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MASCOT IN WONDERLAND

Breaking new ground with the Hayabusa2 mission

QUIETER FLIGHT

AUTOMATED TRANSPORT

DLRmagazine 159

Dear Readers,

“One man’s meat is another one’s poison”. This age-old adage could hardly be more fitting for 2018. The vintners are delighted, the farmers devastated. An abundance of berries, the corn harvest a disaster. Glorious sunshine, lakes drying out. A year of dichotomies is drawing to an end, not just in terms of the mercurial weather. Contrasts, as far as the eye can see.

Comparing pros and cons is painful at times. But it can also provide impetus, especially when we manage to bring together what seems determined to veer apart. The advantages and disadvantages of technical progress help to drive innovation. The desire for permanent mobility, for instance, is in opposition to the insistence of residents along traffic routes to be allowed to live in peace. So DLR researchers seek solutions for lighter aircraft: the report on the Low Noise ATRA demonstrates how design changes can reduce aircraft noise. Automation in rail transport, as another example, also means that the driver will ‘only’ have to monitor the journey and might be more susceptible to fatigue: DLR rail researchers have taken a closer look and have come up with some proposed solutions. Or satellites: Earth observation and terrestrial communications benefit from this technology. The downside: repairs are virtually impossible in space, and if they are, then dangerous and expensive. DLR engineers are now using holography to develop robotic solutions for this quandary. And here is an example from energy research: renewable energy sources can replace fossil fuels. But their fluctuating availability requires smart storage systems, a field in which the DLR energy researchers are currently hard at work.

The opposing poles of pros and cons permeate beyond science and technology as well. Christmas, for instance, a family celebration with almost mandatory peace and conviviality, can quite often end in a rumpus if grandma is too hectic or the grandson is bored to distraction. Naturally, the DLR scientists do not have patent remedy for these situations. But it is worth remembering the wise words quoted above and perhaps take them as an implicit appeal for serenity.

We wish you a harmonious end to the year!

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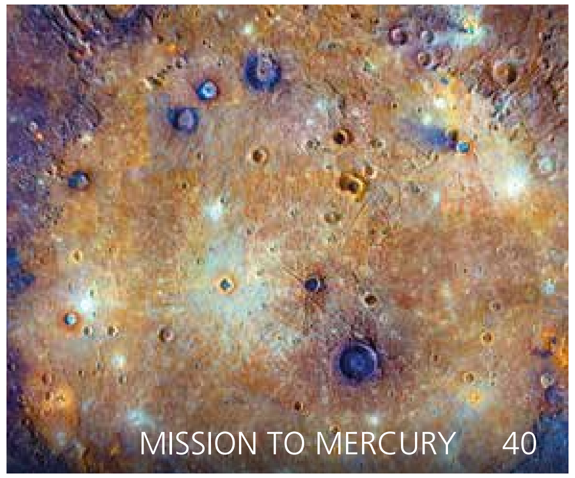
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MORE THAN SUN AND WIND

Commentary by Karsten Lemmer

Karsten Lemmer is the DLR Executive Board Member responsible for transport and energy research

Good news! For the first time ever, the global growth of photovoltaic power has surpassed that of other energy sources. It is therefore moving forward with the Energy Transition. The bad news: greenhouse gas emissions have also been on the rise for several years. So while we are doing something right, we are also doing something wrong. What do we have to do to achieve the ambitious COP23 climate targets and bring our energy-intensive lifestyle into harmony with the environment?

It is clear that Germany's efforts to support the Energy Transition allowed the country to reach a good position at a relatively early stage. The Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz; EEG) provided plenty of impetus and brought about both a change of direction and a rethinking among society at large. Renewable energy is no longer purely a matter of ideological environmental policy, but rather a self-evident purpose that is slowly shaping our everyday lives. This is apparent in a number of places, such as the city of Frankfurt or the district of Fürstenfeldbruck, which have made the complete switch to renewable forms of energy. But in the meantime, the Hambach Forest near Cologne, Germany reflects the dilemma that we face today between coal and solar power. The activists occupying the forest rightfully reject coal mining and its environmental consequences on moral grounds, while the energy company is justifiably asserting its legal right to use the land, with the support of state authorities. Instead of demonising the energy company as greedy and behind the times, we should see it as a guarantor for the fulfilment of our energy needs and accompany it on the path to the renewable age. Coal-fired power plants are an investment – they should be profitable for both the operators and the taxpayers subsidising them. At the same time, these are employers to thousands of people throughout numerous regions. Existing mining areas can be repurposed for solar power plants or wind farms, while the power plants convert the harnessed energy into electricity or hydrogen. Supplemented by large power-to-heat-to-power storage systems, they will store the energy from renewable sources on a regular power-plant scale, thus transforming unpopular coal-fired power plants into climate-friendly energy suppliers.

Renewable energy holds the key to the Energy Transition, but it also presents the energy system with new challenges. Millions of roofs with solar panels, solar power plants in sunny areas far and wide, and thousands of wind turbines at sea and on land make this point clear; while until now energy has been fed into the system by just a few power plants and suppliers, many different energy producers will contribute to a carbon-neutral energy supply in the future. And this will only work if there is sunshine and wind. At the same time, the transport sector is changing energy requirements through electromobility and renewably generated synthetic fuels. As such, the energy system has to change – with the help of digitalisation and artificial intelligence – in order to be able to meet the diverse needs of society and industry for electricity, heat, cooling and mobility using decentralised, heterogeneous, fluctuating energy sources. This simply cannot happen without smart networks and storage systems.

Germany can be proud of what it has achieved so far. However, we are still a long way from reaching our goal. Protests like those held in the Hambach Forest, scandals like 'Dieselgate', laws like the EEG and agreements like COP23 all help to advance the cause. Through concepts and technologies for sustainable power generation, flexible energy storage and decentralised grids, DLR is building bridges towards a sustainable Energy Transition – with renewable energies and without emissions.

SOLAR POWER PLANT SAFETY – SILICONE OIL PASSES QUALIFYING TEST

DLR scientists have teamed up with international partners in the southern Spanish province of Almería to demonstrate the practical suitability and functionality of a new silicone oil-based heat transfer medium. Operational safety is an important issue in the development of components and heat transfer media used in solar power plants. But until now, there has been a lack of clear or internationally recognised procedures and standards. The PROMETEO test facility at the Plataforma Solar de Almería (PSA) offers developers ideal opportunities to demonstrate the safe operation of a new heat transfer fluid.

A burst pipe was simulated as part of a field trial conducted by WACKER Group, DLR and CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas). The leakage, simulated using a very fast opening valve, caused the 420 degree Celsius hot heat transfer fluid to escape without igniting. The process was supported and monitored by TÜV Nord. The trial was one of the final steps in the complete qualification of the silicone oil HELISOL®5A, a heat transfer fluid for parabolic trough power plants developed by the WACKER Group in Munich. The oil had previously passed the so-called 'proof of concept' successfully during an aptitude test, in which it was solar operated for 480 hours at an operating temperature of 425 degrees Celsius in the demonstration plant (totalling 1100 hours of solar operation).

PROMETEO test facility at the Plataforma Solar de Almería

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THE AUTOMATED ENERGY CONSULTANT

Algorithm for cost-effective, comparable information prior to energy upgrading

Approximately 400,000 housing units are modernised in Germany every year, and for many of them this includes an energy upgrade. This is preceded by energy consultations, the costs of which can reach four-figure sums. However, they vary markedly in quality. The DLR spin-off company neofizient has now developed a measuring system that evaluates energy information for buildings. "Our algorithm is designed to make consultations more objective, faster and thus more economical," says Silvan Siegrist, who heads the project alongside Arne Tiddens.

The infrared measuring system in the hands of Silvan Siegrist (right) reveals heat loss, presented on the left by Arne Tiddens.

The system is based on cameras that capture a 360-degree view of a space and cover the visible and infrared ranges. The image data is then superimposed on a model. This allows aspects such as the heat transfer coefficient to be measured, showing where and how much heat is being lost and revealing thermal bridges that penetrate the insulation of the building. Examples include steel girders that protrude through a wall, poorly insulated window frames or damp on walls. These data can then be assessed by energy consultants, trades people or those conducting the renovation themselves. "The measuring system should be economical enough that people can afford to adopt it themselves, and simple enough so that even laypeople can use it," explains Silvan Siegrist.

Siegrist and Tiddens are currently working at the DLR Institute of Solar Research in Jülich. They have also been awarded funding of around 250,000 euro up until the end of 2019 under the Helmholtz Enterprise start-up programme. Their measuring system is due to be launched on the market in spring 2019.

Capturing the road environment accurately in an image: The radar satellite TerraSAR-X records distinctive points on the roadside (DriveMarks), such as traffic signs and guardrail posts (here at the Hittistetten motorway junction near Ulm). The information about lane markings was acquired from aerial images provided by a DLR research aircraft equipped with the Institute's own 3K camera system.

TO THE POINT.

FROM EARTH OBSERVATION TO AUTONOMOUS DRIVING

Bright and piercingly sharp – a constellation of tiny white points appeared before Hartmut Runge's eyes every time he looked at the radar images acquired by TerraSAR-X. Focusing his gaze on these bright clues, the scientist from the DLR Remote Sensing Technology Institute made a surprising discovery – these were none other than lamp posts, traffic lights, street signs and similar objects along roads. At first, they were not useful for creating typical Earth-observation products, such as land use maps or digital elevation models. But the curiosity of the experienced researcher in the area of transport was sparked – because some of his colleagues had recently developed a high-precision position measurement technique.

The DLR-developed DriveMark® technology now makes the creation of high-resolution digital road maps from space possible

By Bernadette Jung

GPS, Galileo and other global navigation satellite systems (GNSS) have become our loyal companions on unfamiliar and even well-known routes, always on hand to point us in the right direction. Such systems pinpoint our position with ever greater accuracy, depending primarily on the satellite signal. Every centimetre matters, especially when autonomous vehicles are increasingly part of road transport. Today's new cars are equipped with plenty of assistance systems and semi-autonomous functions that relieve the pressure on the driver. To achieve full autonomy, cars must be equipped with both satellite navigation and a system that indicates the correct route without using GNSS – should the signal be interrupted.

When Hartmut Runge identified the points of light in the radar image as traffic-related objects, the idea for DriveMark® was born: navigation using landmarks. Using vehicle sensors and a network of landmarks creates a globally available, highly accurate and reliable navigation system, independent of GNSS. "With the TerraSAR-X radar satellite and a special geodetic processing chain, we can pinpoint the x-, y- and z-coordinates of landmarks to a few centimetres without being in that exact spot. This makes it possible to record large or difficult-to-access areas very efficiently. With DriveMark®, we use satellite remote sensing technology and methods for navigation applications. We create reference points and road maps that are particularly useful for driver assistance systems and automated vehicles," says the DLR scientist in a calm and thoughtful manner. In recent years, he has had to present his application idea to key industry representatives in a host of presentations and pitches – and they showed a great deal of interest.

In 2013, his proposal won over the expert jurors in the international 'Copernicus Masters' idea competition, which is held annually by the AZO Anwendungszentrum GmbH Oberpfaffenhofen. The DLR scientist did not only win the individual 'BMW Connected Drive Challenge' invitation to tender, but was the overall winner of the competition.

Runge's award included consultation sessions with the Munich-based car manufacturer, allowing him to define the requirements for modern maps for autonomous driving and to further develop his idea in a targeted way. The patented DriveMark® system thus emerged as the theme of an innovation project with DLR Technology Marketing and support from the Helmholtz Validation Fund.

Classic measuring principle and state-of-the-art technology

The basic principle of finding one's way using landmarks comes from traditional surveying. For centuries, people have used church towers, mountaintops and other fixed points of reference to triangulate the coordinates of other objects in the area. In the past, these landmarks always had to be plotted by a local survey team – any other method would have proven inaccurate. This was a cumbersome process that, unlike the satellite-based method, does not allow comprehensive mapping. Nevertheless, remote sensing satellites do not provide the required level of accuracy for navigation applications. DriveMark® now serves as a bridge between age-old measuring techniques and the very latest cutting-edge technology, opening up new horizons for future applications. To achieve this, Runge's team has developed a three-part automated processing chain that converts remote sensing data into digital road maps with an absolute accuracy of 10 centimetres. As such, DriveMark® also meets the requirements for use within the autonomous mobility sector.

For this purpose, it is necessary to first identify traffic-relevant landmarks within the radar image and determine their exact coordinates. Traffic signs and guardrail posts are ideal for this purpose, as they stand on flat ground immediately adjacent to the road, thus forming a right angle. As such, they act as retroreflectors and return the radar signal in a highly focused form. In the radar image, they have a distinctive signature – sharp, bright dots against a dark background. "This is the same effect as the flash of cateye reflectors on a bicycle when the headlights of a passing car shine upon them – you simply cannot miss it," the radar expert explains. Runge uses the base of the masts and poles as measuring points, known as 'ground control points' (GCPs), for the landmarks. In an automated process, the geodetic SAR processor – developed by the DLR Remote Sensing Technology Institute – determines the most suitable GCPs in the radar image and calculates the coordinates. It also takes account of, and compensates for, contributing factors that distort the measured results, such as ionospheric and tropospheric disturbances, as well as geodynamic effects due to tidal forces.

The 'optical co-registration processor' is used to transfer the coordinates of the landmarks from the radar image to optical images from satellites or aircraft. This is essential if the end product is to be used as a road map, and has the additional benefit that aerial images offer particularly high resolution. The processor ensures that a precise georeferenced view of the GCPs is generated, with an absolute accuracy of 10 centimetres. In the final processing step, topographical features are also extracted and digitalised from the optical image. The special 'road feature extractor' recognises, for example, road markings and supplements the landmark overview with lanes, side lanes and exits, creating a digital road map. "We have developed the technology in close collaboration with car manufacturers in order to offer a user-oriented product. The automated digitalisation of the control points and the map as a whole are essential features of and prerequisites for the marketability of DriveMark®."

