago. The AEC sees itself as a museum. If we look into that word a little more closely, we discover that it means 'House of the Muses' – and so it is, if a Muse of Digitalisation exists. Ars Electronica is also collaborating with the Los Angeles Philharmonic and proponents of other art forms for a project involving Ravel's 'Mother Goose'. And this then leads to the realm of fairy tales... Some advance notice: No road is too far from Linz to forgo the amazement of a visit here.

With a lightness that finds material expression in the architecture, we are absorbed by the shifts in light – a passageway formed from emptiness, space and height. Few colours are present here – yellow surfaces, warm grey, muted tones. We pause. The sense of being in a sacred place is rather soothing. Our eyes seek out anything that might allude to the name – to Ars, to Electronica.

Our gaze remains fixed on a replica of the Nike of Samothrace, in gold-coated wood. Gold, rather than white! Classical beauty transmuted. Fortunately, this will be the only exhibit here that really pains the eye.

Ars Electronica's declaration of intent – 'art, technology, society' – might seem somewhat modest, but that is certainly not the case in places like the BioLab, the FabLab, the BrainLab or the VRLab. Others follow – Futurelab, SoundLab, Deep Space 8K and GeoCity. We might also describe it in terms of tangible bits or radical atoms. In these globalised times, such words have a veneer of coolness to them. Here, names such as Spaceship Earth, New Views of Humankind and the Kids' Research Laboratory all seem poignantly outdated.

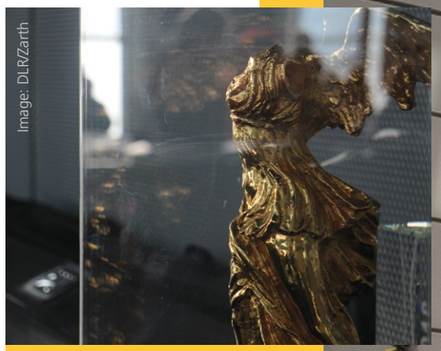


Image: DLR/Zarth

Not classical ... but beautiful? The gilded Nike of Samothrace – Ars Electronica's prize to the festival winners.

A museum listens

What follows is a glimpse of the aesthetic world of the future. Tomorrow is already here, and we can reach out and touch it. In part, this is thanks to Scott Ritter and Jakob Edelbauer, "the masterminds of interior design," as Gerfried Stocker, Artistic Director of Ars Electronica, describes them. "Being able to freely use technology here engenders respect. We want a museum that can and does really listen to the visitor." Young people, in particular, have been careful not to damage anything precisely because so much can be used here. Art at the AEC encourages design, discovery and experimentation. Even the explanatory panels are astounding for the remarkable brevity of their text.

Always pushing the limits

Having just come out of the lifts, where many virtual jellyfish will have surprised them, visitors turn a corner or walk down the long flight of stairs to find the AEC buzzing with life. When have you ever seen so many people in one museum? Almost every age group is represented here, with many immersed in (inter)active pursuits. "The architects sought to implement the wishes, ideas and requirements for Ars Electronica in a functional and aesthetic way," Stocker says. The space, the expanse – there is plenty of room for your thoughts to wander.

"We point out boundaries, and then break them down," says Andreas Leeb, Austria Manager at the European Space Education Research Office (ESERO) and an AEC employee. As a biologist, he is interested in what is universally applicable; what connects every living being and constitutes the defining factors of life. Genetics is wonderful, emerging by chance, he says. But even chance occurrences raise questions. Ars Electronica is constantly crossing boundaries.

Image: Ars Electronica

The Ars Electronica Center is also an architectural masterpiece

What does it mean to be a body?

In the BioLab, we can see for ourselves what Leeb means. Judith Wittinghofer, an ‘info trainer’, explains the wonders of the human retina: “This is where our picture of the world comes to life,” she says, traversing the boundaries between biology and Earth as she draws a connection between the visitor’s eye and a depiction of the Retina Nebula in the constellation Lupus. The two are astonishingly similar; there is a cosmos in each of them.

As we cultivate this vision of our very being, it is fitting to quote one of the museum texts, which says it all: “How do I see myself? Who or what influences where I turn my gaze? Our bodies think along with us. What does it mean to be a body? That is one of the key questions that arise in the development of Artificial Intelligence. New technologies would not exist without a person, to put it in a nutshell.” We can sum up our tightrope walk into artificial realms that succinctly.

Festival, Prix, Centre, Futurelab

The boundaries between art and technology are blurred. Discovery, research, experimentation and investigation are all encouraged – instead of definitions. For Ars Electronica, the key objective is to establish how art, technology and science influence society, and how they work their way into it.

