Cover image

Shown here is the spherical structure of a novel biopolymer aerogel developed by DLR researchers in a laboratory experiment. It is produced by combining chitosan with a thermoset. You can read more about the versatile aerogels and about Barbara Milow who, together with her team, is ‘cooking up’ new recipes, on page 30.

Printed on recycled, chlorine-free bleached paper.
Dear reader,

The spherical, cornflower-blue object on the cover does not – as you might suspect – come from the realm of botany (even though plants are also a topic in this issue of the DLRmagazine). Could it be a sponge? You are getting warmer. Air pockets have an important role to play here, after all, as they turn raw materials into a high-tech substance. This is an aerogel. Lightweight, electrically conductive and thermally stable – combining all of these properties in a single material fascinates Barbara Milow. They make aerogels of enormous interest, whether as stable materials in their own right or for use in filters, as insulation or even as implants. Milow and her team are constantly creating new aerogels and discovering interesting further applications that may extend their use to electric cars or aircraft.

We mentioned plants. What would you like? Tomatoes, herbs or rocket, perhaps? We have them all – in Antarctica, no less. There, DLR researcher Paul Zabel investigated whether plants can thrive without soil and sunlight in the EDEN ISS laboratory – and he succeeded. This process is suitable for inhospitable regions on Earth and for space exploration missions. That said, the Universe can now be explored virtually, as DLR researchers are demonstrating with a virtual reality system in which the Solar System is within arm’s reach.

Simulations are also playing an increasingly important role elsewhere – in aircraft design, for example. In future, the certification process will be able to dispense with tedious testing and countless hours of flying. DLR is creating new techniques in this area, primarily through the use of high-performance computers that make the process faster and more straightforward. This is also opening up possibilities for completely new types of aircraft. The climate impact of air transport will no longer be a concern if DLR’s vision of zero-emissions aircraft becomes a reality – a topic that we examine in this issue.

Last but not least, the July 2019 issue would not be complete without mentioning the 50th anniversary of the first Moon landing. We have put together a selection of items about the Apollo missions and hope that you find them interesting, along with all of the other articles on aeronautics, space, energy, transport and digitalisation!

Your magazine editorial team.
Our task is to improve existing aviation and rethink how it might look in future. Improving current aircraft and the way in which they operate can be achieved via aerodynamic oxides by 90 percent and noise by 65 percent by 2050, relative to the figures from 2000. Commission’s Flightpath 2050 vision paper, which DLR has actively contributed to. achieving a better environmental and climate footprint for the air transport sector.

Reduction Scheme for International Aviation (CORSIA) will come into effect in 2020. out by the rapidly growing demand for air transport. For this reason, DLR is working closely with aircraft manufacturers and their suppliers, airlines, air traffic control organisations, airports and public authorities to put research findings into practice more quickly.

However, we are aware that previous efforts from research organisations and the aviation industry with regard to environmental sustainability have been partially cancelled out by the rapidly growing demand for air transport. For this reason, DLR is working with aircraft manufacturers and their suppliers, airlines, air traffic control organisations, airports and public authorities to put research findings into practice more quickly.

The German Federal Government’s aeronautics research programme offers an instrument that enables industry to further improve its products and break new ground. This includes conducting research into alternative fuels and propulsion systems. Electric flight is another new area of focus. DLR can and will find answers to the pressing challenges faced by this sector. What is feasible for each size of aircraft, how and to what extent? What are the costs and benefits of manufacturing, operations, maintenance and disposal? This year, DLR will be investigating electric flight using a commuter-class aircraft with up to 19 seats.

Our vision for the future of aviation is a zero-emissions aircraft. However, this will take time and perseverance – in government, research and industry alike. And it will not be without cost …

“OUR VISION: ZERO-EMISSIONS AIRCRAFT”

By Rolf Henke

In 2018 a team of students from Munich demonstrated the boundless creative potential of young people by designing an ‘iFly’ aircraft concept that slashed energy consumption. This design was submitted to the DLR/NASA Design Challenge, which was back for the third time in 2019. This year, the focus is on aircraft designs and concepts for making remote regions accessible with small aircraft. The designs should be economically efficient and be applicable for both uncrewed cargo aircraft at night and crewed passenger flights. DLR and NASA have set the task for students in Germany and the United States. The launch of the competition took place on 12 April 2019 at the DLR site in Braunschweig. In autumn, the German winners will travel to NASA, where they will present their work alongside the US American competition winners.

There are remote regions across the globe that are effectively only connected by air. This requires small aircraft with the lowest possible fixed and operating costs, and flexibility of use for both passenger and freight transport. This calls for new technology ideas, ranging from aircraft design to uncrewed operating scenarios. “Aviation connects the world – from isolated airfields, to airports and major hubs,” said Rolf Henke, DLR Executive Board Member for Aeronautics Research and Technology, at the launch event. “It is hard to imagine life without the connection of remote regions by air, and so, together with our partners from NASA, I am looking forward to fresh inspiration from young people with designs and operational concepts that will stimulate regional air transport.”

Some 40 students from five German universities (RWTH Aachen, TU Berlin, TU Dresden, TU Hamburg and the University of Stuttgart) are taking part in the DLR/NASA Design Challenge.

Students are invited to contribute aircraft designs to DLR and NASA’s Design Challenge

DRONES IN THE CITY

DLR tests the City-ATM system at the Köhlbrand Bridge in Hamburg

Towards the end of April 2019, DLR and its partners in the City Air Traffic Management (City-ATM) project conducted successful flight tests around the Köhlbrand Bridge to demonstrate how drones are already able to cooperate with one another, as demonstrated by flying around a bridge, amid active shipping and road traffic. The tests were conducted at a time of day when ship and road traffic were active. This demonstrated how automated camera drones can fly safely together within the urban airspace. Safe flight was achieved with the help of flight planning, detection and identification, flight monitoring, and conflict detection and avoidance.

The system developed for City-ATM involved several steps. First, the pilots and drones were electronically registered and authorised for take-off clearance. Simultaneously, the flight missions were planned in detail – with any spatial flight restrictions accounted for. Once the essential waypoints had been determined they were converted into flight paths (trajectories). The system also took account of the flight performance of the devices as well as local and temporal conditions. This allowed potential conflicts to be identified prior to take-off. In future, package drones, air taxis and unmanned inspection aircraft will be able to fly around cities. As such, it is crucial that unmanned flying objects are able to detect and avoid one another reliably.

The theme of the 2019 student competition is aircraft designs and concepts for creating transport links with remote regions

t1p.de/09/5

UP, UP AND AWAY

t1p.de/mu1h
**FUEL FOR THOUGHT**

DLR transport researchers have teamed up with Aral to examine how mobility behaviour is changing and what impact this will have on fuel stations in the future. The researchers have shown that the distance travelled by passenger cars and commercial vehicles in Germany will increase by 24 percent by 2040 due to changes in mobility patterns and increasing commercial traffic. This provides fuel stations with new responsibilities but also a range of opportunities. In major cities, fuel stations can provide service-oriented mobility centres where e-bikes, autonomous car-sharing facilities and air taxis are available for use. In less congested urban spaces these could serve as interchanges with all-round facilities. In rural areas, fuel stations – with attached parcel services and shopping facilities – can take on the function of transhipment points with local supply services. Motorway stations will provide services for freight and long-distance transport, including for switches from autonomous to driver-operated lorries for urban transport.

**PLANNING SOFTWARE ASSISTS WITH THE REDESIGN OF ENERGY INFRASTRUCTURE**

Through open_eGo (open electricity grid optimisation), the DLR Institute of Networked Energy Systems in Oldenburg has developed an open data and software pool for the optimised planning of German network and storage infrastructure. Whether it involves an outpost on the Moon or a long flight through space, humans are unable to survive in such conditions without technological systems that provide everything necessary for life. They require a system that is as closed and independent as possible to provide for their needs. The Photobioreactor experiment marks a big step in this direction, with algae converting the carbon dioxide exhaled by astronauts into oxygen and edible biomass by means of photosynthesis. The Photobioreactor has been devised to produce breathable air on the International Space Station for six months, and is supported by the Advanced Closed-Loop System (ACLS). Photobioreactors are of particular interest for planetary base stations or very long missions, as in addition to the breathable air that they produce, the resulting algae biomass can account for around 30 percent of the astronauts’ food intake. Similar systems can be used on Earth for indoor air treatment or the removal of carbon dioxide. The experiment was initiated by the Institute of Space Systems at the University of Stuttgart and the DLR Space Administration, and was built by Airbus Defence and Space.

**MONITORING GLOBAL FORESTS**

Forests are considered to be the lungs of the Earth and represent vital resources for humans and animals. Yet despite their importance for the Earth’s climate, they are disappearing. Satellite images show that only one third of the Earth’s land surface is forested. More than half of the world’s forests, which have fallen victim to deforestation since the middle of the 20th century in particular, have already been lost. DLR has created the global TanDEM-X Forest/Non-Forest Map to record and assess this condition: ‘green lungs’. It has been developed using data from the elevation model created by the German TanDEM-X radar satellite mission, and has a resolution of 50 metres. The global data processing was carried out using algorithms derived from artificial intelligence. For the first time, the Forest Map provides service-oriented mobility centres where e-bikes, autonomous car-sharing facilities and air taxis are available for use. In less congested urban spaces these could serve as interchanges with all-round facilities. In rural areas, fuel stations – with attached parcel services and shopping facilities – can take on the function of transhipment points with local supply services. Motorway stations will provide services for freight and long-distance transport, including for switches from autonomous to driver-operated lorries for urban transport.

**THE PHOTOBIOREACTOR EXPERIMENT**

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Strong blizzards with wind speeds of up to 150 kilometres per hour, temperatures below minus 40 degrees Celsius, weeks spent in total darkness, and most importantly no escape capsule promising a quick return home, as is the case on the International Space Station. These are just some of the many challenges faced by the EDEN ISS team during its space analogue mission at the German Neumayer Station III in Antarctica, which is run by the Alfred Wegener Institute (AWI). The EU-funded research project led by DLR involves research into how plants might be cultivated in future habitats on the Moon and Mars, thus making a significant contribution towards the development of bioregenerative life support systems.

A greenhouse in Antarctica provides insights into future plant cultivation on the Moon, Mars and Earth’s desert regions.

By Daniel Schubert

On 3 January 2018, the South African research vessel S. A. Agulhas II rammed into the sea ice of the Atka Bay near Antarctica’s Ekström Ice Shelf. On board were the two EDEN ISS greenhouse containers. The wait was finally over for the four-man EDEN assembly team from the DLR Institute of Space Systems in Bremen, who arrived in mid-December. Poor weather conditions had delayed the arrival of the containers by two weeks. The unloading of the ship was a cause for celebration, as it marked the culmination of four years of intensive planning, hardware development, testing and enhancements. This marked the beginning of the long-awaited Antarctic mission. From the sea ice, a team of AWI engineers pulled the two greenhouse containers and a support container housing spare materials and consumable supplies over a distance of 24 kilometres to Neumayer Station III, which would serve as the base for the upcoming isolation mission. The very next day, the AWI assembly team placed the two greenhouse containers on the pre-installed platform 400 metres south of the station, which together make up the EDEN ISS Mobile Test Facility (MTF). In the weeks that followed, the DLR EDEN team installed external stairways, cable ducts, thermal, outside lighting and the carbon dioxide storage and supply system. Power was supplied by a seven-centimetre-thick electrical cable running from Neumayer Station III to the greenhouse, which had been buried in the ice the previous summer.