Autonomous mobility and other applications

The ground control points obtained can be used individually as reference points as well as in the overall view of the navigation map. As such, they can be used as anchoring points for 'mobile mapping' and the ego-localisation of autonomous vehicles. Since the GCPs are digitalised, they can be fed into existing assistance systems, so that a vehicle equipped with an on-board camera, for instance, can aim for these control points and thus determine its own position. Drivers know exactly where they are at any given time or place regardless of GPS and other such systems. This makes automated driving with clear lane guidance and complex driving manoeuvres, such as changing lanes and making a turn, possible.

Hartmut Runge and his team have already developed the next process and applied for a patent. With DriveLine®, crash barriers and noise barriers on the edge of the road can be used to position the vehicle accurately within the lane. With the help of remote sensing, it is therefore possible to not only map the street itself, but also buildings in the surrounding area. Distance sensors in the vehicles continuously determine the distance to the 'DriveLines' and constantly compare these measurements with the map. This lane-keeping method serves as redundancy, for example, when back light causes glare in conventional camera-based systems. An accurate map can – if thought through consistently – also be used to prevent collisions and help to precisely locate sudden changes in surroundings due to accident sites and temporary roadwork.

This new method can also be used within the transport sector to map the test areas for autonomous driving in a targeted way, as this requires fast and precise data. In addition, map service providers can check their products for spatial accuracy, allowing efficient and independent quality control. Using ground control points is also a very attractive method in the construction industry, as there is no need for labour-intensive GNSS measurements on-site, especially in difficult-to-access areas. DriveMark® provides aerial and satellite images with exact coordinates, making them suitable for classic surveying and mapping tasks.

In the future, this unusual combination of remote sensing and navigation may also give rise to an array of new technologies and potential applications. Could Runge have predicted this turn of events when he first saw those bright pinpricks of light in the TerraSAR-X images? "No, of course not," the experienced scientist says with a laugh. "I had no idea how big the project would become. In fact, when you take into account the preliminary studies, developing the technology and preparing it for industry, it was actually three projects in one. At the outset, I simply wanted to know whether these points could be used for traffic applications at all." Well, this point has been made clear.

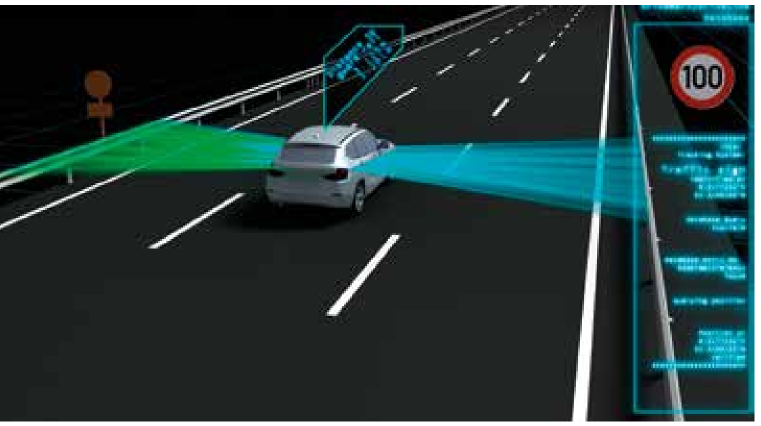
INTERVIEW WITH ROBERT KLARNER, DLR TECHNOLOGY MARKETING

Robert Klarner

How is the technology transfer process progressing for DriveMark®?
The innovation project has been successfully completed and the results have been validated. The requirements have been met in full; indeed, in some areas the level of precision is even better than expected. As such, we have started marketing it to potential users of the technology. The initial orders for sample data show that there is real interest out there. The aim is to transfer the DriveMark® solution in such a way that commercial licensees can independently enhance or validate their highly accurate mapping products.

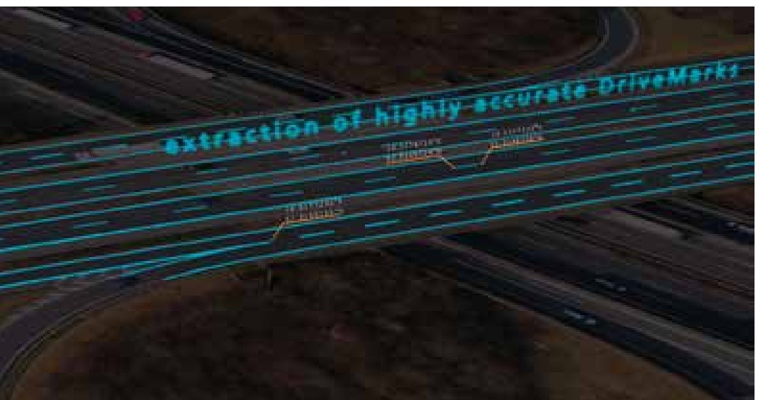
Car manufacturers are already testing autonomous vehicles. How can advanced concepts like DriveMark® be used within this context?
Experts agree that the new generation of navigation maps in the best possible resolution – meaning HD – are indispensable for safe and highly automated driving. DriveMark® can play its part by providing exact reference points that allow lanes and 'road furniture' to be pinpointed with precision. One particularly advantageous aspect of the system is that it can be applied comprehensively and automatically everywhere – in the United States or Asia, as well as in Germany. All of these are crucial success factors for the practical application of the technology.

DriveMark® and DriveLine® are registered DLR trademarks – how does this drive a project?
We are aware of the fact that our new process requires careful explanation and needs to become established. That is why we have opted for the registered trademark – it raises the profile of the technology with a focus on its key application. Ultimately, it is about developing the technology to create a new product for our clients and their customers. In the meantime, DriveMark® has become an international brand with recognition value within DLR and beyond. After all, innovation is what matters to the outside world for market execution.

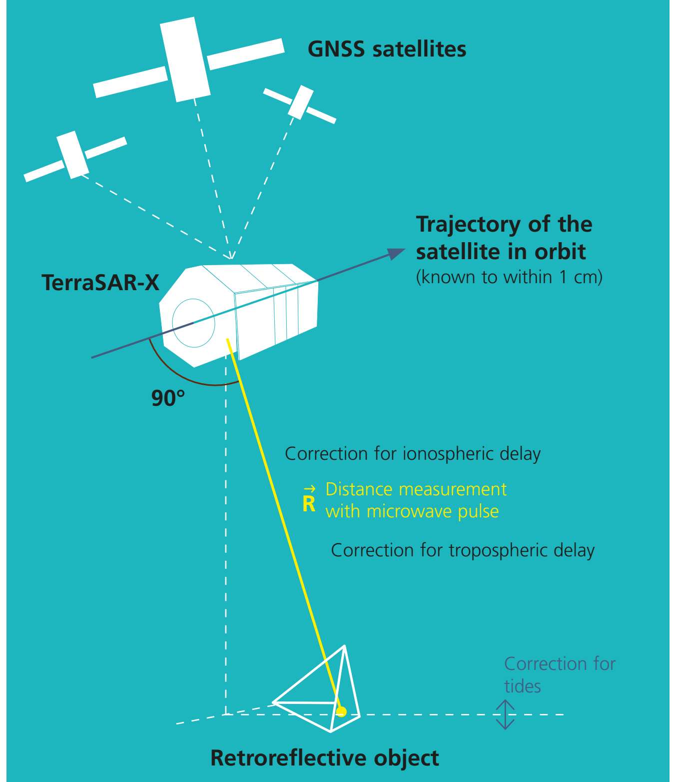


Positioning of an autonomous vehicle within the lane of traffic. The 'DriveLines' (crash barriers as well as the lines with the lane markings) are incorporated in the map with their exact coordinates. The traffic sign serves as a 'landmark' in order to safeguard the vehicle's position once again.

Lane markings with their exact coordinates are extracted from the aerial or satellite image



REMOTE SENSING OF GROUND COORDINATES WITH TERRASAR-X



Hartmut Runge is a communications engineer and has been involved in SAR technology development at DLR from the very beginning. He has been working in the field of transport applications for about 10 years.

TerraSAR-X AND TanDEM-X

DriveMark® uses data from the German radar satellites TerraSAR-X and TanDEM-X to determine the position of objects on the ground. The orbits of the twin satellites are calculated with centimetre precision by the German Space Operations Center in Oberpfaffenhofen. Similar accuracies are achieved thanks to modern radar geodesy for the distance measurement between the satellite antenna and the object on the ground. Several shots from different angles are necessary for position determination in geodetic x-, y- and z-coordinates. The high precision of the DriveMark® process is further enhanced by the high geometric resolution of the radar images in the so-called 'spotlight mode'. The radar satellites have been in orbit since 2008 and 2010, respectively, and are in excellent condition both in terms of battery performance and the radar instruments on board, so that operation can be expected to continue beyond 2020.

HEADING DOWN THE TRACK OF AUTOMATION

Railway operations are becoming digital. The automation process does not stop at the work of rail traffic controllers or train drivers. Software is taking on more and more tasks, and people often only monitor the technology. In human factor studies, DLR's Next Generation Railway System (NGRS) project is looking into how this affects everyday working life, the safety risks that can arise, as well as the measures to be taken by companies.

DLR scientists investigate the railway operations of the future and present design ideas

By Theresa Sieberhein

People are necessary – this will continue to be the case in the high-tech railway system, even with increasing digitalisation. The way in which humans and machines share the work, however, has changed significantly in the past few decades. Through digital assistance and automation, people are increasingly being tasked with monitoring and supervising technical systems, while the volume of manual work is decreasing. But this division of responsibilities between human and machine can become a security risk, according to researchers from the DLR project Next Generation Railway System.

"Passive surveillance activities are a problem from an occupational psychology perspective. They harbour the risk of monotony, a cause of fatigue," says Anja Naumann, Head of the NGRS subproject Cognitive Ergonomics. The result: attention subsides and employees are less aware of the actual situation – and this is precisely what is more important to be able to react quickly in the event of an emergency.

For this reason, rail-human-factor research at DLR is looking to develop measures to maintain or increase employee attention. With this in mind, the project will also consider the workload of rail traffic controllers and train drivers – in particular how automation leads to monotony. "Our goal is to optimise the work of rail traffic controllers and train drivers in order to achieve a medium level of cognitive load. It will also lead to optimal performance," Naumann says. This will help better prevent emergency situations or even accidents, such as the one in Bad Aibling in 2016.

For their work, the researchers first developed a situational awareness survey tool and the DLR Workload Assessment Tool (DLR-WAT), which detects the level of the participants' cognitive load. With the help of these and other methods, the researchers observed rail traffic controllers and train drivers in simulator studies that considered different levels of automation.

"Our results confirm previous research, showing that a highly automated work environment leads to a subjective feeling of being underloaded. Rail traffic controllers who already work with automated route-setting equipment often feel they are not being challenged enough. This applies even more so to drivers on trains with automatic speed control," Naumann says.

Driver's cab simulator RailSET (left) and examiner's workplace (right)

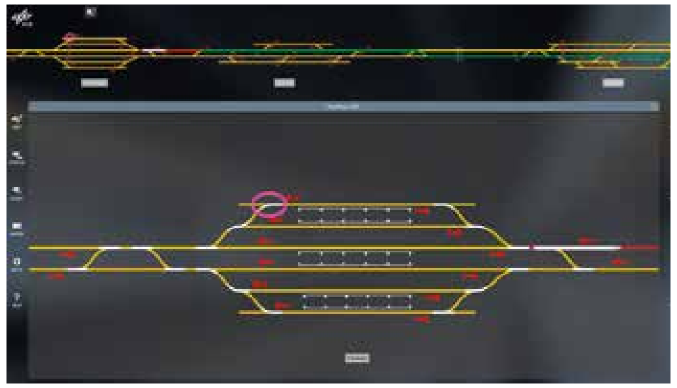
A rail traffic controller's stress levels can change rapidly. In the simulation, these increase abruptly in the event of a disruption or fault. "Instead of being able to focus solely on the situation, the operators are distracted by a non-optimally designed user interface and by having to carry out several time-consuming tasks. In the event of an alarm, for example, warning messages only appear in a collective message display. The operator must quickly analyse the situation, report the incident, and provide the driver with instructions," Naumann says. The researchers recommend: if the alerts are better visualised – for example by clearly marking the faulty element – the operator will not only be able to comprehend the situation more quickly, but also respond better to it.

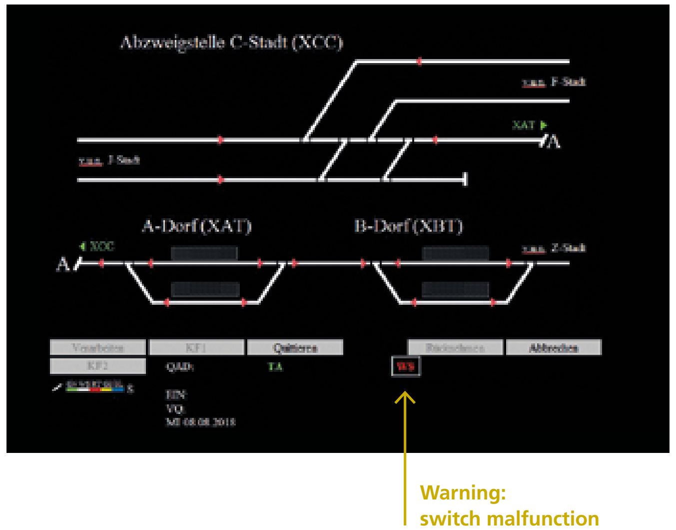
The researchers are examining two options to improve the situation for train drivers. Firstly, the drivers must be aware of which assistance systems and automation processess are active at any given time. This will allow for the employees to be better supported by the train systems. In the course of the year, the researchers want to further investigate how this should work. Secondly, timetable information should be displayed more clearly in order to improve the overview of the overall situation.

The DLR researchers are also working on a new concept for automated trains. In the event of a malfunction, a train operator – who could be based at an operations centre – could assume remote control of the train. As there are currently no automated passenger trains in the railway system, DLR researchers are breaking new ground.