Ars Electronica embodies a holistic concept: “The starting point for the entire thing – including the ‘Ars Electronica Festival’ (1979) as a forum for artists engaged in computer and media art; the ‘Prix Ars Electronica’ (1987); the ‘AECenter’ and the ‘Futurelab’ (1996) – arose from interest in a discourse that had yet to take shape in the 1970s,” says Kristina Maurer, AEC Exhibitions Producer. “Science and art work together to break down boundaries. Thinking is a driving force for us all – even if it takes us in critical directions.” While media artists might have been the target audience back in 1979, today the public, children and young people are included, too, she says. “The guiding theme of the 2018 Ars Electronica Festival – ‘ERROR: The art of imperfection’ – continues the discourse on Artificial Intelligence, which was also our focus area in 2017,” Stocker says. “Our question is this: Where does our strive for perfection come from?”

Essence of a robot

It is a big claim: “More than any other institution, Ars Electronica takes an all-embracing approach to addressing techno-cultural phenomena,” say the organisers. The Futurelab is seen as a “driving force for research and development.” This area “has been designed as a think tank for art and science, and as a studio lab or lab studio. In the form of futuristic prototype sketches, the innovations dreamed up here are intended to serve as a basis for discussion, as well as an impetus for society to participate in the discourse on future-related topics.” Questions include: “What is the essence of a robot?”; “How can people and machines maintain dialogue?”; “How can familiar art forms be expanded and shaped?”

Collaborative partners working with the Futurelab scientists range from companies such as SAP through to the Japanese telecommunications group NTT, as well as universities. The discourse is open to all: “Depending on the theme of our festival, we invite all sorts of people – from philosophers to Zen monks to technology critics – encompassing a whole spectrum of thought, not least because we want to open up a philosophical dimension to this discourse,” Stocker says. “However, we are not a philosophical colloquium.”

How can we grasp the digital in the physical world?

We may now leave theory to one side and get our hands on tangible bits. The Tangible Media Group at the MIT Media Lab – an offshoot of the Massachusetts Institute of Technology – has provided the ‘SandScape’ exhibit. The AEC has long worked together with MIT, according to Stocker. An ‘info trainer’, Armin Pils, makes his way over to us. Many of these info trainers are university graduates. Stocker refers to them as ‘our heroes’. They bear the brunt of the educational communication work.

Pils has a degree in Fine Arts, specialising in painting and graphic design. He invites you to stick your hands into a mass of white tapioca pearls. What seems like an orange-yellowish sandpit is actually “a place where magic happens,” he claims. A text panel puts it a bit more prosaically: “Tangible Bits is a successful attempt to overcome the dominion of pixels and make information comprehensible. The ‘Tangible User Interfaces’ created by the MIT Tangible Media Group provide an intuitive translation of digital content into material forms and formats.” Today, Hiroshi Ishii’s ‘SandScape’ is seen as a classic of media art. According to Stocker, this has given rise to terms such as ‘hybrid identity’ and ‘radical atoms’. The Tangible Media Group poses an astounding question: “How can we grasp the digital in the physical world?”

The alchemists of our time

Working closely with Ishii, the AEC is striving to answer this question, under the slogan ‘Radical atoms – rethinking materials’. The ‘radical atoms’ in question stand for a kind of “digital core meltdown that fuses information and matter.” Information is “liberated from the confines of the pixel domain, while the atoms are released from their frozen state and made to move.” The result is “smart matter that can be remodelled over and over again.” Scientists and engineers have used this to develop high-tech materials with new properties and capabilities. Neuro- and biotechnologies also play an important role, as do robotics, hardware, software and craft traditions.

In the meantime, ‘SandScape’ shows the shape that we are making out of the tapioca balls as a 3D image on screen. Is this where rationality meets magic? The title of an Ars Electronica programme on this topic from 2017 still has a certain charm: “Radical atoms and the alchemists of our time.” Armin Pils takes a more down-to-earth view: “I hope that a visit here might change the way people think. In any case, this is a lifelong kindergarten, where you can always get a fresh take on things.”

Deep Space 8K – utterly unique

We have reached a high point. There is nowhere else quite like this – an expanse of wall measuring 16 by 9 metres, with a 16 by 9-metre floor projection, in addition to laser tracking and 3D animations – entire visual worlds are projected in 8K resolution. There are gigapixel images, time-lapse videos, 3D historical images of ancient Rome and the like, a trip to the International Space Station and outer space, pictures taken inside a human body, and games. The possibilities afforded by Deep Space 8K mean that no presentation is the same.