Storms, deep snow, frost and polar lights

The test facility went into operation on 7 February 2018, with the sowing of tomato, pepper and cucumber plants. Radishes, Kohlrabi, rocket salad, lettuce, leafy Asian vegetables, and herbs like parsley, basil and chives followed over the next few days. The isolation phase began once the last summer crew left the station on 18 February 2018, leaving only the 10-strong overwintering team. From that point on, DLR researcher Paul Zabel ensured the smooth operation of the system on site.
On 20 May, the Sun set for the last time, and the polar night began for the German overwintering crew. The greenhouse continued to operate over this extreme phase. It became an endurance test. The outside temperature regularly fell below minus 30 degrees Celsius. Both the greenhouse system and the overwintering crew had to contend with storms and darkness, but the occasional aurora borealis brought some light.

**Scientific experiments in a unique environment**

The DLR team pursued a demanding scientific programme over the course of the mission. During the isolation phase, Zabel took over 400 plant and microbiological samples from various positions within the greenhouse. The plant tissue samples were used for food quality and safety analyses. The collected samples were passed on to project partners in Italy and Ireland for analysis upon their return from Antarctica. The microbiological samples travelled to Cologne for examination at the DLR Institute of Aerospace Medicine. In addition, several experiments took place directly after the harvesting of the plants, including measurements of the nitrate content of the fruits. This will serve as the basis for developing rapid harvest tests for future astronauts.

The researchers used special questionnaires and several moderated discussions to study the psychological effects that the regular supply of freshly harvested vegetables had on the isolated Neumayer crew. Tests to investigate the taste of the vegetables grown here rounded off the on-site psychological examination.

**The EDEN ISS greenhouse – an international research platform on the eternal ice**

The researchers regularly tested out different procedures for cultivating plants within closed systems, similar to habitats on the Moon and Mars. The working steps taking place in Antarctica were followed live from the mission control centre at the DLR Institute of Space Systems in Bremen, where the researchers were in constant contact with the greenhouse and had full remote control of its operations in the event of storms. Thirty-four cameras took pictures of the different plants every day, offering the project partners and specialists from all over the world the opportunity to observe the plants growing inside the Antarctic greenhouse and provide feedback to the mission team.

By mid-November 2018, around 270 kilograms of vegetables had been harvested despite the harsh conditions. Having over 20 types of vegetables made a welcome change to the crew’s diet. With almost 240 days of isolation, 15 system- and validation tests, more than 20 scientific experiments and over 40 procedural tests, the Antarctic analogue mission marked the highlight of the EDEN ISS greenhouse project. The experience acquired will be vital for a robust and reliably functioning greenhouse on the Moon and Mars and for plant cultivation in Earth’s desert regions.

Meanwhile, the EDEN ISS greenhouse will continue to be operated with support from the new AWI overwintering team. In future, it will also be open to other research groups as an international research platform, allowing their technologies, methods of cultivation and procedures to be tested under realistic isolation conditions in Antarctica.

Daniel Schubert works at the DLR Institute of Space Systems, where he is responsible for the EDEN research group. The EDEN ISS project has fulfilled his long-cherished dream of testing such a system under real conditions in Antarctica.

The research greenhouse is packed with modern cultivation systems (controlled environment agriculture; CEA). These allow independent and accelerated plant growth within the growing chamber of the Future Exploration Greenhouse (FEG).

The fully automated nutrient supply system provides two precisely calibrated nutrient systems, one for vegetables like lettuce, basil and parsley, and the other for fruit-producing plants like tomatoes, cucumbers and peppers. A mixing computer uses various micropumps to compile the exact amount of nutrients for the plants and adjusts the pH value of the nutrient solution. Eight high-pressure pumps then spray the fine nutrient mist into each plant vessel’s lightproof root compartment. The roots hang freely in the air and are able to absorb the blend of nutrients and water directly. This soil-free irrigation method is referred to as aeroponics and is highly resource-efficient.

The internal atmosphere management system regulates the temperature to 20 degrees Celsius, the humidity to 65 percent and actively sprays carbon dioxide (1000 ppm) into the growing chamber. The plants need carbon dioxide for photosynthesis. Air circulates around the greenhouse and is purified by various filter systems (preliminary, HEPA and activated carbon filters). The water sweated out of the plants is recovered by the system and fed back into the nutrient supply system, closing the water cycle. The only water that leaves the system is in the biomass of the harvested lettuce, herbs and fruits.

The artificial lighting system consists of specially developed LED systems. A total of 42 LED lights are installed in the greenhouse. The light spectrum of each lamp can be individually adjusted to the type of plant, with the wavelengths blue, red, far red and white. The LEDs are water-cooled, creating thermal stability within the cultivation room. An innovative thermal control system ensures sufficient heat dissipation on the roof of the greenhouse.
Mr Zabel, you have been back in Germany for a few months now, after spending a year conducting research in Antarctica. What did you find most striking on your return home?

1. At first, I was completely overwhelmed by all of the sensory impressions. The smells and sound of civilization were mind-blowing after the first few days. Getting reacquainted with a big city and traffic is not so easy after a period of overwintering. That said, it was wonderful to see friends, family and colleagues again. Although I had a great deal of contact by telephone and the odd video call while I was there, actually seeing my family and being able to give them a hug was a completely different matter.

2. Why all the effort of spending a year in the Antarctic testing out plant cultivation in a greenhouse container? Could this not have been investigated in a more hospitable region on Earth?

3. An interview with DLR Antarctic gardener Paul Zabel

What did you find most striking on your return home?

1. The vegetables tasted completely normal, but home-grown vegetables went down very well with all of the overwintering team, as they were as realistic as possible, so it had to be just as isolated as a mission to the Moon or Mars. As far as I was concerned, Neumayer Station III was just like a base on another planet. Without this kind of isolation, people would not survive for long in Antarctica. You are just as dependent on technology as people are during a crewed space mission. Everyone must work together and look out for one another. The station only has food supplies for the three-and-a-half months of summer. The rest of the year, the crew relies on frozen, dried and preserved provisions. A journey to the nearest electronics store or a jaunt to the nearest electronics store or a jaunt to the nearest supermarket is just as dependent on technology as people are during a crewed space mission. Everyone must work together and look out for one another.

2. Did all of the plants cope well?

3. As for the polar night, my daily routine changed somewhat. I got up as early as I could and got to work before the early morning darkness forced me to bed. By mid-winter, it would be dark for months on end. As for the polar night, my daily routine changed somewhat. I got up as early as I could and got to work before the early morning darkness forced me to bed. By mid-winter, it would be dark for months on end.

4. What did the crew think of the first crops ‘made in Antarctica’?

5. How do Antarctic vegetables taste?

6. How was your first salad harvest?

7. Growing vegetables with no soil, under artificial light and using a computer-controlled nutrient solution. It sounds very sci-fi. Did all of the plants cope well?

8. The lettuce plants and other leafy vegetables really thrived. We are also more than satisfied with the growth of the tomato and cucumber plants, but we ran into some problems with the peppers and strawberries. Both types of plants did very well and grew many flowers, but the pepper plants produced almost no vegetables, and the strawberries produced no fruit whatsoever. We are currently carrying out an evaluation with our Dutch project partners to determine the cause.

9. What did you find most striking on your return home?

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12. Why all the effort of spending a year in the Antarctic testing out plant cultivation in a greenhouse container? Could this not have been investigated in a more hospitable region on Earth?

13. As each member of the overwintering team had their own area of responsibility, we actually hardly ever saw each other during the day, but we would arrange a set time to have lunch and dinner together as a team. Of course, we also supported one another when dealing with difficult or time-consuming tasks. The gave me an insight into different areas, like station technology, meteorology, geophysics, atmospheric chemistry and sea ice physics. Weather permitting, we made joint trips to the nearby emperor penguin colony or explored the area surrounding the station on snowmobiles and snowcats.

14. What did you find most striking on your return home?

15. You spent the year with nine other members of the overwin-tering team at the Neumayer Station III of the Alfred Wegener Institute. How often did you actually see one another during the day?

16. Almost everything in Antarctica made a big impression on me – from the ever-changing weather conditions, storms, cold, weeks of darkness, weeks of no darkness, and snow formations created by storms to the incredible starry sky in the biting cold of minus 35 degrees Celsius. I would go back in a heartbeat!

17. The greenhouse is still in place and is currently being run by the present overwintering team, who are also using it to grow fresh vegetables. Next year, more members of our project team are set to travel out there to continue with the research. At the moment we are working hard on evaluating the results from last year, and have already learned a lot about how a future space greenhouse might work. We also want to use these findings to improve the greenhouse in Antarctica step by step.

18. What did you find most striking on your return home?

19. The interview was conducted by Falk Dambowsky from DLR Public Affairs and Communications.
THE VIRTUAL PATH TO CERTIFICATION

Those wanting to get an aircraft in the air, a rocket into space, a car on the road or a train on the rails have a long journey ahead of them. Not only does the development of new technologies and vehicles cost researchers and manufacturers a great deal of time – the approval or certification process also often takes many years. But what if all of the test drives and flight tests were no longer necessary for approval or certification, because the majority of the required showing of compliance could simply be provided virtually, using computers?

In the cross-sectoral project Simulation-Based Certification, 15 DLR institutes and facilities are working on a tool for digitalised certification.

By Yvonne Buchwald

If the Airbus A380 had been allowed to make its maiden flight using computer simulations, the aircraft’s manufacturers certainly would not have carried out 800 test flights. Much of the 2600 flying hours and large parts of the five-year test programme – with the high costs involved – would not have been necessary. Not to mention the fact that the risks for the test pilots and aircraft would have been lower. At present, every vehicle and product that is intended for market must go through a completely physical, tangible process chain for operational authorisation, in order to prove to the relevant authorities that all of the necessary safety and environmental requirements have been satisfied. “Today, we can design an aircraft or vehicle using computers, and make statements about it, even though it does not yet exist in reality. When it comes to approval or certification, however, you need a real product that can be tested,” explains Sven Geisbauer of the DLR Institute of Aerodynamics and Flow Technology. According to the aerospace engineer, who leads DLR’s Simulation-Based Certification (SimBaCon) cross-sectoral project: “Tests are still predominantly being conducted in real life, and the regulation authorities are still sceptical about computer-derived data.” This is for a good reason – up until now, the reliability of simulation data for certification purposes has only been proven in a few selected cases. Researchers from 15 DLR institutes and facilities want to change this. They are working on interdisciplinary tasks to further develop numerical simulation methods from aeronautics, space, energy and transport in such a way that they can be accepted by the relevant authorities as a tool for verification.