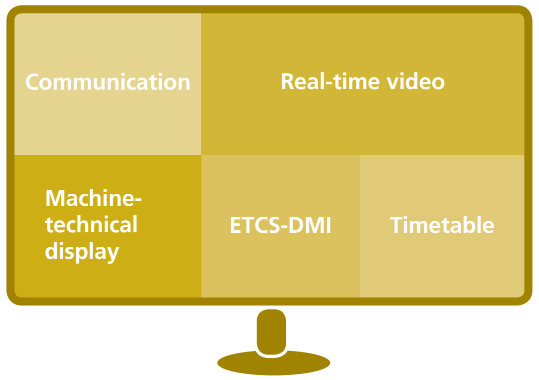
"Overall, our results show that when designing both workplaces, attention should be paid to achieving a balance between automated processes and the involvement of the rail traffic controller and the train driver," DLR researcher Naumann says. "Even if routine processes are further automated, the strength of people lies in their ability to analyse and solve problems. Humans will therefore continue to play a central role in rail operations. Through our research, we want to support employees in their tasks."

Theresa Sieberhein is responsible for communications at the DLR Institute of Transporation Systems.





Optimisation of the user interface for the rail traffic controller; top: highlighting the fault at the malfunctioning track switch itself with a flashing fuchsia border; bottom: original display for the electronic interlocking system.



Workplace concept for a train operator (ETCS-DMI = European Train Control System-Driver Machine Interface); source: Brandenburger, N. & Naumann, A. (2018). Enabling automatic train operation through human problem solving. Signal + Draht 3/2018, pp. 6–13.].

MONSOON BOTH SPREADS AND REMOVES POLLUTANTS

A layer of air pollution hangs over southern Asia during the winter months, with emissions from burnt biomass and fossil-based resources accumulating primarily over northern India, Nepal and Bangladesh. Only with the arrival of the monsoon season does what is known as the atmospheric brown cloud disperse. Scientists from the international Oxidation Mechanism Observations research project (OMO), which includes researchers from DLR, have been examining the processes at play in the atmosphere. Their results have now been published in the scientific journal Science (bit.ly/2L2zs1w).

A huge cloud of pollution – the atmospheric brown cloud – emerges every year over southern Asia, and is dispersed by the monsoon.

The research showed that the monsoon partially frees the air of pollutants with the help of hydroxyl radicals – highly reactive compounds consisting of a hydrogen and an oxygen atom. When they react with pollutants, there are two results: some molecules, such as methane, which adversely affects the climate, are converted into less harmful substances. Others, such as sulphur dioxide, are converted into water-soluble acids. These then form particles at freezing altitudes of 13 to 17 kilometres. The particles are often washed away by rain as soon as winds transports them around the world and to lower levels. Following the same principle, monsoons also disperse pollutants that do not react with hydroxyl radicals.

In order to prove this, the scientists followed the pollutants from Southeast Asia to the Middle East using DLR's HALO research aircraft. They also discovered why the hydroxyl radicals in the monsoon work so efficiently: nitrogen oxides can virtually recycle any hydroxyl radicals in a chemical cycle. Nitrogen oxides from lightning and traffic in Asian urban conurbations are plentiful during the monsoon season. It would therefore seem that the monsoon has two faces: it cleans some of the air over southern Asia, but also spreads its pollutants around the world.

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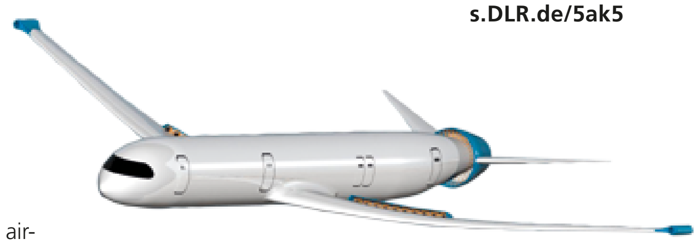
STUDENTS DESIGN AIRCRAFT WITH TURBOELECTRIC PROPULSION


The 'eRay' aircraft concept by the winning team from the Technical University of Munich.

A team from Munich has won this year's student competition to design the aircraft of the future. The runners-up were teams from Stuttgart and Aachen. The 'eRay' Aircraft Concept significantly reduces energy consumption and emissions, as the aircraft has a turboelectric propulsion system. Notable features of the aircraft include the propulsion units on the trailing edge of the wings as well as a horizontal stabiliser, making the integration of an electric turbine at the end of the fuselage possible. The 'boundary layer ingestion' principle was used, in which the boundary layer, which actually increases aerodynamic drag, is absorbed by the engines to increase efficiency. In doing this, the aerodynamic drag is reduced by creating smaller control surfaces. Furthermore, the structural weight is diminished by introducing an innovative cabin concept, as well as actively reducing turbulence.

Seven teams from six universities entered the NASA/DLR Design Challenge. The winning team from Germany travelled to NASA in the USA in autumn 2018 to compete with their US peers.

Image: Fichtner Bauconsulting


In future, the H2ORIZON test field will also be made accessible to DLR science and industry partners.

100 TONNES OF HOMEMADE NITROGEN

The 2000-square-metre H2ORIZONS research and demonstration facility has started operations at the DLR site in Lampoldshausen. It is set to produce 100 tonnes of nitrogen every year in future. Most of the gas will be consumed on site, as the DLR Institute of Space Propulsion's rocket test rigs make it one of Europe's biggest hydrogen consumers. The site's electricity and heat supply from two gas engine combined heat and power plants is also set to be supplemented by hydrogen. Like the end users, the power generators are also in close proximity to the site: a one-megawatt connection links the hydrogen production plant to the nearby Harthäuser Wald wind park. The plant is also intended to provide technological and systems solutions for the construction of a hydrogen-based, networked energy system.

DUSK FOR DAWN

A historic mission has drawn to an end. NASA's Dawn space probe fell silent on 31 October, after running out of fuel. On 27 September 2007, Dawn set off on its 6.9 billion kilometre voyage to explore the asteroid Vesta and the dwarf planet Ceres, which are located in the asteroid belt between Mars and Jupiter. Dawn was the first mission that travelled to two bodies in the Solar System and researched them from orbit for a prolonged period. After arriving in 2011, the probe orbited Vesta until 2012 and then continued to Ceres, which it has orbited since 6 March 2015.

On board Dawn is a German camera system, developed and built by the Max Planck Institute for Solar System Research (MPS) in cooperation with the DLR Institute of Planetary Research in Berlin-Adlershof and the Institute of Computer and Network Engineering at the University of Braunschweig. The two Framing Cameras made a significant contribution, delivering spectacular and high-resolution images to map the two asteroids and helping the probe to navigate. Insights acquired into Vesta and Ceres will help answer fundamental questions concerning the formation and evolution of planets. Following the strict international planetary protection guidelines, Dawn will remain in 'quarantine' for at least 20 years, orbiting Ceres in silence before crashing to its surface as planned.

s.DLR.de/p2ey

Image: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA


A last view of Ceres by Dawn

EARTH OBSERVATION SATELLITE ADM AEOLUS MEASURES WIND PROFILES

A new 1.4-tonne Earth observation satellite has been orbiting Earth since 22 August 2018. The European ADM Aeolus mission carries a high-performance laser system used to create vertical wind profiles and capture timely data relating to global wind fields in the atmosphere with high precision and for the very first time. As such, the aim is not only to improve understanding of dynamic processes in the atmosphere, but also to enhance mid- to long-range weather forecasting and the quality of climate observation. The laser system sends short, powerful pulses in the UV range into the atmosphere. The telescope collects the reflected light and the receiver analyses the data for speed and wind direction in close to real time.

s.DLR.de/4290

Image: ESA/CNES/Arianespace

MEET DLR AT ...

MATERIALS COLLOQUIUM 2018
4 December 2018 • Cologne, Germany
Creating a sustainable energy supply is among the most crucial societal challenges of our age. Problems associated with climate change paint a disconcerting picture of things to come. The research community is therefore called upon to prioritise the development of safe, green and efficient concepts for safeguarding our energy supply. In this regard, it is necessary to consider the entire energy chain from production, conversion and storage through to utilisation. At this year's Energy Colloquium DLR will present its material and concept/system developments in the field of energy. In addition to showcasing research and development projects on a wide variety of materials, there will also be opportunities to discuss the diversity of their potential uses.

ASIM WORKSHOP SIMULATION OF TECHNICAL SYSTEMS/ FUNDAMENTALS AND METHODS IN MODELING AND SIMULATION
21–22 February 2019 • Braunschweig, Germany
The workshop of ASIM groups STS/GMMS and DLR will take place at the DLR site in Braunschweig. The programme covers the full range of current simulation research and provides a forum for discussing methodological approaches and practical applications in the fields of simulation and modelling. The event aims to promote discussion and exchange of information and experience between professionals from academia, research institutions and industry in an open atmosphere. Take the opportunity to participate in the ASIM workshop with your own lecture. Contributions can be both application-oriented and research-oriented. New ideas or ongoing projects are also welcome and do not necessarily have to correspond to the given thematic priorities.

12TH INTERNATIONAL WORKSHOP ON SUBSECOND THERMOPHYSICS
3–6 June 2019 • Cologne, Germany
This will be the 12th of a series of well established workshops on experimental and theoretical aspects of thermophysical properties of matter where scientists from different areas of thermophysics, materials science and metrology can exchange knowledge, ideas, and experiences on the latest trends in the field. The workshop, held every three years, covers all aspects of thermophysical property research under extreme conditions, such as high temperatures and pressures. The investigated timescale regimes range from milliseconds to picoseconds, including rapid resistive or inductive (volume) heating, laser pulse heating, levitation techniques on ground and under microgravity, as well as other recently developed fast investigation techniques. The 12th IWSSTP will be organised by the Institute of Material Physics in Space.

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INTELLIGENT ROBOTS IN DIGITAL PRODUCTION

The DLR cross-disciplinary project 'Factory of the Future' interlinks DLR research for Industry 4.0

By Manuela Braun

Of all things, a carpenter who crafts bespoke products tailored to the customer's requirements is an apt analogy for the Factory of the Future. Admittedly, the laboratory of the DLR Institute of Robotics and Mechatronics looks nothing like an atelier producing individual items for specific customers. Greyish-blue robotic arms, metal components, grippers and engineers sitting at computer screens are all illuminated by the LED light in the spacious high-tech laboratory. Workshops for the production of individual products, such as custom-made furniture, with individually selected materials, shapes and dimensions look different. Roman Weitschat of the DLR Institute of Robotics and Mechatronics, and coordinator of the DLR project 'Factory of the Future: Intelligent robotics in digitalised production' nevertheless sees the carpenter and his customer orders as a good point of comparison. After all, the focus of research and development at DLR should bring about a Factory of the Future that can do just that: produce customised products flexibly and on demand. However, this should not only be affordable for a few customers, but also for a larger market.

This is known as 'mass customisation' – mass production according to individual customer requirements. This principle is already being applied in the automobile industry, with the production of vehicles that buyers have individually configured from a number of possible choices. Whether it is by customising the rims, paint colour, door handles or side mirrors, for some types of vehicles customers can specify what their dream car should look like. "However, this involves considerable effort in the planning and implementation of production, which often is only profitable when it involves large quantities," says Korbinian Nottensteiner, deputy project manager, also from the DLR Institute of Robotics and Mechatronics.

Pooling expertise

The cross-disciplinary project was launched in 2018, with scientists from 11 DLR institutes and facilities from the fields of space, aeronautics and transport all contributing their diverse expertise. The intention is to link and harmonise existing research activities. In addition, there are new focal points and objectives, derived from the shared vision of a fully networked, digitalised production system, in which humans and robot assistants collaborate to advance flexibility and effectiveness. "DLR developments are already playing a significant role in shaping Industry 4.0 in the areas of robotics, automation and lightweight construction," says Alin Albu-Schäffer, Head of the Institute of Robotics and Mechatronics and founder of the project. "The development of cutting-edge aerospace technology places us in the special position to essentially break new ground in terms of flexible and networked production, innovative production processes and new fields of application."

The task is far from simple – the trend towards individualisation means that the Factory of the Future must be able to produce small quantities of complex products while remaining cost-effective. The interdisciplinary nature of the DLR institutes should help to achieve this goal by incorporating different perspectives, research methods and existing knowledge into the cross-disciplinary project. In addition to robotics and autonomous systems, the Factory of the Future requires innovative sensor technology, artificial intelligence, simulation methods, as well as digitalisation techniques and lightweight construction.

Programming through demonstration: The lightweight robot SARA learns from its human operator, who not only shows the robot what task it should perform, but also how it should be performed.

Humans and robots on the same team

"In the 1980s, people envisaged fully automated factories in which robots would replace humans entirely – but apart from the technical hurdles involved, that would ultimately prove too expensive," Weitschat explains. Given the increasing variety of models and ever-changing trends, this kind of automated factory would not be able to keep pace any more than the carpenter in his little workshop could. The aim for the future is that humans and robots will work together in a digitalised production system, gaining a competitive edge by combining their respective abilities: people will 'direct' production, while the robots will be their intelligent assistants. Humans will create the conditions, while the robot will relieve workers in carrying out their duties. "Robots can be intelligent, but never enough as humans," Weitschat says with confidence. "Without the flexibility and diversity of human skills, this will not happen in the near future."