Melinda File, an info trainer and senior presenter, leads a group of children and teens into the exhibit. They could soon lose themselves in this ostensibly 3D space. File, however, is adept at keeping them under control and makes sure her talk is straightforward and to the point. Even the liveliest children soon calm down.

We end the tour thoroughly impressed and enjoy a sojourn in the completely glass-walled Cubus restaurant, with its view over the city and the Danube river. But the true highlight is yet to come …

Play the façade

It is long past midnight, around four in the morning. Despite the early hours, a few scattered young people dance around the main square of Linz, surrounded by the dim light of the streetlamps. The sky is coloured in dark blue. We walk towards the bridge over the Danube. Opposite us is the Ars Electronica Center, seemingly made of light. Right where its interior merges with the exterior is a glass membrane that now glows in different colours with a transparent lightness. They morph from metallic green to light blueish-purple to crimson-red, before turning a deep burgundy, gently and silently, without eagerness.

Anyone can programme the lighting of the façade to match the rhythm of their favourite music, controlling the change of colours via a public terminal and their smartphone. “There is no reason why art and technology should be out of bounds to each other,” Stocker says.

“I was in the future”

Towards the end of her time at the AEC, a visitor asked, “Having visited the future, what effect might it have on the way I feel about things?” The question remains unanswered. The artistic director would no doubt be pleased.

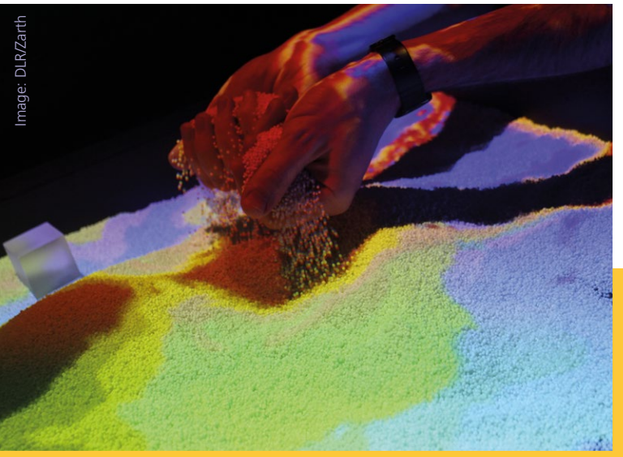
Does Gerfried Stocker have a favourite fairy tale? He looks completely surprised and has a think. “Maybe ‘The Sorcerer’s Apprentice.’ The way in which Goethe tells the story really resonates with our preoccupations – even in this day and age. We humans have brought about a crisis – professionally, morally and ethically. The question is how we are going to deal with it. It is up to us to take responsibility as we look towards a new future of technology and machines.”

Can we see thoughts, hear ideas, and touch bits? Ars Electronica brings thoughts and the senses closer together. There are no definitive answers, but rather a foray into a building that raises questions.

Image: Ars Electronica

Ars Electronica Center – the art of light.

Image: DLR/Zarth



SandScapes – the MIT Media Lab wants to free information from the ‘pixel universe.’

Ars Electronica Linz

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4040 Linz
Austria

www.aec.at

Opening times:

Tuesday, Wednesday and Friday	09:00–17:00pm
Thursday	09:00–19:00
Saturday, Sunday, public holiday	10:00–18:00
Monday (including public holidays)	closed

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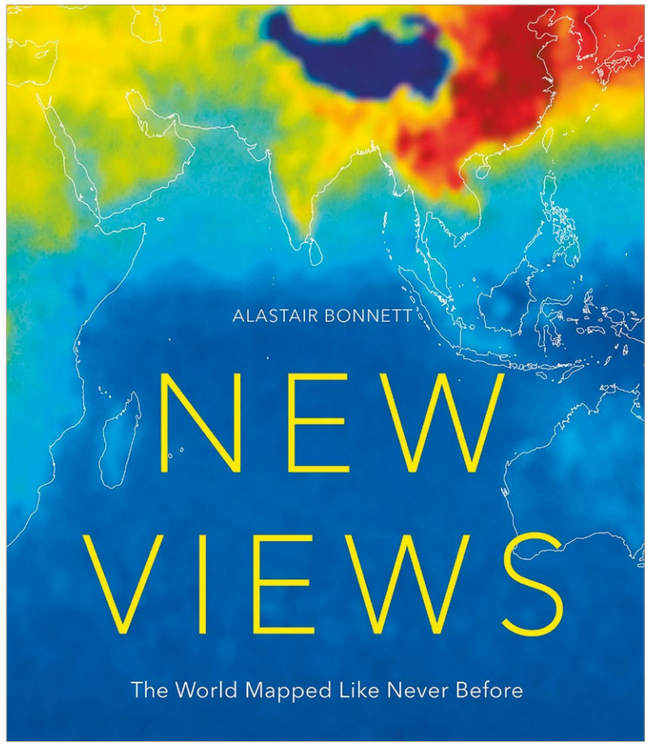
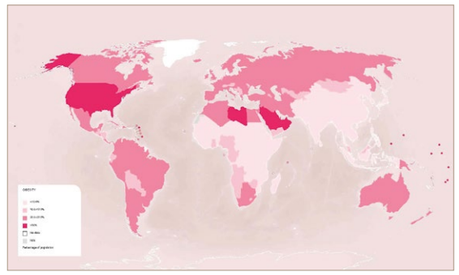