From initial analysis to virtual testing

Sven Geisbauer explains how this would work, step by step: “First of all, we need to know exactly what the authorities need – the certification requirements.” In other words, an analysis. At the beginning, the researchers try to determine areas that offer potential for cost and time savings. Then, a catalogue of requirements can be drawn up and the simulation methods aligned with it. Once the requirements for certification have been exactly defined, the researchers make some initial comparisons between real-world testing and driving or flight tests and those conducted in the computer laboratory. Subsequently, the digitalised verification is tested and demonstrated on the computer, looking at components, subsystems and, if possible, entire systems like engines, aircraft, cars or trains. “Virtualisation should be applied to as many product development processes as possible – from the initial design to the development of materials and components, and through to the entire airborne or ground-based vehicle,” explains Geisbauer. This means that the product design is much better attuned to the requirements for production, certification and operation from the very outset.

Virtualisation needs to be applied to more and more research and development processes – right up to digitalised approval and certification.

PARTICIPANTS IN DLR’S SIMBACON CROSS-SECTORAL PROJECT

Institute of Aerodynamics and Flow Technology
Institute of Aerelasticity
Institute of Propulsion Technology
Institute of Composite Structures and Adaptive Systems
Institute of Flight Systems
Institute of Combustion Technology
Institute of Materials Research
Institute of Structures and Design
Institute of System Dynamics and Control
Institute of Vehicle Concepts
Institute of Transportation Systems
Flight Experiments Facility
Space Operations and Astronaut Training
Simulation and Software Technology Facility
DLR Systemhaus Technik

DLRmagazine 161 SIMBACON CROSS-SECTORAL PROJECT

Virtualisation needs to be applied to more and more research and development processes – right up to digitalised approval and certification.
At the end of this demanding process, there are officially verified and technically developed and implemented digital simulation tools that can be used to show compliance for certification. The simulations should allow "real" vehicles, components and systems to perform a virtual maiden flight or be rolled out for their first test drive and receive a simulation-based certification.

**Saving costs and minimising risks**

The benefits are clear: by bringing together all of DLR’s research into numerical simulations from the areas of aeronautics, space, energy and transport, we are in a unique position to be able to meet the challenges of simulation-based certification," says Rossow.

In doing this, DLR researchers have broken new ground. Personnel from 36 departments at six different DLR sites have teamed up under the direction of the Institute of Aerodynamics and Flow Technology to create synergies. "This cross-sectoral project allows us to harness the potential for innovation across DLR and benefit from working with one another," explains Sven Geisbauer. Although certification in the areas of aeronautics, space, energy and transport may look very different at first glance, the individual areas could benefit from being combined in ways that have previously not been possible.

For this purpose, the cross-sectoral project was initially divided into seven target areas, with the relevant research and technical expertise pooled within each one. The target areas are self-explanatory: aircraft, helicopters, spacecraft, ground-based transport, software, construction methods and structures, as well as engines and gas turbines. All the work is focused on the further development and improvement of simulation processes, as well as addressing the challenges specific to each area. Examples include the simulation of complete flight manoeuvres by free-flying helicopters or material and structural behaviour in the case of a high-speed crash or a vehicle collision. According to Geisbauer, "Ultimately, we will identify our areas of common interest in detail, and our pooled knowledge will allow us to address important subjects more effectively than is currently the case."

**The objective – realistic simulation**

Sven Geisbauer always keeps the vision of the virtual product in mind – that is, the entire digital life cycle, from the initial design of an aircraft or vehicle to its development, certification, entry into service, maintenance and eventual decommissioning. However, he is also aware of the challenges that this presents: "Showing compliance to certification requirements solely based on simulation data, without other flight or ground tests, is a long way off. Yet he believes that: "We can already simulate a large number of flight and driving conditions, some of which are critical."

One example is the installation of antennas on the top of aircraft fuselages in order to allow passengers to access internet access during their flight. Before such modifications are certified, it must be proven that the air flow around the aircraft will not be significantly altered by such antennas, and that all of the safety requirements are still being satisfied," explains Geisbauer. The conventional method is to conduct flight tests to demonstrate that the aircraft will not experience any impairments, such as vibrations, within its flight envelope. The certification regulations explicitly require flight tests in this case, but the authorities are already beginning to accept simulation data. The prerequisite for this is that has been met in advance to the authorities that the underlying simulation method really is able to correctly model the physical flow processes. For manufacturers, this means that costs and risks can be minimised.

The days when test pilots had to perform risky flight manoeuvres that took the aircraft to its physical limits in order to provide the necessary proof of safety are long over. In many areas, it is now possible to provide precise predictions of whether an aircraft has the correct design and load capacity using ground tests and simulations. The test pilot then simply has to demonstrate this within a certain safety margin, up to the calculated limit values. Researchers have taken this as their starting point for improving their numerical processes in order to define these critical points more accurately, with implications for the development of aircraft and vehicles and their certification.

"It will be some time before the simulations on our screens fully match the real behaviour of vehicles and allow us to truly replicate all of the conditions," says Geisbauer. "That said, with our interdisciplinary approach and the availability of ever-increasing computing power, we are already building trust in our computer data and showing that in a few years we will be in a position to digitalise certification processes using modern numerical methods." The cross-sectoral project has a total of 26 million euro of DLR core funding. It will initially run for four years, from 2018 to 2021. The follow-up steps for the coming decades are also being designed and planned, as the researchers wish to work not only in an innovative way, but above all with foresight.

Yvonne Buchwald is responsible for internal and external communications at DLR Institute of Aerodynamics and Flow Technology.
Using virtual reality to plan future space missions

By Simon Schneegans and Markus Flatken

The notion of researchers planning a future mission to Mars while being there – without leaving their workplace – will soon no longer be a futuristic fancy. Virtual reality (VR) will make it possible to wander around the surface of distant planets, carefully prepare rover missions, measure distances and identify landing sites. To achieve this, planetary researchers and software engineers at DLR are developing CosmoScout VR, a software that makes virtual travel through the Solar System and to individual planets possible.

Combining large amounts of data

CosmoScout VR can display huge datasets for entire moons and planets in detail. But this capability is also one of the greatest challenges facing engineers during the development stage. The difficulty lies in that the volumes of data acquired by today’s satellites are so vast that they can only be analysed in batches when using conventional methods.

The European Space Agency (ESA) Mars Express spacecraft, which has been orbiting our planetary neighbour since 2003, is a prime example of this precise issue. One of its seven measuring instruments is the High Resolution Stereo Camera (HRSC) developed by DLR, which images the Martian surface in high resolution. The datasets acquired by the HRSC, to date amount to approximately five terabytes. As researchers need a virtual copy of reality that is as detailed as possible for scientific analysis, the software must combine different datasets, including multispectral data, simulated atmospheric data and subsurface radar data. The data used are often from various missions. The total amount of data for analysis can range from a few hundred gigabytes to several terabytes. But state-of-the-art high-end graphics cards offer only 48
The Solar System is big – very big

An additional challenge faced by the developers is the hard-to-imagine size of the Solar System. CosmoScout VR uses NASA’s SPICE Toolkit to calculate the motion of celestial bodies. DLR researchers have developed algorithms that make it possible to represent planetary surfaces with millimetre precision. Given the colossal size of our cosmic neighbourhood, this requires a high degree of accuracy not needed for other VR applications. To travel through space at speed, CosmoScout VR always adjusts the maximum speed of movement by using the distance to the nearest celestial body or satellite. If the users are located outside the Solar System, they will travel at many light years per second, but as they approach a planet or satellite, their maximum speed is progressively reduced to a few kilometres per hour. Additionally, the users automatically follow the position and rotation of the corresponding celestial body. This makes it possible for researchers to see Mars rotate around its axis once a day from orbit, and the Sun rise and set from the Martian surface. This motion technology allows researchers to both survey the surface of a planet centimetre by centimetre and get an overview of the planet from orbit within seconds.

In order for the scientists to be able to interact with their environment, the next virtual celestial body must never be more than an arm’s length away. If the Solar System were always represented on a 1:1 scale, the virtual planetary surface would be too far away to work effectively with the simulation. Instead of actually covering a virtual distance of hundreds of kilometres to enter planetary orbit, the software shrinks the planet. Researchers travelling through the Solar System see the foot-proportional planet from the perspective of an interplanetary giant and can touch it by stretching out their arm.

Virtual reality offers benefits for collaboration

A key advantage of using VR to plan future missions is that the gestures and facial expressions of the researchers – who are all working from different locations – are also transmitted as they interact. This makes collaboration much more efficient. In addition, the VR application offers scientists a tool that allows them to conduct field tests on other planets in the same way as they would on Earth. The application is not restricted to merely depicting reality but can extend it to cover a range of options that are impossible in real life. For example, information such as height values or angle of inclination can also be displayed. In addition, the scientists have more efficient navigation options at their disposal – making travelling at the speed of light possible.

Through the VR headset Mars looks close enough to touch.
DIGITAL – FROM TOWER TO FLIGHT DECK

27 March 2019, 10:11 – the DLR Falcon research aircraft takes off from Oberpfaffenhofen Airport; its flight is a world first. On board is a demonstration version of the new L-band Digital Aeronautical Communications System (LDACS). In future, it should enable cryptographically secured, efficient data exchange between air-traffic control and the flight deck. In addition, the researchers are testing an alternative navigation system that will guide aircraft safely to their destination – even in the event that their satellite navigation systems fail. By the time the Falcon completed its approximately 90-minute journey, the team had taken a major step towards LDACS standardisation.

LDACS digital aeronautical communications – secure data and voice transmission.

An article from the DLR Institute of Communications and Navigation

The technology underlying the rather cryptic LDACS acronym can be compared to a terrestrial mobile radio network specifically adapted for aviation. The ground station is analogous to the mobile network base station, and the radio equipment in the aircraft corresponds to a smartphone. The new system will allow a better exchange of instructions and information between air-traffic controllers and pilots, as data and voice can be transmitted simultaneously. A team of DLR researchers has been working on LDACS with external partners since 2007. Alongside Frequentis AG and the University of Salzburg, the European Organisation for the Safety of Air Navigation (EUROCONTROL) and Deutsche Flugsicherung GmbH, the German air-traffic control organisation, have also been involved in developing the technology from the beginning. German industry partners Rohde & Schwarz GmbH & Co. KG, BPS GmbH and iAd GmbH became partners approximately six years ago and have been playing an important role since then.

New air-traffic management requires a modern aeronautical radio communications system

The new development is driven by the need to modernise the current air-traffic management system. Advanced, efficient communications are an important prerequisite for ensuring the safe and effective management of steadily growing traffic volumes. “Analogue technology from the 1930s is still being used for aeronautical radio communications today. This is seen as highly inefficient and cumbersome in the modern age. It needs to be upgraded urgently,” says Michael Schnell, Project Manager at the DLR Institute of Communications and Navigation. An example of one such unwieldy process is the method of changing flight sector. At present, pilots must verbally register and deregister with the air-traffic controllers and manually enter the new radio frequency when changing flight sectors. The air-traffic controller then communicates route changes to the pilot verbally, using voice radio, which the pilot reads back to rule out possible misunderstandings. The pilot then manually enters the changes into the flight management system on board the aircraft. In future, such data will be transmitted automatically and activated upon confirmation by the pilot.