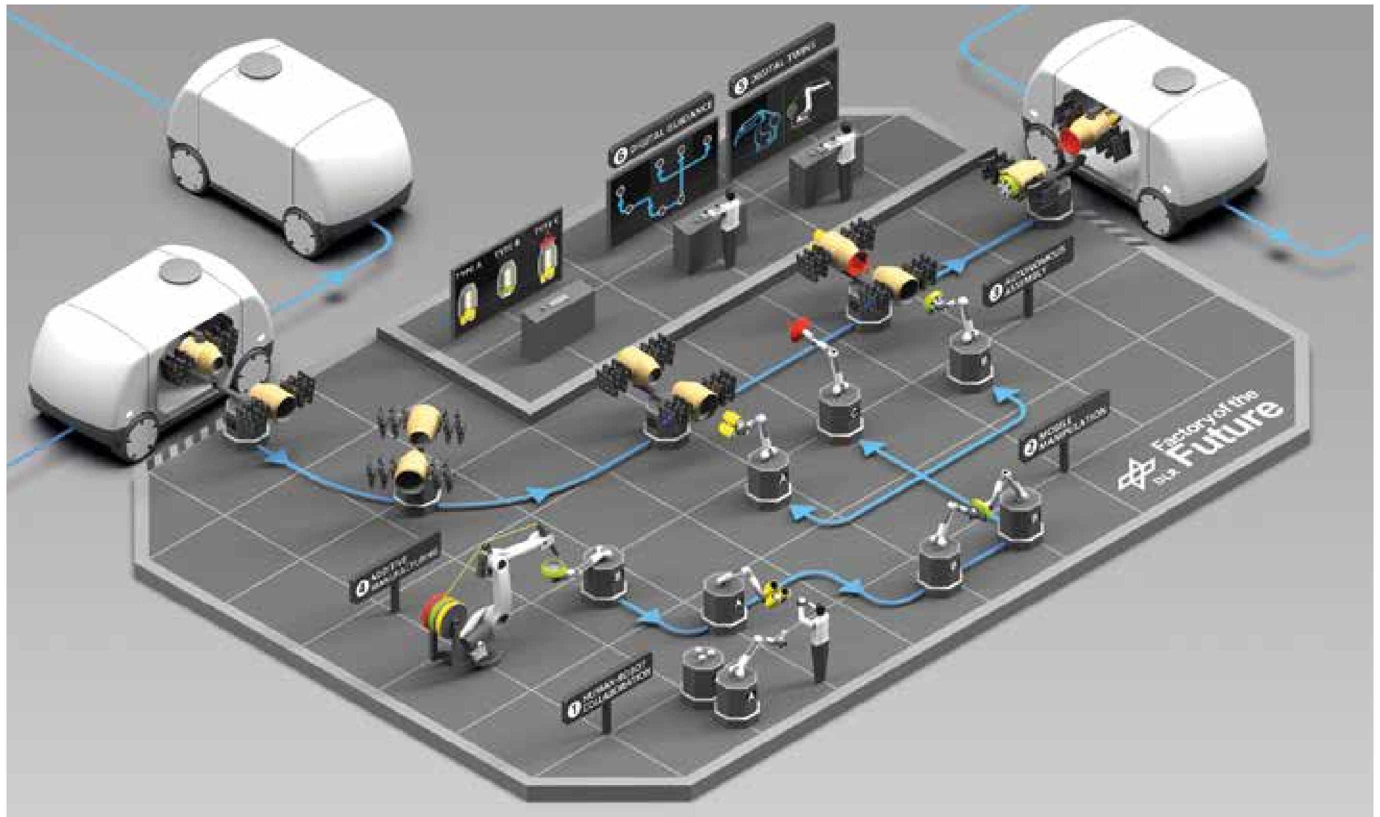
A third arm for humans

Human-robot interaction will be safe and intuitive – just like the robotic working cell in production of the future, where the robot is sensitive and can simply be programmed using manual guidance. While the operator demonstrates a task, the new DLR lightweight Safe Autonomous Robotic Assistant (SARA) records the corresponding position and force trajectories. The robot then configures its working environment swiftly and automatically, depending on its assigned task. "The quick reconfiguration of a robotic system often represents a bottleneck in industry processes," Nottensteiner explains. Until recently, robotic arms were still installed behind barriers, lacked flexibility and worked without taking the actions of their human co-workers into account. Thanks to DLR's development of lightweight robots and their commercialisation through partner companies, such as KUKA, so-called cobots – robots that collaborate with humans – are now an industrial reality. "The robot is like having a third arm," Weitschat says. They are part of the most striking innovation in robotics in recent years. With SARA, the latest prototype, DLR is setting new standards in collaborative robotics – speed, sensitivity and precision, as well as fast and intuitive programming make previously unexplored applications possible. For example, the application of elastic seals on an aircraft window and their installation can be demonstrated by a person and then reliably carried out by the robot – all within just minutes.

Knowing where things are headed

A robot that is permanently fixed to a defined position and preprogrammed to perform a single task on a single product will not be able to keep up in such a Factory of the Future. Mobile, platform-mounted robots of the kind planned for future factories are not confined to a particular location, but can be used wherever they are needed, and can move there on their own. The more flexible the robot, the easier and more versatile the production process. One of the objectives of the project is determining what is required to put such ideas into practice. The two project coordinators enumerate the requirements: "A robot needs a sophisticated sensor system for mobile manipulation. It must be able to locate objects and identify grip points. And it will only be sufficiently autonomous to assist if it is able to plan its path carefully, create a 3D image of an environment that may not be completely familiar, and recover from errors on its own." This means flexible systems that can reconfigure themselves to a new product quickly, instead of rigid assembly lines. These are mobile robot assistants that are among humans, move around independently and take on unpleasant, monotonous tasks.

In the Factory of the Future, humans and robots collaborate closely in a digitalised production process. The robots are 'smart helpers' that relieve the worker in carrying out various activities. DLR institutes specialising in space, aeronautics and transport are working together to develop the Factory of the Future.



The robot should be able to independently decide which capabilities it will have to deploy for individual working steps. "The aim is to cover different product variants without needing involvement from an expert," Nottensteiner says. For humans, this means no longer having to plan and program every single working step in detail, but rather assigning a task to the robot. Fixed programs for a robot to work through are a thing of the past; instead, the robot adapts its capabilities automatically to the job at hand. Over time, the robotic system should also gain experience and continuously improve the quality of its work by optimising process parameters. For this purpose, scientists and engineers have to develop methods for making future robotic systems 'smart' – for instance by semantically linking data from the working cell to the knowledge databases, or by devising intelligent algorithms for pattern recognition and machine learning. The system will thus be able to compensate for uncertainties and guarantee a robust and reliable execution by using artificial intelligence methods.

Creating components layer by layer

In future, it is expected that the relevant components will increasingly be created through additive manufacturing processes – in other words, 3D printing. "This will enable the creation of complex components and their optimisation for particular applications." As a result, vehicle structures will be safer, while space components will become more cost-effective. The major advantage of this is that structures and components that were once considered infeasible can easily be manufactured in small quantities. The design opens up new possibilities, with production becoming more material-efficient because material is only used where it is actually needed. In addition, the use of different materials, such as light metal alloys or plastic, fibre reinforcement and the hybridisation of components offer advantages.

INSTITUTES INVOLVED IN THE CROSS-SECTORAL FACTORY OF FUTURE PROJECT

Space:
- Institute of Robotics and Mechatronics
- Institute of System Dynamics and Control
- Institute of Data Science
- Institute of Optical Sensor Systems

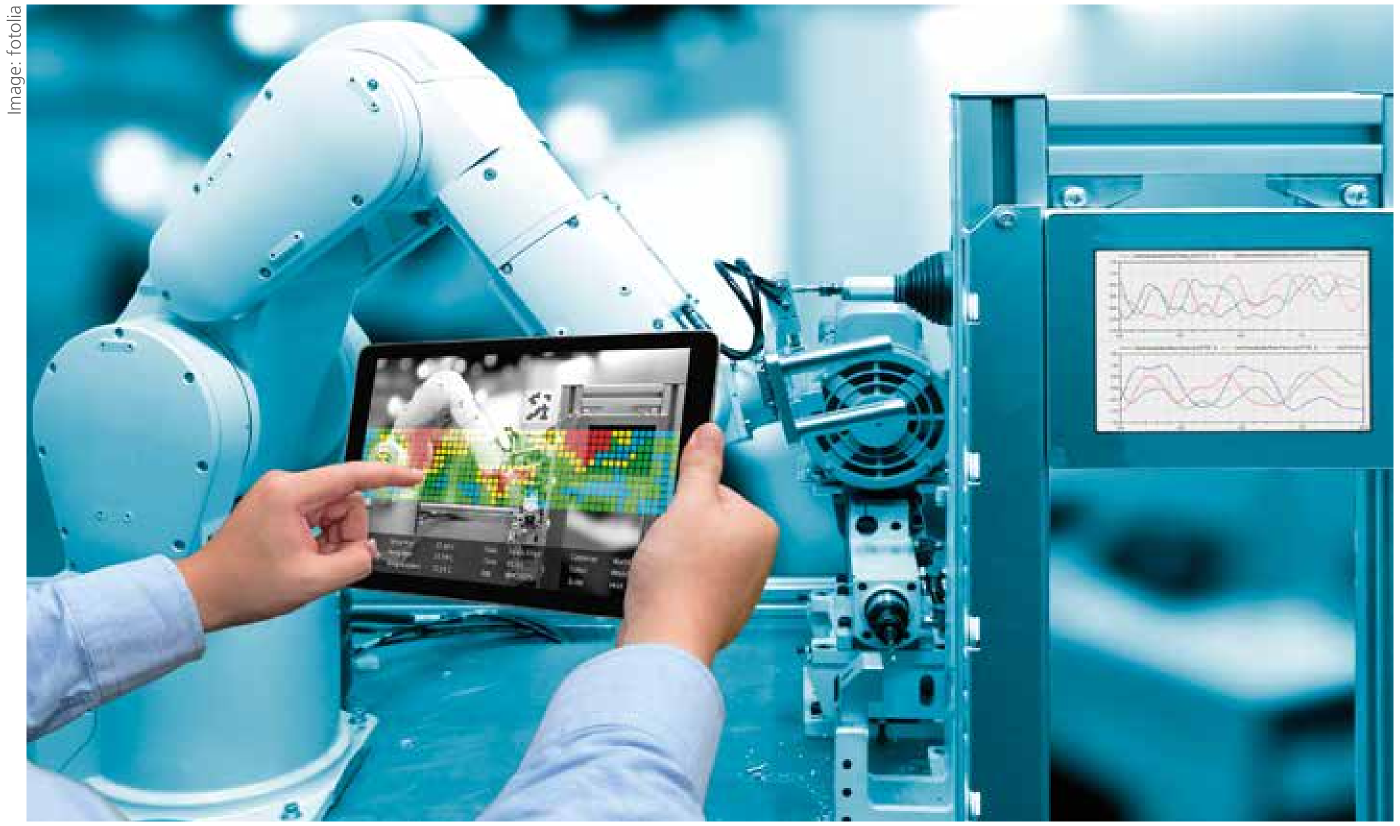
Aeronautics:
- Institute of Structures and Design
- Institute of Materials Research
- Institute of Composite Structures and Adaptive Systems

Transport:
- Institute of Transport Research
- Institute of Vehicle Concepts

Associated institutes:
- Institute of Maintenance, Repair and Overhaul
- Institute of System Architectures in Aeronautics

Humans and machines work together in the Factory of the Future. The robots are operated intuitively.

Image: fotolia



Robots that configure their own working area and adapt to the respective task are part of the everyday production process in the Factory of the Future

Production facilities like these at DLR's Center for Lightweight-Production-Technology (ZLP) in Augsburg will have to be designed in the most flexible way possible so they can be adapted to market demands.

The robot will choose its working location in the future. To do so, it must be able to perceive its environment, plan its trajectories and identify objects.

The application possibilities are manifold: in aviation, for instance, individual parts are required for repairs and retrofitting and need to be produced either in very small batches or even individually. The requirements are different when it comes to road vehicles: electromobility and autonomous driving demand the development of new vehicle concepts and structures. In the field of space technology, metal components for satellites could be produced using additive manufacturing. The Factory of the Future project thus draws upon the 3D printing experience accumulated by the DLR Institute of Vehicle Concepts and the DLR Institute of Structures and Design, as well as expertise from institutes focusing on aeronautics and space.

Touch of a button

Production at the touch of a button is made possible through a combination of mobile manipulation, automated assembly, human-robot collaboration, reconfigurable robotic working cells, and additive manufacturing. Such applications are also one of the objectives of the project – to immediately manufacture custom products selected and configured from a modular system, via a Web portal, for instance. At the touch of a button, the order is sent to a supplier that has the required production units. Plans are then devised autonomously at this production site for how the product is to be manufactured, and in which steps, and how the tasks are to be assigned to the relevant production units.

However, what happens in the 'real world' can also be recreated in the digital world. The project also includes a 'digital twin' working package, whereby an image of the real components and the production facility is created. With the help of sensors, all changes made in reality are recorded and transferred to the digital world. The functionality of a system, its productivity and its stability can be monitored at any time. Through this innovative technology, high-quality components can be produced in future and systems optimally utilised.

Cross-linking to achieve objectives

A diagram of the project showing the new production processes can be found on Page 16, revealing the extent to which everything is interconnected and how the Factory of the Future is only possible through the combination of elements. While preliminary products are delivered in one area of production, other required components are already available thanks to additive manufacturing. Mobile robots transport these to the next station, which is occupied by collaborating robots and humans. Depending on the desired product variant, robots assemble the components autonomously. People oversee the workflow from consoles and work with digital twins to optimise production processes.

One thing is also apparent in the Factory of the Future: not many human operators are involved in the production process. "Jobs will change," Weitschat says. This invariably happens whenever there are technological advances: the employee who would once connect all calls in the early days of telephone communications has long since been replaced, while technological progress has resulted in the creation of other professions in the field of communication. Indeed, the Factory of the Future could bring about new jobs: "Many companies have relocated their production sites to low-wage countries, but Industry 4.0 may mean that it would be beneficial for companies to move their manufacturing back to Germany." The ability to respond more rapidly to market demand and the possibility of greater flexibility could give German industry a competitive edge. Weitschat acknowledges that "people often believe that robots represent direct competition to human workers." This is far from justified, he says. "Robots are not a threat, but rather a helping hand – people no longer have to take care of every single detail themselves."