WHAT ANTS CAN TELL US

Fifty maps of a rapidly changing planet and the lives of its inhabitants

A quick flick through the 50 maps in **New Views: The World Mapped Like Never Before** (Aurum Press), most of them showing the whole world, might not cause much initial excitement. World maps cover double-page spreads – often in muted colours – alternating with pages of text, and the occasional diagram or country outline, many in a spartan design, sometimes featuring nothing but a single number. Then comes a brightly coloured map against a black background. Red areas represent forest loss, while dark blue stands for growth. Look closer, and you will see that there is three times as much loss as growth. The following page features orange for the expanses of North Africa and the Middle East, denoting water stress. Maybe this atlas has something going for it, after all. The 224-page volume of images and text by Alastair Bonnett offers much more than would appear at first glance. What is more, the text is more than just an adjunct to the maps; it comprises informative essays that Bonnett, a professor of social geography from England, has written to accompany the overview maps, providing plenty of food for thought. They are invaluable for helping the reader to connect the dots. Once you have properly dipped into the book, you will find yourself returning to marvel at the maps and immerse yourself in the essays again and again. It covers a surprisingly broad range of topics. Their apparent triviality proves provocative, and then you inevitably succumb to their charm.



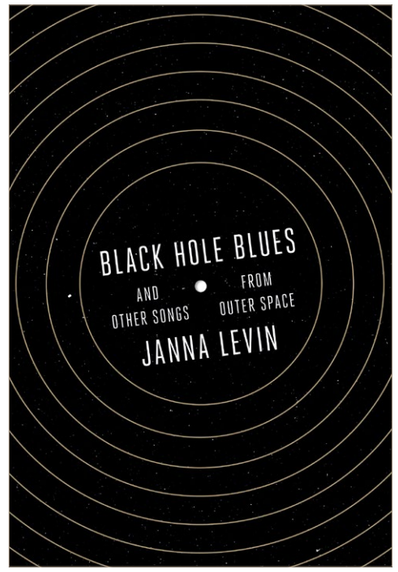
The book is divided into three main sections: Land, Air and Sea; Humans and Animal; and Globalisation. While information on diverse phenomena ranging from asteroid impacts and lightning strikes to air traffic and undersea cables awakens the reader's interest, the maps and essays about the species diversity of amphibians and birds, about neglected tropical diseases, and about obesity and happiness soon spark an emotional connection. Meanwhile, the coverage of fast-food chains, disappearing languages, gun ownership and sugar consumption practically make us wince. Data from Earth observation satellites is used to create images, while modern geographic technologies enable complex issues to be presented clearly on paper. The images engrave themselves on the reader's mind, awakening him or her to the realities.

One of the surprising themes covered by the atlas is ants. Are people really pondering their biodiversity? In actual fact, information about the geographical distribution of ants is highly valuable, not merely because they are among the most successful creatures on Earth, but also because they are some of the most important beings in their ecosystem. They are both disposers and a food source; they improve the soil and hunt insect pests. Of all the creatures on which humans are dependent, the ant is at the very top of the list, declares Bonnett, quoting the famous biologist Edward O. Wilson. We need these invertebrates, but they don't need us. It is a sobering thought.

Alastair Bonnett, whose book Off the Map: Lost Spaces, Invisible Cities, Forgotten Islands, Feral Places and What They Tell Us About the World was published in 2015, engages readers of 'New Views' by calmly drawing them in without lecturing, and dispensing with polemical debate in favour of an almost dispassionate objectivity. Yet it is a thoroughly thought-provoking experience. After reading it, we find ourselves asking: What has been done to our planet? And, more painfully: What are we doing to ourselves, our Earth and our descendants?