In addition, the existing analogue voice radio makes very inefficient use of the frequency spectrum. “Only a limited number of frequencies are available for aeronautical radio communications, yet the number of flights is growing year on year.” notes Schnell, adding: “It is high time for us to enter the digital age!” LDACS will not only make the communication between pilots and air-traffic controllers more efficient, but it will also enable the exchange of complex information that cannot be transmitted using the current analogue voice radio. For example, the transmission of routes will include time information. When combined, the flight path and time data create a 4D flight trajectory. This indicates...
During the flight tests, Michael Schnell’s team managed to carry out another special demonstration, this time of the world’s first cryptographically secured transmission of precision landing data. During the first test, the Falcon flew over four ground stations while LDACS stations, which send and receive digital aeronautical radio data, work together to transmit position determination data in real time. As part of the Integrated Communications and Navigation (ICCANAV) project, the researchers implemented a ‘post-quantum’ cryptography algorithm that will enable LDACS communications to withstand future cyber-attacks of the most modern kind.

The experiment setup installed in the research aircraft

During the first test, the Falcon flew over four ground stations...
The energy transition has two clear winners so far among renewable energy sources – photovoltaics and wind. In total, renewables now generate approximately 40 percent of Germany’s electricity supply. But how can they be developed nationwide to provide heating and facilitate mobility for both people and goods? How can they replace fossil fuels, which are soon to be abandoned? Carsten Agert, Director of the DLR Institute of Networked Energy Systems, believes the answer lies in sector integration, also known as sector coupling.

An interview with Carsten Agert on sector integration in the field of energy supply

The average share of renewable forms of energy within our power supply system exceeded 40 percent this year. This demonstrates the success of the energy transition, right?

1. It is a gratifying snapshot – but we have to look at things in their overall context. Industrialised countries have set themselves the target of reducing emissions of carbon dioxide equivalents by 80 to 95 percent by 2050 compared with the base year of 1990. If we look at what has to be achieved by 2050, we can see a fundamental, far-reaching change ahead – which can probably only be compared to 19th-century industrialisation in terms of its sheer scale.

So, have we been addressing the energy transition too slowly?

1. As I see it, we have been too one-sided. For about the last 20 years, since the Renewable Energy Sources Act came into force in 1998, we have done the obvious – installing wind turbines and solar power plants. So we have harvested the ‘low-hanging fruit’. By contrast, the transport sector has largely been overlooked, which is why we are seeing stagnation in this sector, with the share of renewable energy in fuel at about six percent. The heating sector is looking very similar. So our interim conclusion is this – yes, the energy transition is under way, but we are still at the beginning. Now is when it actually starts to become difficult.

... but are you confident that DLR’s energy research will be able to develop robust concepts for a stable, safe and economically attractive energy supply system?

1. Absolutely. It is true that the expansion of solar and wind power within the electricity sector has reached a level that makes further expansion structurally and technically more difficult. However, if we include the heating and mobility sectors, which are also structurally complex, we will be able to develop attractive cross-sectoral solutions. As researchers, our task is to look for areas of flexibility within the energy system that may help us to cope better with the reality that patterns of production and consumption do not always match. The massive storage and flexibility potential that we need to match supply and demand can only be achieved through sector integration. Although it is a term usually associated with e-mobility, we understand sector integration to mean ‘combining power, heat and transport in such a way that these three sectors can grow together to form a large, integrated energy system.

Why are the interfaces between the different energy sectors so important to the success of the energy transition?

1. Sector integration represents the point of entry from a mere electricity transformation to the true energy transition. At present, for example, the heating sector is still primarily based on natural gas, and, in some cases, also on oil. But if we look at the 2050 climate goals, one thing is abundantly clear: we cannot continue to produce heat simply by using fossil-derived methane or oil. Mobility is facing a similarly profound change. Cutting around 80 to 95 percent of Germany’s carbon dioxide emissions by 2050 means that cars can no longer be allowed to emit fossil-derived carbon dioxide molecules. The average lifespan of a car is 15 years, so the last new car that still burns fossil fuel should be produced no later than 2035 for the German market. The European Union recently held discussions about whether we can call for a 30, 35 or 40 percent reduction in emissions for new cars by 2030. We would actually have to demand 100 percent five years later. In other words, if we are to have a chance of achieving our climate goals, we must very quickly switch the heating and transport sectors completely to renewable energy. Making such changes will give us the opportunity to harness the immense potential for greater flexibility offered by sector integration. We need that flexibility if we want to design a stable energy system around the fluctuating supply of renewable energy. What is more, sector integration gives us access to major storage potential.

How exactly does sector integration work? From a technical point of view, why is it important to make the energy system more flexible? How can we offset fluctuations in the power grid with heating and mobility?

1. If too much energy from renewable sources is fed into the grid – perhaps because there are strong winds – we can reduce the output of the generating plants, or we could use or store the excess energy. If we have to bear in mind that it is much cheaper to store heat than electricity. So if I have an electrically powered heating system that is coupled with a thermal storage system, it makes sense to generate heat when there is a surplus of electricity, not just whenever I need heat. Thermal storage systems therefore give our energy systems greater flexibility.

But sector integration also works in the other direction. Take mobility, for example – we can make hydrogen during the periods when there is too much energy and store it in our transport systems. For example – we can make hydrogen during the periods when there is too much energy and store it in our transport systems.
is more than enough electricity. In this case, the energy is stored as a chemical source. This hydrogen can be converted back into electricity at any point if the demand exceeds the available renewable energy in the grid. Our goal is to couple the transport sector with the electricity sector at both ends – we turn electricity into hydrogen but leave ourselves the option of using transport infrastructure to turn the hydrogen back into electricity. DLR’s energy and transport institutes are already working closely together in this area.

Your examples are based on hydrogen. Do you believe that this chemical source will shape the future energy system alongside electricity?

1. We would do well to agree on a common chemical energy source for the future, within the context of sector integration. I do not imagine, for instance, that we will be using hydrogen for transport, synthetic gas for heating, and perhaps another molecule for a third application, as we would need specialised logistics and infrastructure for each one. However, the question of which energy source that will remain to be answered. Personally, I believe it will be hydrogen.

Let us imagine a future in which one chemical energy source has been selected, and there are sufficient facilities supplying renewable energy. Does that mean that energy researchers have done their job?

1. The technical requirements of the future power system are very complex. Let us take one example – even on days when there should not be any storage problems, as the amount of energy available from the solar and wind generators approximately matches demand, we still need an array of new solutions in order to ensure a stable energy system based on renewable sources. Among other things, this is due to the fact that we are still deriving a lot of benefits from the inertia of large, traditional generators. These help us manage the stabilisation of our electricity system. Turning to solar and wind, we are essentially dealing with power electronics that do not have this inherent inertia. This has a number of implications, especially for the short-term regulation of energy systems. In addition, the energy system will be highly decentralised. It will no longer be a matter of controlling a handful of large power plants, but rather countless small power plants.

Let us look at a current hot topic – the expansion of the major power lines from windy northern Germany to the south of the country. To what extent can the energy system be stabilised by interregional or even European networking?

1. Better interregional networking is a fundamental prerequisite for ensuring the security of supply that we are used to today while using renewable energies in the future. In the decentralised, regional parts of the energy system, we will never find the degree of affordable flexibility that would allow us to manage energy autonomously on a small-scale, at the local level. That is why we need large-scale, high-performance networking for security of supply. Otherwise, we will not be able to create an energy system that is reliable, stable and affordable.

Given all these enormous challenges, do you sometimes wish that you had someone like Greta Thunberg at the Cabinet Table? In future, should the government create stricter framework conditions for the success of climate protection and the energy transition?

1. The spirit of the ‘Fridays For Future’ movement would be good for climate policy, there is no question about it. In the electricity sector, the energy transition is faltering, and the expansion of renewable energy sources has not yet delivered the desired degree of effectiveness in terms of reducing emissions. But the bottom line is that it is still making progress. In the transport, aviation and heating sectors, however, the energy transition has hardly begun. I would argue that the decisions on phasing out fossil fuels should be seen as an opportunity to finally install a nationwide – and cross-sectoral – system for minimum pricing or taxation of carbon dioxide. This would stimulate resourcefulness within our national economy much more effectively than fragmented, hotly contested attempts at regulation. The younger generation is reminding us on a weekly basis that we need to act now.

The interview was conducted by Henrike Mainen of Communications at the DLR Institute of Networked Energy Systems.

The ‘eye2sky’ monitoring network, which is currently being set up by DLR in northwestern Germany, measures the formation and movement of clouds in the sky across the entire country. This allows the yield of solar power plants to be predicted minute by minute. Such exact predictions are not possible using satellite imagery, because the shadows of clouds – rather than their position – are the decisive factor for the yield of solar power plants.
When researchers cook up new recipes for aerogels, it all sounds quite simple. But is it?

By Frank Seidler

Barbara Milow looks intently at a glass beaker, taking in every detail. She likes the excitement of waiting to find out whether the experiment has worked, or whether something has gone askew. Only afterwards will she know whether a test has been a success or an ostensible failure from which she might nevertheless be able to learn something that proves crucial for later research. “This always fascinates me,” says Milow. “I’m enthralled by chemical synthesis, how materials and their properties are related, and the development of entirely new materials.” The scientist, who holds the Chair of Nanostructured Cellular Materials at the University of Cologne, and her colleagues at the DLR Institute of Materials Research have cause for excitement today. The experiment has gone according to plan: the gelation of the silica solution is clearly discernible. And Milow does not want to leave anything to chance. Nevertheless, things do not always go as expected when she and her team of technicians, engineers and scientists literally cook up new recipes for aerogels in their laboratory.

Aerogels are state-of-the-art materials. They essentially consist of air surrounded by a fine yet solid structure, not unlike a sponge. Materials such as silicates, (bio-)polymers and metal oxides are used for the solid structure, accounting for between one and 20 percent of the finished aerogel. Aerogels have a very low density, which makes them extremely light. This is one of many reasons why Milow is so enthusiastic about this material. “In principle, the manufacturing process is very simple,” she says. “You combine the components, they gel, you dry the gel, and the result is a material with an incredible number of applications. It can have the electric conductivity of carbon while also offering good thermal insulation due to its nanoporous structure. It is almost unprecedented for one material to have such a range of properties.”

The scientist has led the Aerogels and Aerogel Composites Department at the DLR Institute of Materials Research since late 2018. With 32 employees, it is the largest research group dedicated to this subject area in Germany. The scientists are working together to gain a better understanding of the materials’ geling process and to open up possible areas of application. Silica aerogels are very stable at extreme temperatures and are being developed for sound and thermal insulation in aircraft cabins or fuel tanks. Thermoset aerogels, meanwhile, make outstanding insulating materials, as they are neither toxic nor flammable. Biopolymer aerogels have an inner structure that is similar to felt, and are used for the adsorption of air pollutants, humidity or materials that are susceptible to oxidation. Due to their definable nanostructures, carbon aerogels can contribute to new battery concepts or be used to optimise casting processes. When combined with other...
AEROGELS AND AEROGEL COMPOSITES

Biopolymer aerogels consist of naturally occurring macro-molecules such as cellulose, chitin or agarogen. Chemically bound nanometer-thin fibres give the material its stability. This felt-like structure makes them particularly suitable as filters, for example, for regulating humidity in aircraft cabins, as well as for the adsorption of carbon dioxide.