AUTOMATED PRODUCTION OF AIRCRAFT FUSELAGES

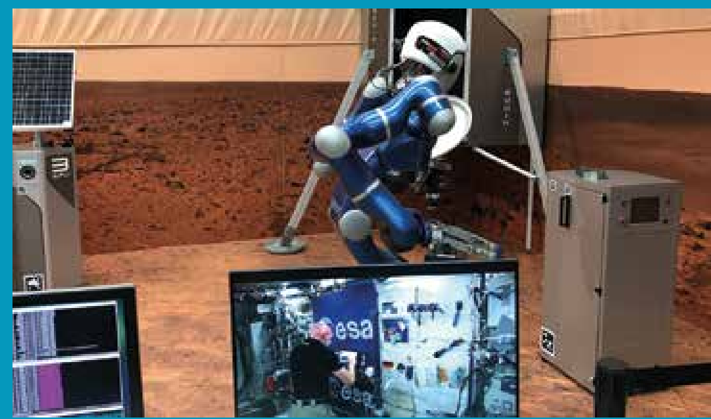
Robots lay aluminium sheets at ZLP Augsburg

Using coordinated robot technology, DLR has developed automated processes for the production of high-performance fibre metal laminate (FML) components. By utilising FML, an aircraft can have far thinner walls and is therefore lighter, while the automated production processes make FML more economical than using components made of carbon fibre reinforced plastic (CFRP).

For the first time, DLR's Center for Lightweight-Production-Technology (ZLP) at its location in Augsburg recently demonstrated the laying of curved aluminium foils using a multi-robot system, while ZLP in Stade premiered the placing of fibreglass on aluminium in combination with automated tape laying (ATL) and automated fibre placement (AFP) technology.

The ProfiRumpf project of the German Federal Ministry for Economic Affairs and Energy (BMWi) is funded within the framework of the German Aviation Research Programme (Luftfahrt Forschung; LuFo). Among others, the research and industrial partners involved in the project included the Fraunhofer Society, Airbus, its suppliers Premium Aerotec and Fokker, as well as Stelia Aerospace.

THE FUTURE OF HUMAN-ROBOT COOPERATION IN SPACE

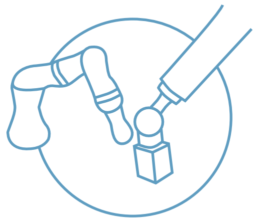


Alexander Gerst controls Rollin' Justin

Robotic co-workers will become increasingly important in future space exploration, construction and maintenance tasks. They can support the work of people in orbit and on Earth to explore difficult-to-access high-risk regions. German ESA astronaut Alexander Gerst recently demonstrated this potential. On 17 August 2018, Gerst remotely controlled the humanoid robot Rollin' Justin at the DLR Institute of Robotics and Mechatronics in Oberpfaffenhofen from the International Space Station (ISS) using a tablet PC. Gerst not only had to master the most complex telerobotic tasks ever conducted in space, but also react to unexpected situations.

The METERON SUPVIS Justin experiment is a collaborative enterprise between DLR and the European Space Agency (ESA). As part of the European Union's METERON (Multi-Purpose End-to-End Robotic Operation Network) range of experiments, robotics experts at DLR have further developed their telerobotics technologies and created realistic scenarios for planetary exploration. The experiment is one of approximately 50 German experiments conducted as part of Alexander Gerst's horizons mission.

A CLEVER ROBOT DUO



Henry Ford revolutionised car manufacturing more than 100 years ago. Not only did he introduce the moving assembly line to production, but he was also the first to establish systematic quality control. This helped to identify faulty cars at the end of the manufacturing process. Today, scientists and engineers at the DLR Center for Lightweight-Production-Technology (ZLP) in Augsburg are investigating how the manufacture of large aerospace structures can be automated using robots, and how quality can be ensured during the production process itself. The focus is on lightweight components made of fibre composite materials such as carbon fibre reinforced plastics (CFRP).

Quality assurance for the production of lightweight fibre composite components

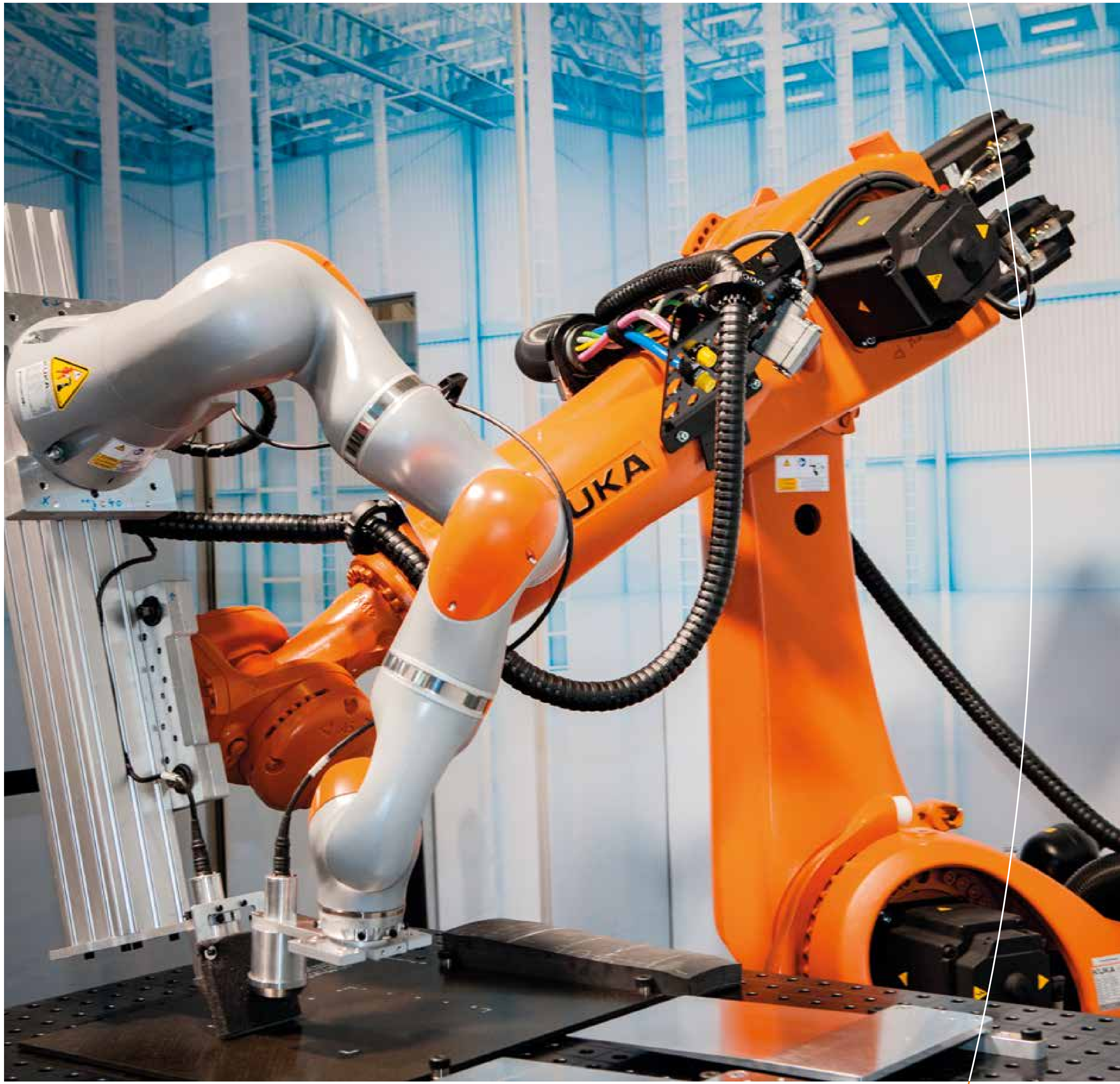
By Nicole Waibel

Mistakes in production can soon prove expensive. "In the aerospace industry, in particular, where very large structures are manufactured and high safety standards apply, it is incredibly important for quality assurance to be integrated into the production process, in order to avoid rejects and reworking," explains Michael Kupke, Head of the Center for Lightweight-Production-Technology (ZLP) in Augsburg. DLR researchers from the Institute of Structures and Design in Augsburg are currently working on non-contact testing methods and their automation, with a view to being able to test structures during production itself.

Air instead of water

Non-destructive inspection is Armin Huber's area of expertise. He is researching air-coupled ultrasonic testing as part of the Production-Integrated Quality Assurance group at the ZLP. "To conduct such measurements, a coupling medium is required to transmit the sound. We are familiar with this from the field of medicine, where a gel is used for ultrasounds," Huber explains. A water-coupled method is used in the conventional ultrasound testing of components. However, this type of testing is not contact-free, as the component is splashed or dipped in water. This requires complex infrastructure, such as pools or sprinkler systems. Moreover, testing with water is a separate process step, unlike air-coupled ultrasound, which can be integrated into the existing procedure. Another drawback is that water penetrates the component during the testing process. As CFRP components are still unsealed at this point in the production process, such a procedure is only suitable under certain conditions. "We prefer to keep things dry," Huber says. "As such, we are working on a process in which air is the coupling medium."

At this year's automatica trade fair, which was held in Munich in June 2018, DLR researchers presented the current state of development. Their aim is to be able to test components automatically using air-coupled ultrasound. The scientists demonstrated the industrial suitability of the



Adaptive air-coupled ultrasonic testing

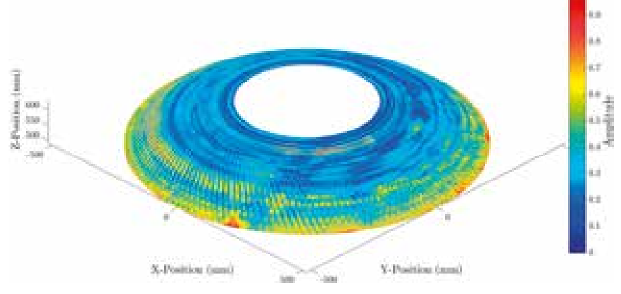
AIR-COUPLED ULTRASONIC MEASUREMENT: OPPORTUNITIES FOR INDUSTRY

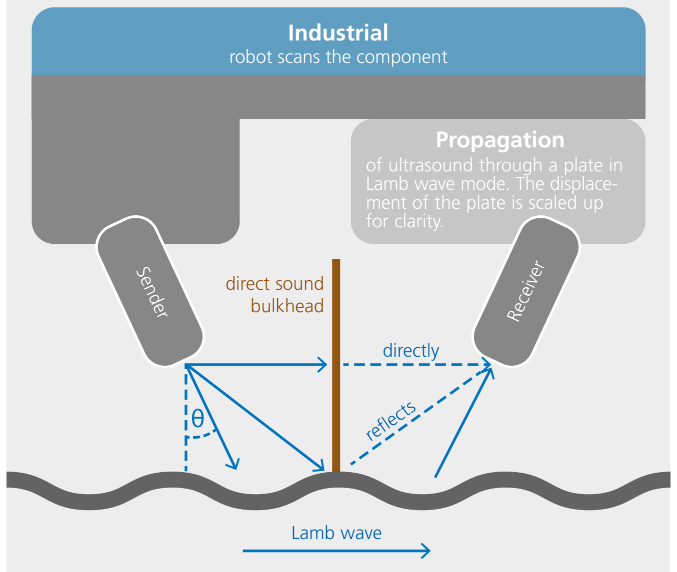
A rocket engine pressure vessel made of carbon fibre reinforced plastic (length: 3.7 metres; diameter: 1.4 metres; laminate thickness: up to 40 millimetres) and developed by MT Aerospace AG was tested for defects at the ZLP Augsburg using air-coupled ultrasonic testing back in 2014. This was a largely automated process, conducted by robotic sensing equipment.

However, at that time, the angle of incidence had to be manually adjusted for different component thicknesses. The lightweight robot from the pair of robots on display at automatica 2018 now performs this task automatically.

Since the sound waves are sent and received on the same side, the component only needs to be accessible from one side. This is an advantage, particularly in the case of complex geometries. Speeds as high as 230 millimetres per second were reached during the test, and much higher speeds are also possible. The whole testing concept is designed for flexibility, high speed and reproducibility, making it suitable for use in industry.

Ultrasound image of the test result for the dome area of a CFRP rocket booster casing





Simplified graphic illustrating the operation of non-destructive testing with adaptive air-coupled ultrasonic endeffector

air-coupled process back in 2014. In cooperation with an industry partner, they tested a segment of a rocket booster using air-coupled ultrasound. They are now looking to further automate the process to make it more efficient. This can reduce manufacturing costs, thus increasing competitiveness, while the high level of automation also allows quality-related data to be collected and evaluated in real time. "This is very important to be able to detect problems at an early stage," Huber says.

Cooperating robots

Two ultrasonic transducers – a transmitter and a receiver – are required when testing a component with ultrasound. The transmitter emits ultrasonic pulses. "The sound is transmitted via the coupling medium – in this case air – and excites what are known as Lamb waves in the component. These are acoustic waves that propagate through the component and make it vibrate gently," Huber explains. "You can imagine it as the skin of a drum. The vibration of the component also sets the air at the interface in motion." These sound waves are, in turn, picked up by the receiver. If the Lamb waves encounter defects in the component, they react to such flaws, allowing conclusions to be drawn about them.

The correct alignment of the transmitter and receiver with respect to the surface of the component is vital in order to excite Lamb waves in the component. This depends on the stiffness and thickness of the material. "In the past, we had to set the angle of incidence manually, so the testing procedure had to be interrupted if we needed to adjust it," says Huber, thinking back to the previous method. "That was complex and time-consuming." The angle can now be calculated in advance using software developed by Huber. His colleague Manfred Schönheits has integrated a lightweight robot (LWR) into the system of the industrial robot, allowing the angle to be adjusted automatically. While the industrial robot performs the scanning procedure, the LWR aligns the transducers according to the calculated angle of incidence. "The difficulty with the process is that the coupling of the two robots is not fixed, but must be varied depending on the position relative to the component. To achieve this, we use a lightweight robot as additional kinematics, as it offers a lot of flexibility for examination with its seven degrees of freedom. The positions of the robots are pre-calculated using Huber's algorithms, and the robots are synchronised with each other in real time," explains Schönheits, who works in the Flexible Automation Systems group.