Cordula Tegen

SONGS FROM OUTER SPACE

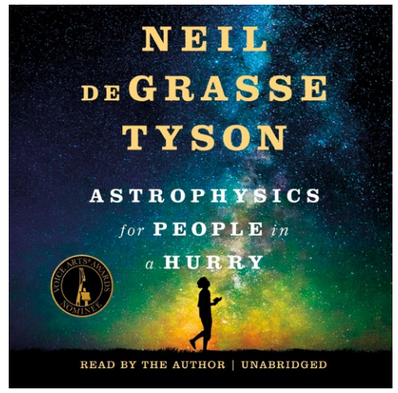


Deep in the heartlands of eastern Louisiana we find a strange contraption: two large, hollow concrete tubes four kilometres long that are joined together in an L-shape. Why anyone would want to build such a mysterious object in an alligator-infested swamp could be a mystery – unless you have been following the developments in gravitational wave observation.

In **Black Hole Blues**, Janna Levin tells us the inside story of the arduous road towards the discovery of gravitational waves at the Laser Interferometer Gravitational-Wave Observatory (LIGO). Their existence was first predicted by Einstein in 1916, but their direct detection would not take place until one century later – on 14 September 2015, LIGO detectors made the world's first direct detection of gravitational waves, heralding a new era in astronomical exploration. Levin does an excellent job describing the hardships that the scientists faced, but she also emphasises their unwavering optimism throughout. Although the depictions of the various principal scientists' lives can be slightly long-winded, they do provide some lighter material that helps to create a balance with the somewhat more technical descriptions of the experiment. Most of the book was written before the first detection was made, which provides an interesting perspective in which the feasibility of the experiment has yet to be confirmed. Combined with the fact that the book requires minimal background knowledge, it is a nice read for anyone interested in modern physics and astronomy.

Ruben Walen

HASTE MAKES WASTE



Astrophysics for people in a hurry (Audible Audiobook) requires time and patience. Although this contradicts the title, author Neil deGrasse Tyson may have thought it too optimistic. The astrophysicist introduces the listener to the formation of the Solar System. So you are ready to engage in small talk that revolves around the Big Bang, black holes or even quantum mechanics. The author's efforts to convey all his knowledge in a conversational tone are noticeable. Tyson also reads the text professionally and at a pleasant speed. And yet: Here you can hear technical terms faster than neurons can follow the tour of the Universe. Questions like 'What is the nature of space and time?'; 'How do human beings integrate themselves into the universal structure?'; and 'Is the Universe even inside us?' cannot be answered so easily and do not require haste from the listener – but rather patience and concentration.

Manuela Braun

RECOMMENDED LINKS

PUBLIC FORUM FOR ALL THINGS SPACE
s.DLR.de/d231
In this forum, users post and discuss space-related news, ventures, ideas, hobbies and more. It even has its own rocket launch calendar! The Reddit format allows open participation by hobbyists and experts alike and lends itself well to questionnaire sessions with professionals.

VISUALISATION OF RISING SEA LEVELS
s.DLR.de/u1c9
Sea levels are on the rise due to global warming, posing a threat to civilisations. This interactive site by makers of the National Geographic documentary 'Before The Flood' shows which areas will need to undertake massive protective measures to prevent flooding.

STORY OF THE UNIVERSE AND OUR PLANET
s.DLR.de/sv2c
Khan Academy has many excellent free courses on various subjects. Their Cosmology and Astronomy course starts with the formation of the Universe and stars before moving on to the geological history of planet Earth and of life on our planet. If you are interested in a simple, but clear explanation on these subjects, be sure to check it out!

MAP OF RENEWABLE ENERGY
s.DLR.de/27h1
This handy tool by the Smithsonian Magazine shows you a global map of energy consumption and renewable energy production by country. It includes historical data and the shares of each type of renewable energy. The tool provides an easy way to identify the countries that lead or lag in the global Energy Transition.

#ASTEROIDLANDING LIVE
twitter.com/@MASCOT2018
How do an orbiter and lander study asteroids? The DLR/CNES MASCOT lander and JAXA Hayabusa2 spacecraft arrived at asteroid Ryugu and are telling the world about their adventures via twitter – @MASCOT2018 and @haya2e_jaxa. Follow them using #asteroidlanding.

DLR INSTAGRAM ACCOUNT
www.instagram.com/germanaerospacecenter/
DLR's Instagram account offers images from all of the Center's research areas. During special events, it is used to publish images in near real-time. Recent posts include images of the control centre for the MASCOT asteroid lander and the interior of the EDEN ISS 'greenhouse' in Antarctica.

About DLR

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

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

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Cover image
6 June 2018: A Soyuz MS-09 rocket brings Alexander Gerst and his team to the International Space Station. The horizons mission begins. On the ground, a much larger team ensures that the mission is successful.
Image: ESA / S. Corvaja

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