Thermoset aerogels are lightweight materials that insulate heat and sound. Accordingly, they are of particular interest for the construction of vehicles, planners and aircraft, or as an alternative to polystyrene. They can range from brittle to super flexible, depending on the composition and drying process. They are based on an aqueous resin-casting-formaldehyde solution. When combined with other aerogels, such as silica-aerogel granulates, they form composites with better thermal and mechanical properties.

Carbon and silicon-oxycarbide aerogels are formed during the thermal treatment of thermoset, biopolymer-based or hybrid aerogels. They are very stable in high temperatures and can be used in the casting process in foundries. Their large internal surfaces allow them to absorb the gases that occur during the casting process, thus preventing casting defects such as gas bubbles, non-metallic inclusions or sand adhesion. DLR is working to transfer its manufacturing process from the laboratory to a pilot-plant scale.

Silica-based aerogels, also known as frozen smoke, are the most studied type of aerogels. Due to their low thermal conductivity, they are used as an insulating material, but other applications include aerogel particles in cosmetics. In recent years, researchers have developed a new variant, soft, flexible aerogels that remain stable at temperatures of up to 500 degrees Celsius. DLR scientists are working on new formulations to further improve the material.

materials, their positive properties can be harnessed to form innovative aerogel composites. In conjunction with the University of Duisburg-Essen, the DLR researchers have also developed an aerogel concrete that is not only very light, but also provides excellent heat insulation. "The possibilities that we are now seeing are almost limitless, and new areas of application are emerging all the time. It is amazing, considering that research into aerogels began nearly 90 years ago," Milow says.

Good things take time

In the 1930s, scientists working on removing fluids from wet gels – also known as hydrogels. Aerogels were considered to be any materials that were produced from wet gels and that – after drying – bore the network-type structure of a hydrogel within the material. These early researchers found it extremely difficult to control the forces that acted upon the pore walls inside the material during the drying process without destroying the structure of the gel and causing the pores to collapse. In the beginning, the drying process would take around a week, so industrial use was out of the question. It was not until the 1960s that scientists succeeded in greatly simplifying and thus accelerating the aerogel production process. They realised that the pore fluid in wet gels might predominantly consist of methanol. Researchers also discovered that material transformations could be controlled via the pH value. Milow was just a child at the time.

During the period when companies like BASF, Hoechst and Henkel were deploying various solutions for wet gels in the 1980s, with a view to developing aerogels with a range of properties, she opted to study chemistry at the University of Cologne, followed by an internship at the Chemical Investigations Office in Trier. “For my doctorate, I went to the DLR Institute of Space Simulation, where I conducted experiments with liquid-liquid systems in microgravity conditions. I was even lucky enough to be able to support the ground-based research for the D2 space mission as a doctoral candidate, which was something that many of my predecessors wanted to do,” Milow says. “At that time, I had very little to do with aerogels.”

A few scientists at the same institute were working with this interesting material, but it would be another 10 years before Milow became intensively involved in aerogel research. That is how long she worked at what is now the DLR Institute of Solar Research, focusing on the decontamination of waste water using solar energy. “When my contract ended, I needed a reference from my old institute and contacted one of my former colleagues,” she recalls. “He was the one working on aerogels with his team back when I was doing my doctorate. I wrote to him, saying, Lorenz, I need a reference or a job, and he replied, I can give you both.” That was in 2005. Aerogels have been my focus ever since.

Research into the unknown

At that point, the group was facing an existential dilemma: although funding opportunities were opening up for their projects, the researchers learned that the working group was to be disbanded after a change in the institute’s management. “We could not just bury our heads in the sand, so we began to actively raise the profile of this area.” The team visited countless foundries across Germany in order to research and develop their production process. In doing so, they gradually opened up a wide range of applications for their materials. For instance, the group developed aerogel structures as model systems for bone implants. Today, their working group at the University of Cologne is making implants out of ‘foam-like’ biopolymer structures and have reached a stage where these aerogel structures are not rejected after being inserted into the tissue.

Milow and her team consider it important to replace syntheses that include toxic substances and to use other processes instead. “Apart from formaldehyde, the chemicals that we use are all environmentally friendly. We are always looking for materials that we can work with in a sustainable way.” The group has found some unorthodox ways of achieving this feat: “On one occasion, we used cinnamaldehyde to make aerogels. It made the whole laboratory smell like Christmas. Unfortunately, it proved to be more detrimental in the required concentrations.”

An ambitious vision

“At first, I was sceptical as to whether the team would stick together, everything would work out and the funding would come through. I wrote numerous proposals. But it turned out even better than I could have hoped, and today we are bursting at the seams.” Since then, Milow’s attention has turned to the next generation. Today, she and her department are working on components for all areas of research at DLR. They are currently developing a material to prevent aircraft fuselages from icing up on long flights. Hydrophobic – meaning water-repellent – aerogels should stop water from accumulating and forming heavy layers of ice.

“My dream is to have a separate centre of excellence for aerogels here at DLR, where we can produce prototypes and very small series of new raw materials and components,” the researcher says. The staff at the University of Cologne, where Milow recently became a professor, would also be able to work there. She is proud of that, and her delight at working in this field is apparent when she talks about future projects and new areas of application. Of course, it all takes a lot of work, and perhaps she could have restricted herself to one or two specific areas. But Milow shakes her head: “Keeping things small just isn’t my kind of thing.”

Frank Seidler is responsible for marketing and communications at the DLR Institute of Materials Research.
Anko Börner and his team at the Institute of Optical Sensor Systems have developed the Integrated Positioning System (IPS), which allows reliable orientation in space. In an interview with DLR Editor Julia Heil, he explains how his idea became a market-ready product, and why going up and down in a lift more often proved crucial to the project.

The Integrated Positioning System – IPS – enables position determination without satellite navigation systems.

Navigation is now an almost indispensable part of our everyday lives. Knowing our position in space is vital to understand how to get somewhere, generate measurement data or create accurate models of our surroundings. What are the problems with currently available systems, and what was your idea for addressing them?

If we want to get from A to B, we enter our destination into a navigation system. This then determines what was your idea for addressing them?

Anko Börner is Head of the Real-time Data Processing Department at the DLR Institute of Optical Sensor Systems in Berlin-Adlershof. He is responsible for the IPS project. He and his team began working in the field of satellite-independent navigation 15 years ago.

Anko Börner

The result is the Integrated Positioning System, known as IPS, which can orient itself in a similar way to humans.

× Yes, that is the basic principle behind IPS. The system includes a stereo camera system, comprising two parallel cameras spaced a defined distance apart. These record image data every 100 milliseconds. The images are transmitted to a computer in real time. There, an algorithm searches for landmarks – conspicuous points. These could take the form of a door handle indoors, or a tree outdoors, to give a couple of examples. The stereo camera system provides three-dimensional information relating to the landmarks it observes. If I continue moving with the system, tracking the object points and thus picking them up from different positions, I can estimate the distances travelled between image acquisitions. Over time, a movement path emerges, and IPS gradually explores the space.

As IPS can only determine relative movements, it cannot determine whether it is in Dresden or Berlin, so it is important to integrate the information into the real world. We use systems such as GPS, WLAN or visual landmarks for this purpose. This is not necessary for every application, but the system provides for such solutions. IPS is also suitable for 3D modelling of its surrounding environment.

Depending on how you move around a space with the system and what is recorded, you can create a complete 3D model of the environment, or even examine specific areas in detail. In which sectors is this of particular interest?

At present, our system is designed for inspection tasks. For instance, when inspecting ships, it is important that particular areas, such as the ballast tanks, are inspected at regular intervals. For this, a person has to descend into each tank and document its condition for the inspection. Nowadays, this is done with a notebook and a camera. In the process, the person must maintain the sense of direction. Our system makes it much easier and more reliable. The inspector can take a picture of damaged areas using IPS, ensuring that the damage is documented, along with the exact position. This inspection application works remarkably well. In addition, other areas of application can really benefit from navigating with such technology. One example is automated driving. In this case, a highly accurate and absolutely reliable navigation system is a fundamental prerequisite. Any mobile robot or autonomous system needs to know where it is and what its surroundings look like.

That is why we need technology like IPS, which is not dependent on satellite data. The system is also a perfect testing platform for artificial intelligence. We can create training data sets, let the system learn and what is recorded, you can create a complete 3D model of the environment, or even examine specific areas in detail. In which sectors is this of particular interest? A

The new DLR system also helps to orient the user in industrial plants in which satellite data cannot be received.
The project began in 2004. How did it develop from the initial idea to the finished product? At the beginning of our research, it was a question of whether a system could reliably navigate independently of satellite navigation systems. Our first ‘test device’ was an aluminium extrusion, to which we attached two cameras and an inertial measurement system. We connected a laptop to this structure and investigated whether this kind of assembly would actually work. Back then, commercialisation had not even crossed our minds. The idea only came to fruition when we met up with Det Norske Veritas – Germanischer Lloyd (DNV-GL), a major ship insurer, at a DLR workshop. The DNV-GL representatives said that they needed just this kind of system for ship inspections, thus constituting a potential user. That was about five years ago. Up until then, we had financed the project from a variety of basic funding sources, with the help of DLR Technology Marketing, and third-party funding.

So, you found your user with the ship insurer? Exactly. This meant that we took a giant leap forward. They were able to specify exactly what they needed from this kind of system – how heavy the device could be, what it would need to withstand, and which data were required by the inspectors. Knowing this allowed us to design the device as it is today and address the quality assurance of this type of product. A commercial system has to be absolutely reliable. For instance, it has to work even if one of the cameras does not have a clear view or if people walk across its field of view. One of our favourite experiments was travelling in a lift with IPS. This forced it to recognise that it could not trust its eyes but had to rely on its sense of balance – meaning the inertial measurement data.

Financing the project nevertheless remained a challenge. We applied for funding designated for transferring technological developments from large research institutions to industry. We were very confident that such funding would be awarded, as we had a great idea, an excellent consortium and many applications. But our applications were turned down several times – sometimes because we could not prove the required market maturity, sometimes because we were too application-oriented. Members of staff who had worked in this area had to be transferred to other projects, and IPS appeared to be on the verge of failure. Fortunately, DLR Technology Marketing stepped in and took over financing of the decisive phase. We are very grateful that they did! The entire technology transfer process also gave us an insight into where we can make future improvements in order to be successful. In particular, we need to be much faster with administrative matters.

The navigation system was awarded the Berlin Brandenburg Innovation Prize in November 2018. In retrospect, what were the decisive factors for its success? At the beginning, we really did not know whether the basic idea was actually feasible. After all, we are talking about technology that did not yet exist, rather than the umpteenth replica of a product that has undergone minor evolutionary changes. Once we had established that it worked, we wanted to make the project a commercial success, too. An experienced team that can work on this specific topic over long periods – and we are talking about five to 10 years – was essential. It was also important to get members of staff with different areas of expertise involved. Our core team consisted of engineers, mathematicians and geographers, with ongoing support from the wider institute, in the form of the secretariat, technicians, scientists and the management team, as well as the overarching infrastructure. Together, this has paid off 100 percent. It was a constant learning process. Usually, our research affords us a lot of freedom. In a technology transfer process, there are strict rules that have to be adhered to around the clock, whether you like them or not. Alongside the development work, professional management and quality assurance are also crucial, despite being tasks that researchers are less inclined to take on. If just one of these areas is not given sufficient attention, the whole thing will fail. Our goal was to succeed, and success meant industry adopting our system. We have achieved this, and we are very proud to have done so.