The ultrasonic transducers adapt to the features of the component and thus automatically provide geometrically accurate 2D and 3D images. These show the exact position of defects. The component can be discarded or reworked depending on the size and type of defect. This ensures that only high-quality components enter the production process. Error detection and evaluation is performed automatically using software. All of the measurement data is saved for later use. Detailed documentation of the results makes it possible to refine the manufacturing process further, thus improving the engineering chain and reducing time-consuming reworking.

Teamwork across the entire production chain

Another colleague has been successful in ensuring that the 'adaptive air-coupled ultrasonic endeffector', as the technology is referred to by the scientists, runs smoothly: Philipp Gänswürger, who works in the Assembly and Joining Technology group, created the design, built and produced the endeffector. "It was a cross-team effort. We work just as closely together with experts in production-integrated quality assurance and flexible automation systems as with scientists specialising in assembly, joining technology and process automation," says Kupke, describing what makes working at the ZLP so special. "With the advent of Industry 4.0, interlinking these various skills is becoming increasingly important." The Institute, together with nine other DLR institutes throughout Germany, is conducting research into solutions for Industry 4.0, intelligent robotics and digitalised production across Germany in the cross-sectoral 'Factory of the Future' project.

Knowledge for future production

The conveyor belt, the rationalisation of the manufacturing chain, and the introduction of just-in-time production: Henry Ford's concept of standardised mass production made products more affordable and thus accessible to a growing number of people. Today, thanks to digitalised production, even customised products have the potential to be created automatically. "One of the challenges of digitalisation is identifying data that is pertinent to quality from the vast mass of production data, and then processing and evaluating it in real time," Kupke says. "But mastering this also opens up a fantastic opportunity to increase efficiency, while also improving quality."

As far as Henry Ford was concerned, the quality and continuous improvement of the products were a top priority. "He would certainly have greatly appreciated a consistent, process-integrated, automated quality-assurance system," Kupke says. Manufacturing products cost-effectively and to a consistently high standard of quality is simply essential. Non-destructive testing processes will have a place in the Factory of the Future.

Nicole Waibel is in charge of Public Relations as part of her role at the Center for Lightweight-Production-Technology (ZLP) in Augsburg.

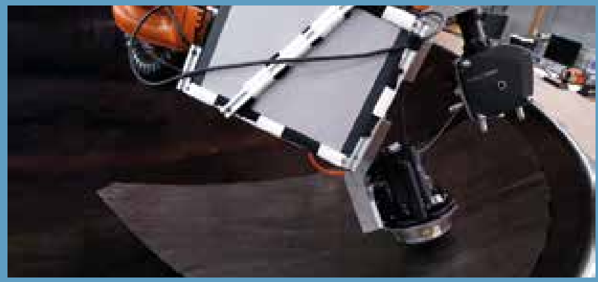
Various teams from the Center for Lightweight-Production-Technology worked hand in hand at the DLR site in Augsburg in the development of the ultrasonic inspection robot

AUTOMATED, NON-DESTRUCTIVE TESTING METHODS AT ZLP AUGSBURG

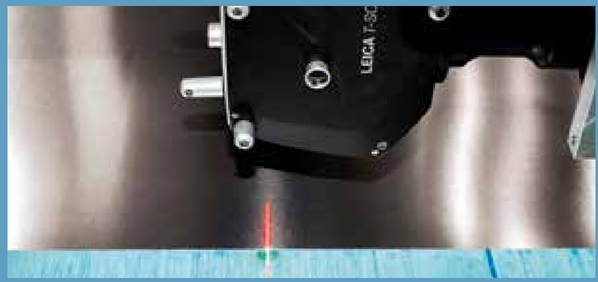
Integrating the measuring equipment and sensors into a robot makes it possible to test larger areas and components automatically during the production process.

Thermography
This test method, which involves a camera and halogen lamps, also detects low-level defects using optical excitation and temperature signals.

Fibre angle measurements
The orientation of fibres in the given sections has a substantial effect on the properties of the component; a slight alteration in the course of the fibres results in a halving of the strength. This can be measured using a fibre angle sensor, consisting of a camera and lighting specially adapted to the reflective properties of the carbon fibres. Only the outermost visible area can be checked. The measured angles are then compared with those calculated in the simulation.



3D laser scanner
A laser-based process helps to identify the position and edges of the deposited cuts. This ensures that these are in exactly the right position, without any gaps or wrinkles.



Deposited aluminium sheet for the fibre metal laminate production

Pascal Kuhn
was born in 1989, and grew up near Tauberbischofsheim. After completing his studies in physics, he joined the DLR Institute of Solar Research in 2016 as a doctoral student, working for the Plataforma Solar de Almería, Europe's largest research facility for concentrating solar power systems.

EYES FOR THE SOLAR INDUSTRY

DLR researchers want to predict fluctuations in solar radiation more accurately using webcams, with a view to making power grids with high solar penetrations more stable.

Florian Kammermeier talks to DLR researcher Pascal Kuhn

A gardener films his flowers as they blossom. A webcam transmits footage of cows grazing on an Alpine pasture. A traffic camera shows congestion on the motorway. These videos make researcher Pascal Kuhn gush: "Pictures like these are a treasure trove of data for meteorologists!" They are available on the Internet in almost unlimited quantities and usually contain information about the weather. Kuhn wants to boost this wealth of information. Thousands of ground-based cameras could be used to supplement the data from weather satellites providing solar power plant and power grid operators with more accurate forecasts of how much electricity the power plants will produce and when. The DLRmagazine spoke with the solar researcher about how it will all work.

Image: foto-webcam.eu

Image: DLR/Ernsting

Mr Kuhn, you are looking to improve solar radiation forecasts by integrating data from publicly accessible cameras into satellite forecasts. What can landscape cameras, for instance in ski resorts, achieve that satellites cannot?
: Weather satellites are technically sophisticated devices that observe the Earth using numerous sensors. However, certain weather conditions are difficult for satellites to determine. In addition, the spatial and temporal resolutions of meteorological satellites are often too low for certain applications. For example, the Meteosat-9 satellite provides forecasts for Europe at five-minute intervals with a maximum resolution of one square kilometre per pixel. Information from public cameras can be of assistance here. Images like these are a source of data for meteorologists, and may help determine aspects such as visibility and cloud or snow cover. The advantage of these cameras is that there are many of them and they capture the local conditions well.

The image quality of publicly accessible cameras is not always good. In addition, their settings and exact position are not always known. Could this cause problems?
: We are breaking new ground with the idea of using webcams to improve satellite-based solar forecasts. Until now, only professional weather cameras have been deployed for such tasks. But these are expensive to install and maintain, and are not widely available. A big challenge is the fact that public cameras have many unknown parameters, such as the direction in which they are filming. Nevertheless, we have already demonstrated that it is possible to derive relevant meteorological data using robust algorithms, for instance establishing whether there are clouds and how they are moving. In recent years, there has also been a clear trend towards cameras with ever-higher resolution, so the quality of available data should continue to improve.

More and more cameras across the globe stream live images, and their resolution continues to increase. How will you be able to evaluate this vast amount of data quickly enough?
: The volume of data is indeed a challenge. At present, we obtain our data primarily from the online platform foto-webcam.eu, which places current and historical images on its own server on the Internet, making them freely accessible. Our real-time capability therefore mainly depends on the connection to the Foto-webcam server. We have already been able to resolve complications that have arisen as a result. However, when millions – as opposed to hundreds – of cameras are involved, new concepts have to be devised. This is why we are trying to persuade well-known manufacturers of surveillance cameras to work with us. If meteorological data is already pre-processed in a smart camera, then it is only necessary to transmit compact data sets instead of lots of images.

Data protection on the Internet is a widely discussed issue. How do you deal with the possibility that webcams may reveal personal data?
: Of course, the complex rules of data protection must be followed. During our research project, we managed to bypass this problem by obtaining explicit permission from Foto-webcam for processing data. Foto-webcam pixelates critical areas itself, and it is usually not possible to make out personal features from images taken by the cameras from a distance.

How will the improved forecasting actually work?
: Accurate, high-resolution radiation forecasts can optimise the network management of power grids with high penetrations of solar energy, thereby helping to make the grid more stable and cost-effective. Power cannot be stored in the network, but must be consumed when it is generated. If less power is generated than consumed, the mains frequency drops. Due to technical limitations, the mains frequency must only fluctuate to a minimal degree. If necessary, reserve power plants have to help out or variable loads are switched off, often requiring lead times of a few minutes. With forecasts that cover this time period, the power grid could be stabilised ahead of time.

Would it therefore be possible to reduce the need for energy storage systems?
: At a power-plant level, better forecasts can partially replace the much more expensive energy storage systems that are already necessary in countries with a so-called negative ramp limit. Negative ramp rate regulations define the maximum allowable power loss of a power plant per unit of time. In Puerto Rico, for example, this is 10 percent of the power plant's capacity per minute. Studies show that these regulations cannot easily be adhered to in the presence of cloud shadows. However, the batteries used for stabilisation are very expensive. Shortest-term forecasts can smooth out the fluctuations in power output at little cost by dynamically curtailing solar power plants. Camera-based forecasts therefore help micro grids with a high proportion of solar power – such as very small power grids in remote areas for example in Western Australia – to launch reserve power supply in sufficient time.

Is it conceivable that your idea of combining satellite with camera data would not just be useful in the solar industry, but could also improve weather forecasting?
: Our research project is very much focused on identifying cloud information from camera data. Clouds are the main cause of short-term performance drops in solar power plants. However, clouds also play an important role in the weather and climate. It is therefore possible that a greater availability of information about clouds, particularly via more detailed verification, may also improve weather forecasting in general.

COMBATING A HIDDEN CLIMATE FOE

Dorottya Gubán's fingers move swiftly and unerringly across her test station. She sets a few more parameters, then starts the infrared furnace and heats the redox material that she has developed to 800 degrees Celsius. This is one of countless series of experiments that the Doctor in Chemical Engineering has performed in the course of developing a suitable method for the sustainable production of fertiliser from the Sun, air and water.

Solar researcher Dorottya Gubán is developing a carbon-neutral production process for fertilisers

By Dorothee Bürkle

Dorottya Gubán

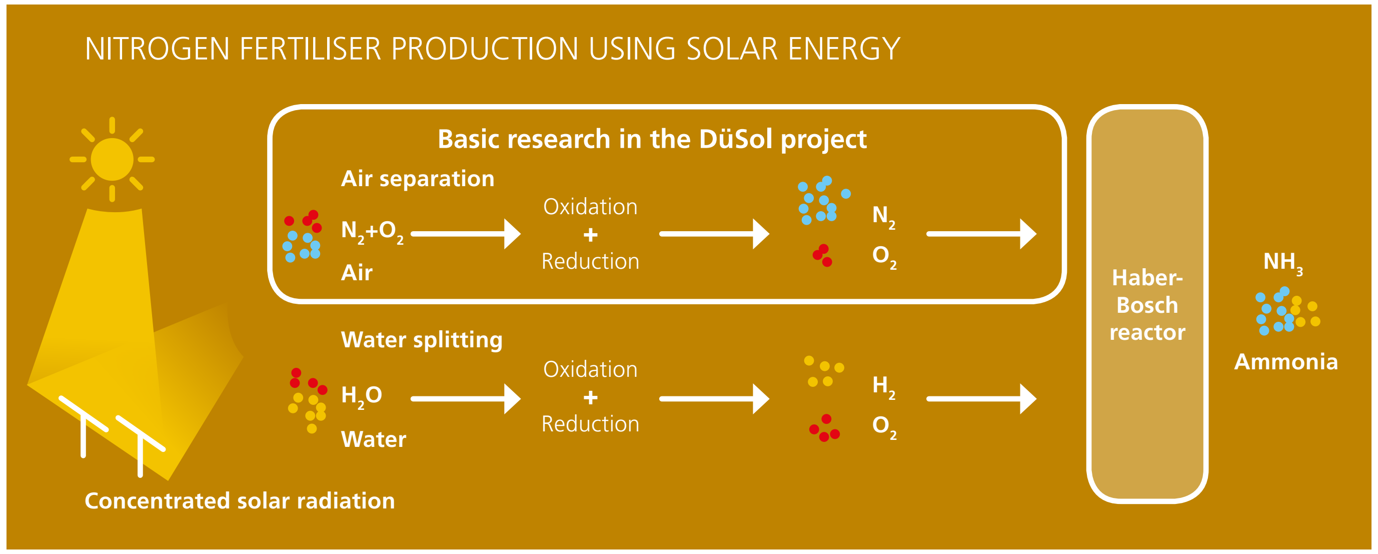
"I am perseverant," says Dorottya Gubán. The Hungarian chemical engineer is working on the foundations for climate-neutral fertiliser production.

Two to three percent of the global energy demand – and the correspondingly high level of carbon dioxide emissions – can be attributed to the production of nitrogen fertilisers. Dorottya Gubán's work as part of the DüSol project is aimed at the sustainable production of just this type of fertiliser. "Over 90 percent of fertilisers used worldwide contain nitrogen. By generating the base substance – ammonia – in a sustainable way, we can significantly reduce the emission of polluting greenhouse gases into the atmosphere," says the scientist. If it were up to her, organic fertilisers with a plant or animal origin would be predominantly used in agriculture. But she is realistic: "On a global scale, we simply cannot ignore industrially produced chemical fertilisers." Even today, around a third of the world's population eats food produced using artificial fertilisers, especially in densely populated countries where agricultural land is scarce. Experts believe that they are set to become even more important for food security in the future. "The development of a carbon-neutral production process for such fertilisers could greatly contribute towards solving our climate problems."

Nitrogen and hydrogen from solar energy

The base substance for all nitrogen-based fertilisers is ammonia (NH_3), which is composed of hydrogen and nitrogen atoms. The two elements have been combined for more than a decade using the Haber-Bosch process. Gubán and her team are looking to produce the necessary elements of hydrogen and nitrogen using solar energy. There is vast potential for cutting back on climate-damaging gases, as the fertiliser industry has long used huge quantities of natural gas (mainly CH_4) for this process. While scientists are working on producing hydrogen sustainably in a number of research endeavours, such as the four HYDROSOL projects, the solar-thermal process for producing nitrogen is in its very early stages of research. The DüSol project pursues the idea of using solar energy to extract nitrogen from the air, which is made up of over 78 percent nitrogen. In the process, oxygen molecules, which make up almost 21 percent of our atmosphere, are separated from the nitrogen in a thermochemical process.

The Hungarian chemical engineer clarifies that her commitment to renewable energies can be traced back to where she grew up – a suburb in Budapest surrounded by lignite mines. "That really made its mark on me. I think it is one of the reasons why I am now working on environmentally-friendly processes." She is undeterred by the fact that the sustainable production of nitrogen is still in its infancy – she is perseverant and patient. She is now working on the basic principles for such a production process and is looking for the right material. It should be able to absorb as much oxygen as possible from the air when exposed to thermal energy. This is achieved through the redox process, which is reversible in a solar energy-powered reactor. The first step is the oxidation of the material, in which the oxygen molecules are removed and the nitrogen molecules remain as a gas.



In the DüSol project, scientists are splitting nitrogen (N_2) from the air, which together with hydrogen is further processed via the Haber-Bosch process into ammonia and then into nitrogen-based fertiliser.

In the second step, the material is reduced again, the oxygen is released and the reactor is thus 'recharged' so that the process can be repeated.

A meat grinder for material production

The decisive factor for the success of a process is not only the chemical composition of the redox material; the material structure also plays a major role in its reactivity. The scientist achieves her best results when she shapes the kneadable redox material into a granulate made up of small spheres about three millimetres across. This allows the material to offer a large surface area for the reaction. "This kind of granulate cannot be bought, so we had to find a way to produce it ourselves." Purchasing an expensive special machine would have put the project budget under too much strain. Together with her colleague Sebastian Richter, Gubán preferred to devise an in-house solution, and simply converted a meat grinder. "We worked with the DLR workshop to develop a suitable attachment and made it using a 3D printer, which allowed us to give the kneadable paste the right granulation for the production of our test materials."

"Time flies when I am working in the lab," says Gubán. She followed her Chemical Engineering degree in Budapest with a stint at the Institute of Material and Environmental Chemistry, working at the Scientific Research Centre. When she helped prepare the international Hydrogen Europe Research Annual General Meeting, she seized the opportunity to set up a Europe-wide network. She joined the company Hydrogen Research Europe, one of the three members of the private-public partnership Fuel Cell and Hydrogen Joint Undertaking (FCH-JU) in Brussels.

English translation for a yoga school

She left the lab for a year for a stint as an expert consultant. "That period was of huge benefit to me, as I learned a lot about hydrogen research in Europe and the way in which funding is granted." Gubán's doctorate formed the perfect footing for her international research work, as did her UN translation certificate for Hungarian and English: "I'm glad to have this back-up skill, even if only for translating the website of my friend's yoga school in Budapest into English at the moment."

With the DüSol project, the scientist has made the switch back from science management to researcher, and in recent months she has discovered some promising materials by testing small samples in the infrared furnace over many measuring cycles. Building on these endeavours, she has gone one step further and tested large quantities of samples in the solar furnace in Cologne. Her aim is to determine whether her samples can absorb the required quantities of oxygen from the atmosphere even in scaled-up, somewhat larger experiments. Bit by bit, the scientist is coming closer to achieving the optimal process. Dorottya Gubán is geared up to play the long game. She hopes that fertiliser production will gradually become more environmentally friendly. "We cannot go from 0 to 100 percent in an instant. At the moment, the most important thing is developing production processes and technologies that work, and putting them to use. That is the only way that they can spread and be further developed."

DüSol

Sustainable fertiliser production from the Sun, air and water

Duration	1 December 2016 to 30 November 2019
Project partners	GTT Gesellschaft für Technische Thermochemie und –physik mbH, aixprocess GmbH
Funded by	North Rhine-Westphalia federal state investment in growth and employment, with funding from the European Regional Development Fund (ERDF).

IN PURSUIT OF QUIETER FLIGHT

The ATRA research aircraft is testing retrofittable noise-reduction technologies

By Falk Dambowsky

An Airbus A320 is on the approach. As usual, the flaps are extended and the landing gear lowered well before it touches down. But then the pilot accelerates the aircraft as it reaches the airport, executing a flyover. The outline of the Harz Mountains and their highest peak, the Brocken, is visible in the background. On this day, in September 2018, we are witnessing no ordinary passenger jet – it is DLR's A320 Advanced Technology and Research Aircraft (ATRA), circling around Magdeburg-Cochstedt Airport in Saxony-Anhalt. But today, something is different about the aircraft – it has external modifications, for example to the exhaust nozzles. These are intended to make the flight quieter. But how many decibels exactly? This is what the researchers on the ground aim to find out by having the aircraft passing by multiple times over two widely laid out acoustic measuring systems. Some 270 microphones are installed on the runway, covering an area of 43,000 square metres. In some places, they are arranged side by side in what is known as a microphone array, which is used to locate the sources of noise on the aircraft. In addition, the researchers also installed microphones to assess the noise radiation directivity and absolute sound pressure levels. The brightly glowing orange-red attachments on the flaps, landing gear and engine exhausts of the ATRA are easy to make out as the aircraft once again nears the airport and the microphones set up there. Michael Pott-Pollenske from the DLR Institute of Aerodynamics and Flow Technology, who heads the newly named 'Low Noise ATRA' (LNATRA) project alongside Henri Siller, points to the ever-faster approaching aircraft: "We made all of these modifications to the ATRA with the aim of reducing aerodynamic sources of noise and demonstrating the kind of component-related modifications that can still be made to passenger jets today."

There is plenty of scope for quieter passenger jets – but what can individual measures exactly achieve, and at what expense? The researchers are exploring this in detail through the meticulously planned flights at Cochstedt. Looking at the preparation that went into the test flights reveals that the modifications required for the prototype entail considerable expense and effort. The initial modifications as part of the project were planned as early as five years ago, and not only had to be designed and built, but also had to undergo a complex approval process – as is customary in aviation. At DLR, the Systemhaus Technik and the Design Organisation division of the Flight Experiments facility made significant contributions towards the development, production and qualification of the noise reduction means. The complex structural alterations to the ATRA began in June 2018, and were made together with external industry partners.

Image: DLR/Lindner

Low Noise ATRA: the modifications to the flaps, landing gear and engine exhausts – clearly visible in orange-red – should make flying quieter.

MODIFICATIONS TO THE LANDING GEAR, WINGS AND ENGINES


Partial cover for the main landing gear


Cover on the nose landing gear


Porous slat side edge


Spoiler splitter plate on the wings
(test flight planned for 2019)


Cover plate on the nose landing gear


Exhaust nozzle modification

New specially designed exhaust nozzles were installed on the engines. In its present form, the landing gear has numerous gaps that cause unpleasantly loud noises. For this reason, DLR has developed various partially permeable cover plates that shield such gaps from the airflow during flight. Smaller covers have also been placed between the wheels of the landing gear for the same purpose. When the flaps are extended, large gaps form between them and the wings. Just like the flap edges, these are responsible for a lot of the emitted noise. Here, the researchers used special materials designed to reduce airflow-induced noise. "In total, we flew with eight different noise reduction measures," reports Pott-Pollenske. "We expect improvements particularly from the cover plates on the landing gear and the new exhaust nozzles on the engines." Improvements are also expected from the filling of a gap between the wing and the leading-edge slats as well as the modification of the flaps." The modifications were initially developed prototypically, with a focus on noise reduction, but they may also form the basis for future wider applications.

Comparison with flights without modifications in 2016

This project and its custom modifications mark a first for the pilots and employees of the DLR Flight Experiments facility. The Airbus A320 ATRA, which now features eight individual modifications conducted by the DLR and with the support of other partners, had never before been modified to this extent. "It has been a truly special experience to fly our beloved ATRA as a kind of prototype with so many new components," DLR research pilot Jens Heider says, who sits in the flight deck during the experimental flights. He was already involved back in 2016, when the first ATRA test flights were conducted at Cochstedt, in order to record the acoustic profile of the Airbus A320 without the planned modifications.

Glancing towards the sky, we see the ATRA circling a little south of the airport, before disappearing into the glare of the Sun as it prepares to make another approach. "We needed the first flights with the unmodified ATRA in 2016 as a comparison that would allow us to clearly identify and quantify the acoustic improvements resulting from the modifications," explains Pott-Pollenske. Back then, the ATRA flew the exact same flight patterns, at the same altitude and speed, and the microphones were set up in exactly the same places as they are today.

New aircraft are already much quieter than they were years or even decades ago thanks to aerodynamic improvements and larger, more advanced engines. However, gaps in the landing flaps, the various structural elements in the landing gear and the engine inlets and exhausts still contribute to the typical aircraft noise. The DLR researchers have made it their mission to reduce such noise emissions. Making such adjustments to reduce aircraft noise has a particularly practical advantage. Whereas new development and market entry often takes decades for newly designed quieter aircraft, noise-reducing modifications offer short- or medium-term prospects for change, and can take effect much more quickly. This is what makes the LNATRA project and the test flights at Cochstedt so important. Aircraft noise research is a key area of focus in DLR's aviation research programme.

Alongside engine noise, airflow around the aircraft is primarily responsible for the level of noise emitted. This dominates the overall sound pressure levels during approach and landing. The noise is extremely loud wherever the air flows over openings, gaps or edges – an effect that can be simply replicated by blowing against the edge of an ID card. This is particularly an issue at low altitudes and low speeds – for example, during take-off and landing. When the landing flaps are extended, they create gaps with the wing, while the landing gear has numerous corners, edges and openings that are exposed to the swirling air when it is deployed. The tank pressure equalisation valve on the underside of the Airbus A320 already features a noise-abatement solution that has found widespread application elsewhere: 17 years ago, DLR developed a small vortex generator that eliminates the bothersome noise from the wing, which is now available as a retrofit kit and is installed as standard on new A320 aircraft.

Ongoing evaluation of acoustic data

The ATRA is now approaching Magdeburg-Cochstedt Airport from the east one last time. It is almost silent. The researchers sit waiting at their control monitors, which they have set up in a container at a sufficient distance from the runway. The Engine Acoustics Department at the DLR Institute of Propulsion Technology is specifically responsible for locating the sources of the noise on the aircraft. Only a gentle summer breeze wafts over the tarmac and the Sun continues to heat the wide expanses of concrete. Gradually, we hear the sound of the approaching aircraft. The ATRA is now flying just 120 metres above the microphones. This is the lowest altitude of today's 59 overflights, which have been arranged according to a meticulous measurement plan. This helps the DLR scientists better understand the acoustic signatures of the different approach phases.

The ATRA finally takes off on the 20-minute flight back to its home base in Braunschweig. Extensive amounts of data are now stored in the researchers' computers, the analysis of which will keep them busy for several months. Only then will they know exactly which modifications have the potential to be used in everyday air transport. Project leader Michael Pott-Pollenske is looking ahead: "We have prepared another two highly promising modifications for the front high-lift devices, known as slats, and the spoilers. We are hoping to examine the effect of these during more test flights over the coming year."

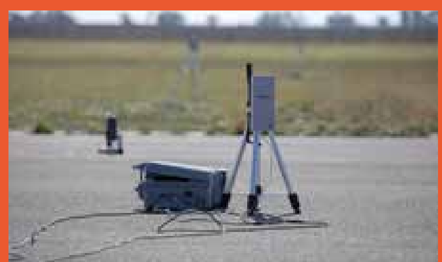
LNATRA PROJECT – EXTENSIVE COLLABORATION FOR QUIETER FLIGHT

Some of the innovative modifications to the A320 ATRA were developed in conjunction with the EU-funded project AFLoNext (Active Flow Loads & Noise control on next generation wing). The brake covers and the cover plates for the lower main landing gear were developed in conjunction with partner Safran Landing Systems. Further noise reduction measures on the nose and main landing gear were developed as part of the DLR-led Low Noise ATRA project. The porous flap side edge was developed jointly by the Airbus Group, Airbus Operations and DLR. A similar structure was installed on all of the side edges of the slats. The sound level of the air brakes on the wings is being reduced using a spoiler splitter plate, which reduces the propagation of the sound waves from the air brakes to the ground, and is set to be tested in 2019. The researchers expect that the new exhaust nozzles, which are clearly visible at the rear of the engines, will reduce the volume of the engine noise during take-off.

DLR's partners for the modifications to the A320 ATRA are AMAS Engineering, Deharde, Spörl, Donaris, Leichtwerk, Lufthansa Technik, SONACA and ASCO.

NOISE-MEASURING DEVICES ON THE RUNWAY


Arrangement of the widely distributed acoustic systems on the ground


Storage and radio control unit for the operation of two widely dispersed field microphones


Free-field microphones as per certification standard

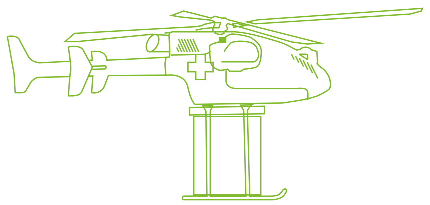

Measurement data logging unit and cable drums


Cable drums for supply and data cable connections to microphones in the ground array (background)


Overflight situation with microphone array along the runway

Images: DLR/Lindner

A 'DROP' OF FAITH



Unmanned helicopter superARTIS in test flights for humanitarian aid

Field report by Johann C. Dauer

» We have been in the Caribbean for a week now, but it is a far cry from the picture-perfect beaches and all-inclusive hotels. This is real life: heat, bad weather, parched landscapes, areas marked by poverty, and, last but not least, friendly people. Our mission: the simulation of a humanitarian relief operation to deliver supplies to hard-to-reach areas in a crisis situation.