OPTIMUM APPROACH: THE NAVIGATION SYSTEM IPS

The Integrated Positioning System (IPS) developed by DLR consists of a stereo camera system (far left and right) and an integrated inertial measurement system. An additional camera (second opening from the right) acquires the inspection images. The LEDs at the centre are used for illumination.

IPS is also used for research in the areas of autonomous driving and surveying of road infrastructure, as shown here with a research vehicle from the DLR Institute of Communications and Navigation.

OTHER POTENTIAL APPLICATIONS OF IPS

In addition to the inspection of ships, the system can be used in the mining sector, as the condition of the facilities has to be checked and recorded on a regular basis. Researchers have already used IPS in conjunction with the spin-off company VINS for forest inventory. At present, only random samples are used to determine the number of trees within a given area of forest. IPS can provide precise information on exactly how many trees there are, together with their height and diameter, within the area in question. The researchers have also developed a functional demonstrator that can be integrated into different vehicles. One of these systems was used on the road in New Zealand in 2018 to survey the traffic infrastructure at accident black spots.

The navigation system was awarded the Berlin Brandenburg Innovation Prize in November 2018.
The DLR site in Cologne turns 60

By Julia Heil and Michel Winand

In 1959, Franz Josef Strauß, German Minister of Defence, laid the foundation stone for one of Europe’s most modern research and development facilities on the site of the former Wahn-dyna-

There is one thing that has not changed at the DLR site in Cologne between the

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The solar furnace is

BUILT TO LAST

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Investing in the future

Together, the research institutes and facilities on the site work

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Schorndorf Real-World Laboratory – DLR transport researchers develop and test an innovative digital concept for on-demand bus services.

By Denise Nüssle

Curiosity, excitement, joy, albeit disappointment and annoyance from time to time. Locals experienced the whole range of emotions on seeing the two little buses from the Schorndorf Real-World Laboratory turning the corners of the sometimes narrow streets of Schorndorf’s Südstadt district. The mission was to pick up passengers on time and at the right place and take them to their respective destination, in accordance with their individual travel specifications. In other words, this was a bus service without fixed routes or bus stops. For about three years, this mid-sized town east of Stuttgart – with a population of around 40,000 – was the scene of a research project that is unique in Europe. Based in the hometown of Gottlieb Daimler (whose name was also given to one of the buses), transport researchers from DLR worked together with their project partners and local citizens to develop and test a forward-looking mobility solution. The bus ran on demand, rather than according to a timetable – not as a new or additional service as is the case with other projects – but as a substitute for two existing bus routes. The aim was to design a more flexible and sustainable public transport network, aligning it more closely with users’ needs. At the same time, it sought to minimise empty runs, thus reducing the amount of traffic and using resources in a more targeted way.

Public transport on demand – flexible even during off-peak times

“Many innovative mobility initiatives concentrate on specific target groups or inner-city areas of large cities. By contrast, Schorndorf’s structure makes it representative of many towns in Germany, which have seldom been considered for this development due to their size and location. Yet many people feel that local transport is insufficient and lacks flexibility in precisely such areas,” says Mascha Brost, a DLR scientist and project manager at the Real-World Laboratory, describing the starting point for the project. One example of this is the dilemma over whether to run local public transport at times of low demand, such as late in the evening or on weekends. If buses operate a tight network, with frequent services, they often carry few passengers or are completely empty. Although running buses less frequently and on fewer routes keeps the costs and environmental impact down, passengers see this as inflexible, making it less appealing. On-demand bus systems are a possible solution. “With the Schorndorf Real-World Laboratory, we wanted to find out how providing buses on demand might work for all sections of the population, and what opportunities and challenges are involved in the introduction of such a system,” Brost says. There were three key focus areas: the operating concept for the on-demand bus, the participation of local people, and the development of innovative vehicle concepts for future on-demand bus systems.

The launch in February 2016 marked the start of an exciting, busy time that was both personally and professionally demanding for the project team. In addition to their scientific analysis, they had to set up a functioning system of on-demand buses that would prove its worth over the pilot period of nine months while ensuring the provision of a proper public service. It was therefore important to take a close look at the status quo on the ground as early as possible, organise vehicles and consider the framework conditions and regulatory requirements for local public transport. This specifically meant finding out where the minibuses from the Real-World Laboratory were generally able and allowed to drive and stop, for example. On their forays around the applicable area in Schorndorf’s Südstadt district, the team recorded traffic signs, pedestrian paths, kerbs and inclines in order to identify more than 200 potential places for getting on and off the bus, in addition to the existing bus stops. These virtual stopping points and flexible routes allowed for new, bespoke direct connections and shorter walking distances to the stops.
Participation as a success factor – Schorndorf citizens provide local expertise

From the very beginning, the Real-World Laboratory team ran an extensive communication and participation campaign – a vital part of the project – in order to inform Schorndorf citizens and community bodies, and to actively involve them. This included public information events, surveys, interviews and the test users, not to mention mobility workshops and several sessions with representatives of different user groups. In the process, discussions were held regarding the opportunities and challenges presented by this kind of mobility system, Gebhardt says in summary.

The operating concept – the digital heart of the on-demand bus system

The Real-World Laboratory group set about developing the digital ordering system on the basis of these insights. As a central component, it connected all those involved with the on-demand bus system. Users could transmit their travel request via the smartphone app, online, by telephone or in participating shops, restaurants and cafes, specifying where and when they wanted to be picked up, and where they wanted to go. A special, continuously optimised algorithm then calculated a route based on all of the requests and informed the users of the actual pickup and drop-off times and places. The drivers of the two minibuses received a current route via a user interface specially programmed for this application. “The expertise of all project partners has gone into the development of this operating concept. As we did not have a long test phase before going live, we were faced with the challenge of making ongoing improvements to the system while it was actually running, meaning fixing bugs quickly and incorporating feedback from users to ensure and improve the system’s performance,” Brost says.

The acid test – premiere of the on-demand bus

After two years of preparation and development, live operation of the on-demand buses began in March 2018. The two minibuses from the Schorndorf-Real World-Laboratory were specially fitted out for local public transport and used from Friday afternoon until the end of operations on Sunday night. The normal timetable applied outside these times. Numerous challenges cropped up over the first week-ends of live operation, in particular, and emotions were running high. Some members of the project team travelled on the buses around the clock, explaining the concept and helping with any issues. “Expectations were extremely high, and especially in the initial phase, when the booking system did not always run smoothly, we were on the receiving end of both constructive criticism and a lot of anger, which we first needed to come to terms with. The bus drivers were very supportive of this project team, Gebhardt recalls: “We were thoroughly thrilled. The bus drivers thought on their feet, came up with solutions on the spot, patiently explained the concept over and over again to the users, and quickly adapted to a very different way of operating.”

The live operation phase for the on-demand bus came to an end in early December, after 39 weeks, and the team was able to look back on a very exciting and eventful time. From a scientific perspective, they had collected a wealth of data and experience; the evaluation of which would provide new insights into designing and implementing forward-looking mobility concepts for local public transport. The two minibuses carried more than 10,000 passengers and covered more than 20,000 kilometres over that time. An average of 250 people used the service every weekend. Two-thirds ordered the bus via the app, while the remaining third used the telephone ordering service. The other ordering options – the website and participating outlets – were rarely used.

“The practical operation of this solution clearly demonstrated the opportunities and challenges presented by this kind of mobility system,” Brost concludes. Compared with the set-route system, around 10 percent of the vehicle kilometres and some 20 percent of potential round-trips were saved due to a lack of bookings. As the team used smaller buses, the fuel consumption was more than halved, and the avoidance of empty runs went down very well with many citizens. A positive trend also emerged from the user surveys: while around 35 percent of people were either satisfied or very satisfied with the Real-World Laboratory bus concept in May, this figure had risen to 50 percent by the end of October. The scientists attribute this mainly to the continual improvement of the system and to the effect of familiarisation. There was also a clear generational split: younger users tended to take to the system more easily, and expressed greater satisfaction than older users.

In retrospect, the DLR researchers agree that the project team achieved the best possible solution thanks to the huge dedication of all participants. “But informing and involving all of the potential users with the limited resources of a research project was harder than we thought, particularly with regard to the topic of barrier-free access,” says Katharina Karnahl, who researches operating concepts for local public transport at DLR and oversaw the implementation of the operating concept at the Schorndorf Real-World Laboratory.

It also became clear that it will take changes to the local public transport system a lot of time to be accepted: “We underestimated how much people rely on their routines,” Karnahl adds. At the same time, the project team was often delighted at the level of engagement from local people as well as their constructive and sometimes very detailed suggestions on how to improve the project by working together. “Over time, a genuine Real-World Laboratory community emerged, made up of local citizens, bus drivers and the project team,” Gebhardt says in summary.

Already during the project, the Schorndorf Real-World Laboratory team received numerous requests to present their work in talks and publications for local communities, associations, companies and academia. Although the project has officially come to an end, the researchers’ work continues: the collected data needs to be finally evaluated and publications need to be written. But the thirst for knowledge is still there: “We all want to continue our research in this area and finding out about innovative mobility concepts. For instance, it would be exciting to develop other scenarios for the use of on-demand bus services,” says the scientists, looking ahead to the future and other possible joint projects.

**SCHORNDORF REAL-WORLD LABORATORY**

**Definition:** A real-world laboratory is a research format whereby scientists cooperate with partners from the real world (companies, municipalities and civil society (local people). Together, they initiate changes and support, observe and analyse the transformation process. The focus is on mutual learning in an experimental environment.

**Funding:** The Schorndorf Real-World Laboratory was one of seven research projects funded by Baden-Württemberg’s Ministry of Science, Research and the Arts to test future-oriented solutions to challenges in metropolitan areas.

The partners: The partners of the DLR transport researchers included Schorndorf Town Council, the Travel and Traffic Association Stuttgart (VVS), Knauss public buses, Eisingen University of Applied Sciences and the Centre for Interdisciplinary Risk and Innovation Studies (ZIRIUS) at the University of Stuttgart.

**INNOVATIVE VEHICLE CONCEPTS FOR FUTURE ON-DEMAND BUS SERVICES**

The Schorndorf Real-World Lab also focussed on the development of innovative vehicle concepts. The team devised virtual design concepts and created some of them as 1:10 scale models for that purpose. The concepts were designed in the most optimal way possible for the requirements of an on-demand bus system. The size, number of seats, barrier-free accessibility and interior design of the buses were given equal consideration, as were matters relating to drive technology, energy consumption and emissions.

**Accessibility was an important aspect in the development of the vehicle concept**

**Design models of forward-looking vehicle concepts for on-demand bus systems**
Ensuring reliable communications with satellites or the International Space Station requires a global network of ground stations and data links. The challenge is to make sure that this communications system works even if it fails. This article is part of the ‘Glorious Giants’ series, which gives an insight into DLR’s large-scale facilities.

A network of ground stations ensures the exchange of information with Earth-orbiting satellites and more distant spacecraft

By Florian Kammermeier

Large amounts of data must be transferred between Earth and space. More than 1700 satellites are operated by Earth’s many countries. Commands have to be sent to space and data has to be received from spacecraft 24/7. However, reliably communications with satellites from the ground can prove to be a challenge. More than 1000 of the satellites circling Earth do so at high speeds and low orbits between 200 and 2000 kilometres. These are primarily research satellites, observing our planet’s surface, its atmosphere and clouds. In the same way as the International Space Station (ISS), many of them circle the Earth in only 90 minutes, completing 16 orbits each day. They move across the sky so quickly that they appear only briefly over ground stations before descending below the horizon after five to 15 minutes of contact time.

Many of these satellites are in what are referred to as polar orbits; this means that every one of their orbits passes over both of Earth’s poles. The plane of each orbit is rotated slightly with respect to the previous one, so that the satellite can eventually pass over every part of Earth’s surface. These satellites often need to receive commands, if they have experiments on board, for instance, or are required to observe a forest fire. They also return large amounts of data – satellites such as Sentinel-5P, which measures the composition of the atmosphere – transmit several terabytes of data to Earth every day.

The Launch and Early Orbit Phase (LEOP) of a mission requires a great deal of contact time with the spacecraft as they make their way to their final orbit, and during their commissioning phase.

No time to stand alone

All this creates a need for as many contact opportunities as possible, each maintained for the maximum time. A single receiving station is seldom sufficient. Satellites in polar orbit come within the range of the DLR ground station in Weilheim, south of Munich, about four times a day, for 10 minutes each time. Antennas located closer to Earth’s poles are able to establish more frequent and longer contacts. In the Arctic, contact can be made during up to 12 of the 16 daily orbits. However, even in the best-case scenario, a single polar antenna is out of contact with any given satellite for over an hour between overflights.
In order to transmit large amounts of data, to enable contact or to send commands at any time – particularly in the event of an emergency – global networks of receiving stations and data links have been created to act as the ‘nervous system’ for satellite operations. DLR has one such network, which is operated, managed and even designed by the German Space Operations Center (GSOC) and the German Remote Sensing Centre, both of which are part of DLR. However, DLR owns only some components of the network – two large ground stations in Germany, a smaller facility in northern Canada and another in Antarctica, together with a few kilometres of fibre-optic cable. Most of this ‘nervous system’ belongs to other organisations. Some ground stations are owned by other space organisations or private companies, while the data links are generally provided by network operators such as Deutsche Telekom. This international collection of systems requires the establishment and maintenance of cooperative relationships. For example, data from the Japanese Hayabusa2 spacecraft, which travelled more than 100 million kilometres to visit the asteroid Ryugu, were received by DLR in Weilheim. For its part, DLR sometimes contacts its spacecraft using NASA antennas or private ground stations, such as the one on the island of Spitsbergen, off the coast of northern Norway. The site from which contact is made also depends on the type of mission. Where is the target object, and what is its orbit? How sensitive does the receiver need to be in order to receive the signal?

Amplifying, translating and relaying

The ground stations are responsible for everything that happens between the reception from the spacecraft and their delivery to the outbound data link. Their personnel service the antennas, activate the correct transceivers for each operation, point the dishes at the satellites and ensure that they are tracked. When the transmissions reach the ground, the signals are amplified, undergo frequency translation and then demodulated and decoded. This translates them into a language that computers and data transmission systems can understand. Analogue signals with noise, errors and encoded data come in, and clean digital data goes out. This procedure used to be prone to failures, says Martin Häusler, and experienced at receiving satellite data, “These days, a data transmission from satellites can be jeopardised by more than stock trading – this can occur when connections simply fail altogether. In one instance, a fishing vessel damaged a transatlantic cable off the coast of Florida. As a result, the direct connection between Oberpfaffenhofen and Houston was interrupted for one week. However, this did not present a problem: “We switched to an alternative connection to Houston, via New York, until the primary link was repaired,” Peinado recalls. The redundancy principle applies to all the connections. Even if they are just a few kilometres long, there are always two separate routes to the same destination.

At DLR, this means that all links lead to Oberpfaffenhofen.

Reserving connection capacity and negotiating with network providers

Similar data links extend to many regions of the world and also connect Europe and America. It is rare, however, for a link to run from the region around Oberpfaffenhofen directly to its destination. In practice, this means booking different links from a receiving station over the shortest possible route, and negotiating with various network providers to make this happen. “If a receiving station is only needed for a special mission, a connection might only be rented for a few weeks,” Peinado says. A number of commercial organisations have also entered this market and are now offering satellite contacts as an overall package. They have ground stations around the world and fixed connections with their facilities. As a satellite operator, DLR only needs to reserve one cable to these hubs, such as those provided by Kongsberg Satellite Services (KSS) in Tromsø, Norway, or the Swedish Space Corporation (SSC) in Stockholm.

Peinado recounts a story that demonstrates how difficult things can become, even when using private data links. When the fibre-optic connection between Europe and Houston had recently been established, the performance of DLR transmissions was repeatedly degraded. This phenomenon was observed over a period of weeks, with the performance degradations primarily occurring at approxi- mately 10:00 on the East Coast of the United States. At first, no one understood why this was happening. “The technology was working perfectly,” Peinado explains. “But then one of our colleagues identified the cause: ‘Wall Street opens at 19:30 New York time. Stock trading was overloading the connection.’”

Data transmission from satellites can be jeopardised by more than stock trading – this can occur when connections simply fail altogether. In one instance, a fishing vessel damaged a transatlantic cable off the coast of Florida. As a result, the direct connection between Oberpfaffenhofen and Houston was interrupted for one week. However, this did not present a problem: “We switched to an alternative connection to Houston, via New York, until the primary link was repaired,” Peinado recalls. The redundancy principle applies to all the connections. Even if they are just a few kilometres long, there are always two separate routes to the same destination.

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In addition to the Apollo programme, the Moon itself continues to arouse great interest – from both the scientific community (DUR Magazine 160, April 2019) and from photographers. One of these photographers is DLR researcher Rolf Hempel, who acquired the impressive photograph of the waxing Moon featured here. It shows the Apollo 11 landing site (marked with a cross). To see the image up close visit dlr.de/vollmondbild.

TRIBUTE TO APOLLO

2019 marks the 50th anniversary of humankind’s Moon landing, so it does not come as a surprise that the Apollo programme has become of public interest. As varied as the honours are, they all have one thing in common: respect for technological and human achievement at a time when modern navigation and communications technology was in its infancy. This section features some selected information on this topic.

THE MOON MISSION AT MUSEUMS

The Technik-Museum Speyer is home to what it claims is Europe’s largest space exhibition, “Apollo and Beyond”. In the anniversary year of the Moon landing, exhibitions on this theme can also be seen elsewhere: “Fly me to the Moon: The Lunar Landing 50 years later” from 20 July until 3 November 2019 at the Museum der Moderne in Salzburg; “Spaceship living room: the Moon landing as a media event” until 12 September 2019 at the Museum für Kommunikation Nuremberg; “Apollo – 50 years since the Moon landing” until 10 March 2020 at the Ries Crater Museum; “Hello Universe! The experience of space travel” until 5 January 2020 at the Heinz Nixdorf MuseumsForum in Paderborn; The special exhibition “RIDE to the Moon: an almost small step” until 8 September 2019 at the Peenemünde Historical Technical Museum.

THE MOON MISSION IN BOOKS

What would the history of the Moon landing be without the impressive photographs taken by those involved? How would we imagine the Universe were it not for the fascinating images acquired by the Hubble Space Telescope? NASA has opened its archive 50 years after the Moon landing. The result is a stunning picture book covering 60 years of the history of space travel – from the very beginnings of rocket development to the latest missions to Mars. The synopsis of The NASA Archives (Taschen) sums it up as “a profound meditation on why we choose to explore space and how we will carry on this grandest of all adventures in the years to come.” “Meditation” hardly seems sufficient given the sheer fascination of this captivating book, featuring over 400 historical photographs, some of them spread across two pages, along with technical sketches and illustrations. This is a book of superlatives, and not just in terms of its size.

This isn’t the place to find the iconic images of Moon walkers or the barren surface of Earth’s satellite. Instead, Apollo the extraordinary visual history of the iconic space programme explains the Moon landings with detailed diagrams and visuals. This debut work by graphic designer Zack Scott is remarkable for its lovingly detailed drawings, and manages to make Apollo, a colossal feat of technology, entertaining even for readers who are not already well versed in the field of space travel.

Apollo to the Moon uses 50 key artefacts from the Smithsonian archives to tell the story of the Apollo programme. The bold photographs, fascinating graphics and engaging stories in the book by National Geographic celebrate one of humankind’s greatest endeavours. Each historical feat is symbolised by a different object, such as a Russian stamp honouring Yuri Gagarin, a real treat for space fans.

A different take on the historical journey to the Moon: Apollo 11 (SelfMadeHero) tells the story of the eponymous mission in the form of a graphic novel, with the focus on Neil Armstrong, Buzz Aldrin and Michael Collins. The fantastic drawings by Mike Collins (no relation to the astronaut himself) bring a unique sense of drama to the adventure and show the more sombre moments alongside the huge successes, in keeping with the tradition of graphic novels, which tend to take a dark tone.

FROM THE APOLLO ARCHIVE

The record for speed on the Moon is held by Apollo 17 commander Eugene A. Cernan, who drove through the Taurus Littrow valley at a staggering 18 kilometres per hour. Due to the low gravity, the rover’s wheels lost their grip several times.

Cernan also boasts a record – in distance. He travelled a total of 357.74 kilometres with the lunar rover. The Soviet Lunokhod 2, part of the Luna 21 mission, travelled a total of 39 kilometres in the surroundings of Apollo 17 in 1973.

400,171 kilometres: Humans were never further away from Earth than on 14 April 1970 – and this occurred during the aborted Apollo 13 mission, which had to be steered around the Moon in order to use its gravity for a “free return path”.

Oxygen, electricity and water were the three goods of vital importance to the astronauts of the Apollo programme. Without water, life on the Moon would not have been possible. The first man to land on the Moon, Neil Armstrong, and his lunar module partner, Edwin “Buzz” Aldrin, took a total of 27.5 kilograms of water with them.

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TRIBUTE TO APOLLO DLRmaGazine 161 49

# Our Moon as an Opportunity

An astronaut’s perspective

The Moon has fascinated humankind since time immemorial. As a constantly recurring guardian in the night sky, many see it as a sign of constancy. For space explorers, it is like a history book, providing us with an insight into the origins of the Solar System. What’s more, it is the ideal platform for testing new technologies that allow people to make use of its resources.

Germany and Europe as a whole have a great and unique opportunity to shape the next decade of space exploration and make a vision come true. With modern technologies such as virtual reality, people will be enthusiastically exploring Earth’s satellite together with astronauts in the future.

We should set a course for the Moon in 2019 and seize the opportunities that it offers.

Matthias Maurer
THE FIRST HUMAN ON THE MOON

Exhibition – 50th anniversary of the Moon landing

The face of a man who had just made history – Neil Armstrong, joy, triumph, relief, but also concentration. In this moment, the Apollo 11 astronauts were not yet back on Earth. Armstrong and Aldrin were still in the Lunar Module, 400,000 kilometres from home. As is the case with mountaineering, the toughest part lay ahead of them – the descent, the return to Earth. However, they had accomplished the decisive feat: they were the first humans to walk on the Moon.

This image reflects the highly challenging mission – the difficulty, the danger and finally the sensational success. One does not see a moonwalker in a white protective suit, but rather the face of a man who had just made history – Neil Armstrong. The words ‘That’s one small step for man, one giant leap for mankind,’ made Neil Armstrong famous. The sentence became an epitaph for the Apollo programme, which turned 50 in 2019.

Neil Armstrong died on 25 August 2012. But this image continues to tell his descendants about his bravery and his emotional state following a pioneering accomplishment. It is as if the photograph wants to tell the viewer something – there is more beyond the horizon.

This photograph, taken by Buzz Aldrin immediately after the completion of the walk on the lunar surface – along with 19 other colour images – is part of the exhibition about the Apollo programme that the DLR Institute of Planetary Research created this year. It shows images from Apollo 8 through to Apollo 17, missions that explored and redefined the limits of what was humanly possible at the time. Visitors can see famous images such as Earthrise over the lunar horizon, but also lesser-known photographs such as the ‘mailbox’, an improvised device with which the Apollo 13 astronauts saved themselves from carbon dioxide poisoning after an explosion caused oxygen to leak from their Command Module. The Apollo 8 to 10 missions, which were preparations for the Moon landing, also have their place in this historical journey. Short texts below the photographs chronicle hair-raising moments, extraordinary scientific achievements and the personalities who shaped the programme. In December 1972, the project of the century came to an end with the completion of the Apollo 17 mission.

The exhibition is accompanied by a directory of literature and a selection of other colour images – is part of the exhibition about the Apollo programme that the DLR Institute of Planetary Research created this year. It shows images from Apollo 8 through to Apollo 17, missions that explored and redefined the limits of what was humanly possible at the time. Visitors can see famous images such as Earthrise over the lunar horizon, but also lesser-known photographs such as the ‘mailbox’, an improvised device with which the Apollo 13 astronauts saved themselves from carbon dioxide poisoning after an explosion caused oxygen to leak from their Command Module. The Apollo 8 to 10 missions, which were preparations for the Moon landing, also have their place in this historical journey. Short texts below the photographs chronicle hair-raising moments, extraordinary scientific achievements and the personalities who shaped the programme. In December 1972, the project of the century came to an end with the completion of the Apollo 17 mission.

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31.5-kilometre test track in Emsland, Germany in the 1980s. One could say that the groundbreaking maglev technology was the forerunner of modern high-speed trains. Even though maglev trains were not successful in Germany, they proved to be a hit in China.

Walking around the museum is like stepping into a time-lapse video and travelling through seven decades of milestones— from the 1950s to the present day. Touching and trying things out is allowed and strongly encouraged at selected stations. Numerous interactive exhibits make the museum a particularly exciting experience for children, as do the experiment tables on phenomena relating to optics, magnetism and acoustics. Anyone who fancies a go on the theremin can try it out here; this harp-like, electrically operated musical instrument can be played simply by making movements in the air. It was used to play music for the soundtrack of Alfred Hitchcock’s thriller ‘Spellbound’.

TV as a new mass medium

Between the two floors, visitors will learn all about the German economic revival. The first flush of prosperity mainly affected the West German population and sparked a growing demand for consumption and entertainment. This was the point at which transistor radios made an appearance in living rooms. And while the Berlin Wall was being built, TV became the new mass medium— first in black and white, and from 1967 in colour. Things were running at a different pace now, quite literally, as an atomic clock had now been invented, losing only one second every million years. The specimen was Germany’s time until 1991 is now part of the exhibition in Bonn. The Paul ion trap that makes it tick, as it were, is explained in detail here.

Just a few metres farther is the rotor system of a very large rescue helicopter, which attests to advances in flight technology. The keen wanderlust of the West Germans spurred on the aviation industry, as reflected in Reinhard Mey’s perennial 1974 hit song ‘Über den Tellerrand’. Astronauts carried out scientific experiments relating to metals research, fluid physics and metals under microgravity conditions in the Materials Laboratory of the Spacelab module. The Spacelab – which had been developed in Europe – strapped to the car seat and badly battered with numerous scratches, patchy paint and missing limbs. The latter half of the previous century was marked by German reunification and the breakthrough in microelectronics. The first mobile phone prototype became available in 1973, and the Gameboy in 1989. Advances in optical storage capabilities led to CD and DVD.

Research possibilities in and on the water as well as in space seemed almost limitless at the end of the last century. From the early 1980s, the Polarstern research vessel enabled the first extensive expeditions to Antarctica and the Arctic. The icebreaker, which is still in use today, can accommodate around 70 researchers and be operated at temperatures as low as minus 50 degrees Celsius. The 1:50 scale model of the ship gives an idea of its features and shows how large and remarkable it was in relation to other ships at that time. Further on, the model of the drop tower is just as exciting, including the drop capsule of the Center of Applied Space Technology and Microgravity (ZARM) in Bremen. ZARM has been conducting research into microgravity, spaceflight technology and hypersonic technology since 1985. Since 2004, a catapult at the foot of the tower has allowed the drop capsule to be launched from below. Using this mode, the microgravity experiment time can be extended to almost 10 seconds.

A new millennium, the euro and Angela Merkel

The advent of the digital age and the new millennium marked a time of huge change. The euro replaced the Deutsche Mark, Angela Merkel became the first female German chancellor and the iPhone conquered the market. The Internet could now be accessed via mobile phones, and digital media began to seep into all areas of life. The exhibition delves into the exciting complexities of this time, looking at the physical context and offering original exhibits from these periods. And since interaction with the exhibits is expressly encouraged, it is hardly surprising that families and school pupils gather at the Deutsches Museum in Bonn. The museum concept is toned down a little for certain exhibits, especially if they are intended to appeal to young visitors. Not all of the exhibits are understandable without an explanation, requiring not only a fascination with technology and science, but also a basic knowledge of these topics. Anyone who has both is bound to enjoy this treasure trove, right at the end of the Bonn Museum Mile.

Microelectronics and optical storage possibilities

The latter half of the previous century was marked by German reunification and the breakthrough in microelectronics. The first mobile phone prototype became available in 1973, and the Gameboy in 1989. Advances in optical storage capabilities led to CD and DVD technology, displacing vinyl records and video tapes. The twentieth century also saw considerable progress in the field of medicine: insulin was manufactured synthetically for the first time in 1960; the discovery of plastic helped with the development of implants; and ultrasound examinations allowed doctors to see inside the body. Modern diagnostic procedures such as amniocentesis started to find their way into hospitals. Here, all of this is clearly explained using display cases, models, information boards and instruments.
The ‘footprint’ that people leave on Earth is rapidly changing our planet. The back-cover of this impressive photobook reads: “These fascinating and often strongholds.

The two half-page images are almost lost amid the lush, mostly double-page picture spreads in the book New Human Footprint. Yet they are a striking testament to the brutal interference of humans with nature. Readers will likely rub their eyes and ask themselves, is that actually true? The satellite images provide the answer: man reshapes his environment areas, in extremely varied, often spectacular and frequently frightening ways. ‘Our World in Transition’, the subtitle of chosen by the publisher, could hardly be more apt.

Many of the pictures will be familiar from previous titles in the Footprint range, such as the shot of the pyramids in Egypt, with the city of Cairo rushing menacingly towards them. Others have never been published before. One example is the image of the Iranian oasis town of Keshl, which looks like a tree with a trunk and leafy crown when seen from space, as though sketched out by an artist, but was actually shaped by a traversing underground river. The ploughed-up landscape of brown-black stripes in the brown coal mining area near Hambach and a sulphur-framed crater lake in Indonesia, are both astonishing and shuddering. A spine-like network of oil wells and pipelines in Kazakhstan, patchwork of evaporation basins for lithium production in Chile, transport routes on salty Bolivian soil that bundle like brush hairs, hundreds of strictly linear arranged rows of parasitic troughs of a solar power plant in Morocco and mosaic-like aquaculture areas in China all illustrate both human resourcefulness and its impact on the environment.

The ‘footprint’ that people leave on Earth is rapidly changing our planet. The back-cover of this impressive 255-page photobook reads: “These fascinating and often surprising views reveal just how big our impact is.” Our Earth, is it still a garden, or has it become one massive dumping ground?

Cordula Tegen


In honour of the 50th anniversary of the Apollo 11 Moon landing, David Eicher (Editor-in-chief of Astronomy magazine) and Brian May (Astrophysicist and lead guitarist of Queen) present Mission Moon 3-D, Reliving the Great Space Race. Former astronaut Charlie Duke wrote the foreword, and the afterword is by Jim Lovell.

The story starts on 25 May 1961, when President John F. Kennedy announces his ambitious goal to land a human on the Moon and bring him safely back to Earth. Eicher paints a clear picture of the social and political context that initiated the space race, and follows it from Sputnik and Gagarin via the Luna programme and the Apollo missions all the way to the ISS. He concludes with some of the more recent developments in space exploration. There is also a chapter remembering those who lost their lives while developing the technology that would enable space travel and Moon landings.

The credentials of the authors alone merit a closer look at yet another account of the mission operations and highlights via the Hayabusa2 twitter account – direct from asteroid Ryugu.

On 3 October 2018, the MASCOT lander successfully landed on asteroid Ryugu, took numerous pictures and carried out numerous experiments. And, although MASCOT’s mission is complete, its mother-ship Hayabusa2 is still hard at work. What is happening on asteroid Ryugu? What is Hayabusa2 doing at the moment? Stay up-to-date on all of the mission operations and highlights via the Hayabusa2 twitter account — direct from asteroid Ryugu.
The Virtual Path to Certification

Buses on Demand

Light as Air and Versatile

Barbara Milow and the Supermaterial

About DLR

The German Aerospace Center (DLR) is the national aeronautics and space research centre of the Federal Republic of Germany. Its extensive research and development work in aeronautics, space, energy, transport, security and digitalisation 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 8,200 employees at 26 locations in Germany: Cologne (headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Bremerhaven, Cottbus, Düsseldorf, Giessen, Hamburg, Hanover, Jena, Jülich, Lampoldshausen, Neunzolln, Oberpfaffenhofen, Oldenburg, Rhein-Sieg-Kreis, Staßfurt, Stuttgart, Traun, Ulm, Weißenfels and Zittau. DLR also has offices in Brussels, Paris, Tokyo and Washington D.C.

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Cover image

Shown here is the spherical structure of a novel biopolymer aerogel developed by DLR researchers in a laboratory experiment. It is produced by combining chitosan with a thermoset. You can read more about the versatile aerogels and about Barbara Milow who, together with her team, is ‘cooking up’ new recipes, on page 30.

Printed on recycled, chlorine-free bleached paper.

Suprematist: Barbara Milow, the German Aerospace Center.

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