We are standing on the road that is to serve as the helipad for superARTIS. I say road, but strictly speaking it is a rugged track that is partly submerged in the growing hypersaline Lake Enriquillo. It is Saturday morning, and way too early. But instead of the sky getting lighter, it is darkening. "A storm is coming. Will we make it on time?" asks Jörg Rößner, our safety pilot. This is our last chance, as we are already running behind schedule. Longer-than-expected waiting times at customs and difficulties in getting Jet A-1 fuel cost us almost two entire days of our two-week stay in the Dominican Republic. As a result, today is all we have to conduct the first of several missions. So we have to try. In the scenario, our unmanned helicopter superARTIS, a Dragon SDO 50 manufactured by the company SwissDrones Operating AG, has to deliver relief supplies to a village isolated by flooding.

It is still dawn as we put everything together. The ground station is set up and the rotor blades fitted to the autonomously flying helicopter. We carry out the pre-flight tests and fill the special transport boxes with food supplies.

Less than an hour has gone by since we left our hotel. A record set-up time! But Jan Binger, our ground station operator, has his doubts as to whether we are working fast enough. The dark clouds amassing in the sky are beginning to worry us. But everything is ready, and we do not want to pass up this chance. Giving up early is not an option. There is no time for chitchat as we go through the checklist for the final launch preparations. The team has perfectly primed for this moment over the last few days. A call from us triggers the roadblock; a hand gesture activates the safety area. From this point onwards, no one will be able to come near our helicopter and us. Leonor, our contact from the local civil aviation authority, confirms that the airspace has been cleared for us. I give clearance for take-off.

The turbine is started, the rotors turn at their nominal speed, and our superARTIS takes off. Its destination lies far out of sight – all the way across the lake. There, it will drop the boxes containing the relief goods. The helicopter is on its way now. Flying at an altitude of 100 metres, it speeds away, and soon all that remains is a small point on the horizon. As always, a strange feeling besets us when the helicopter finally disappears from view. And we suddenly become aware of just how remarkable this test in the Dominican Republic still is. «

The ground station is like a camp, but has everything the crew needs to track the autonomous flying helicopter.

superARTIS' mission is to quickly, cost-effectively and safely transport vital goods to locations in need of assistance.

The aircraft and technology are carefully transported to different test areas of the Dominican Republic

The missions

Together with the UN World Food Programme (WFP) and the Dutch organisation Wings for Aid, the DLR team investigated the use of drones for delivering supplies in simulated emergency situations. The helicopter automatically dropped relief supplies on hard-to-reach targets. The supplies cannot be damaged in the process. At the same time, the outer packaging had to be as inexpensive as possible, as it would remain in the remote target areas and could thus not be re-used. Elaborate and expensive parachutes were therefore not an option.

Wings for Aid has designed special cardboard boxes for this purpose. Flaps that unfold automatically when dropped have a braking and stabilising effect as the boxes fall, while a crumple zone also protects the contents on impact. The boxes are folded during transport and quickly assembled in the field. Moreover, the cardboard itself is biodegradable. In regular emergency operations, various targets can gradually be supplied with around 20 kilograms of aid items per drop. Even technical devices, such as radio units, can be delivered to the affected region using this method.

During the planning phase, it became clear that dropping goods from drones was feasible. The task of the DLR researchers was to determine the extent to which this delivery method really benefits local humanitarian aid. The WFP selected the Dominican Republic for this investigation, as drones have already been used on test runs for different purposes here. The country has been struck by a number of natural disasters in recent years. Floods, in particular, often assume critical dimensions here. Such scenarios were therefore chosen as the area of application for this study. Affected residents and official local bodies follow the test run and will help to evaluate it. The goal is to determine whether the technical solution would prove effective under the actual conditions with which emergency relief workers are confronted.

The area around the 375-square-kilometre hypersaline Lake Enriquillo has been subject to flooding many times and was the site of the tests carried out in the first week of the scientists' stay. The helicopter was to take off from a point from where it is no longer possible to get through and drop supplies at the small village Nuevo Boca de Cachón. It flew automatically, passing over about six kilometres of water and a road, before hovering above its destination for a specified amount of time. Our payload operator was waiting there to monitor the target area and trigger the drop. The helicopter then returned via the same route.

Another area, where the test took place during the second week is located in the northern part of the island close to the Bajo Yuna River. Rice is the predominant crop here. Floods are very common here, as the land surface is lower than the riverbed itself. The WFP and other aid organisations on the ground report that people are cut off from the surrounding areas by flooding here almost every hurricane season. The permanent stationing of a drone, like superARTIS, would even be conceivable for this region, supplementing the use of boats and manned helicopters.

Several missions that tackle different challenges were devised for this second region. For these, the helicopter covered distances between 800 metres and 3.5 kilometres. The take-off and landing sites were dirt roads that were closed to traffic during the flight. The targets for the cargo drops were near settlements that would require supplies in the event of an emergency.

A new approach to safety assessment

Pioneering work was performed not just from a technical and logistical perspective; the researchers also employed a new procedure for approving on-site flights. The approval of drone operations in general airspace is currently a hot topic in the field of unmanned aviation. Working with the country's civil aviation authority, the scientists decided to apply a new safety-assessment procedure – one of the first times this had ever been done. The Specific Operations Risk Assessment (SORA) looks not only at the drone as a product in its own right, but takes account of the mission for which it is intended. This should provide a level of safety that corresponds to that of manned aviation. Depending on the specific circumstances of the mission, obtaining complete certification for the drone is not always necessary. If, for instance, the mission entails only minor risks to people and the surrounding area of operation, the level of required verification can be reduced.

This procedure has hitherto been missing in civilian unmanned aviation when it comes to performing a safety assessment and formally approving more complex operations, such as flight beyond visual line of sight. As such, the European Aviation Safety Agency (EASA) is endeavouring to enshrine this process in binding regulations in the near term. In this case, an unmanned helicopter with a comparable take-off weight was used, with operations restricted to sparsely populated areas and altitudes below 500 feet. The aviation authority ensured that no other flight operations took place during this time.

The hypersaline Lake Enriquillo grows quickly in the rain – a good test area for rapid humanitarian aid.

The boxes adapted for aid operations with drones unfold automatically when dropped

»*The delivery reaches its destination*

The expected downpour has held off so far. Our helicopter has disappeared from view. Jan Binger is monitoring the flight parameters from the ground station. In preliminary tests, we determined the kind of gusts that we could expect over the lake. Now, however, the wind is really picking up and the helicopter is struggling. The artificial horizon is no longer horizontal and the turbine temperature is threatening to tip into the red due to the gusts of wind. We have clearly defined criteria for aborting the mission… but in the end our hopes come true. The wind conditions prove challenging but not critical. The helicopter reaches the other shore safely and flies over the closed-off road.

Our payload operator later describes how the helicopter turned in an impressive performance. "From the noise alone, we could tell that a proper aircraft, rather than a little drone, was on the approach," says Barry Koperberg, Founder and General Manager of Wings for Aid, who was responsible for the cargo drop on this test run.

As the helicopter hovers reliably over the drop point, we gaze spellbound at the control instruments in the ground station. Since the aircraft's total capacity is geared towards transportation, there are no additional cameras on board, so we are reliant on following the engine data. When the fuel consumption suddenly drops, we know that the helicopter must have just become lighter. Just seconds later, our payload operator phones to confirm that the drop has been triggered and that the cargo has landed safely and according to plan.

After the allotted waiting time, our superARTIS sets off on the return journey. We scan the horizon, and, indeed, just minutes later we can make it out: a growing black dot in the sky. The helicopter approaches, flies to its landing site and touches down safely. But there is no time to cheer and pat each other on the back, as we are keen to repeat the mission before the dark clouds break. Shortly after, the helicopter sets off again and delivers another box.

Having been behind schedule for a couple of days, we have now successfully completed the first part of our mission. The whole team is proud of this success, and we are naturally delighted at the positive feedback received in interviews with the region's residents and the representatives of local aid organisations. A great load seems to have been lifted from the shoulders of the flight test team, and as we pack up our things, the mood is almost euphoric. On to the second test area for next week!

As we leave, the weather chart shows us a Dominican Republic completely covered in red and purple. Rain beats down on the roof of the car and visibility is restricted to a few metres. What a stroke of luck!

The following week is all about establishing routine flight operations through variations of the missions. The derived figures help us to assess the efficiency of our transport operations. We complete several flights in Bajo Yuna and repeat the procedure. Thankfully, the weather improves and we are able to bring back ample experiences and data to evaluate at home. What we have learned will greatly advance our research into unmanned aviation technology. And at the very end, before returning to Germany, we manage to sneak in a little trip to one of those picture-perfect beaches. «

Author Johann Dauer is relieved that the researchers have an advantage over the rain clouds

Johann Dauer conducts research into unmanned aircraft systems (UAS) at the DLR Institute of Flight Systems in Braunschweig. He leads DLR's ALAADy (Automated Low Altitude Air Delivery) project, which focuses on unmanned air transport in low-altitude airspace and, among other things, explores new procedures for safety assessment and verification of civilian UAS.

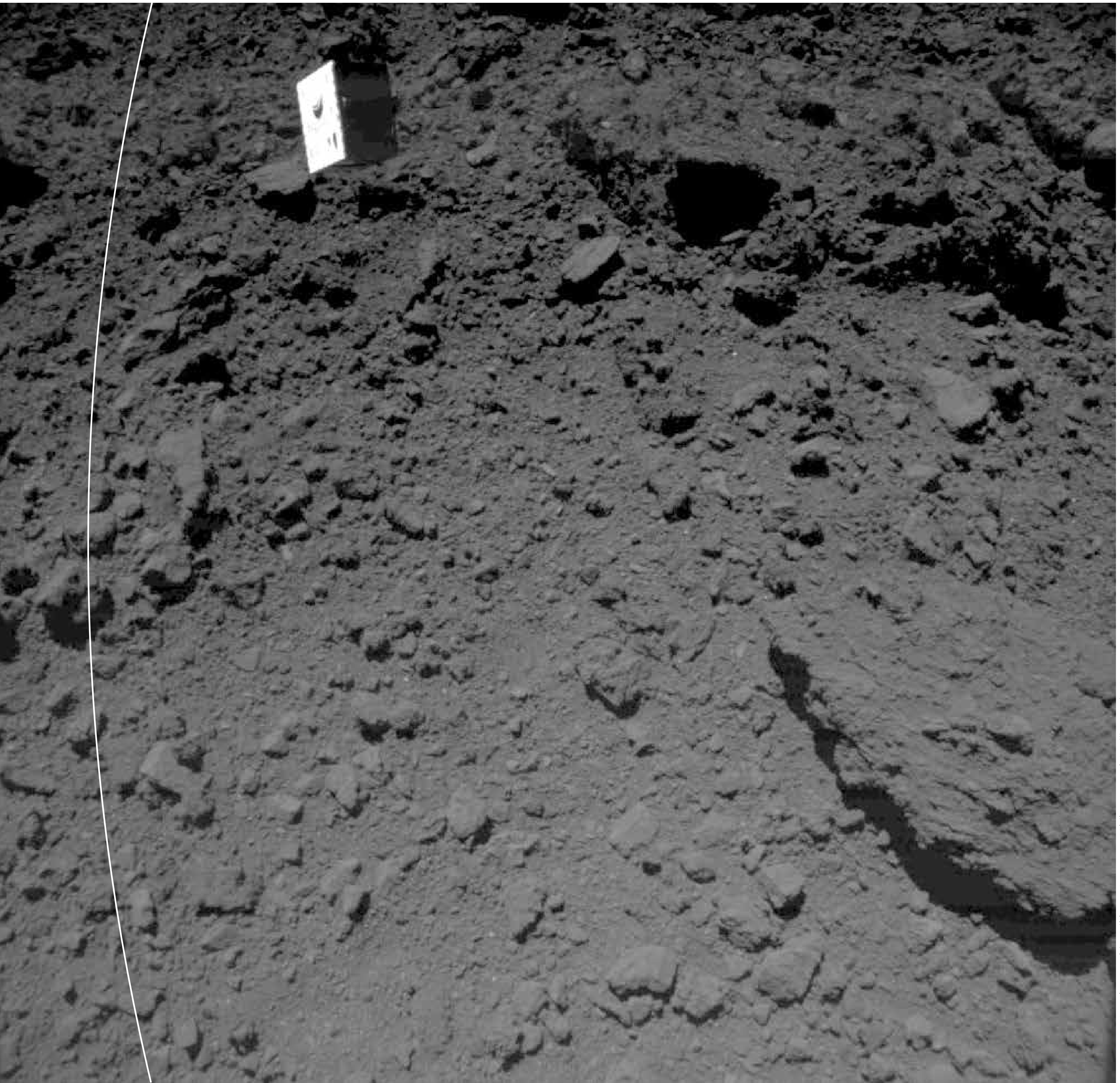
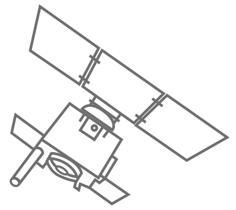


Image: JAXA/U Tokyo/Kochi U/Rikkyo U/Nagoya U/Chiba Inst Tech/Meiji U/U Aizu/AIST

A photograph that will receive a prominent place in the book about 60 years of space travel history. Shortly after the separation of MASCOT 51 metres above the asteroid's surface, the Hayabusa2 space probe's imaging system captured the descent of the French-German landing device over Ryugu's boulder-strewn surface.

MASCOT IN WONDERLAND



The Day of German Unity – 3 October – in 2018 will not be forgotten by those at DLR's Microgravity User Support Center (MUSC) in Cologne. It was a very special day that started very early at the control centre. Most of the MASCOT team was already there on the previous evening. And the remaining scientists from Germany, France and Japan arrived shortly before midnight. Four experiments, four teams. There was a quiet, concentrated atmosphere full of tension, amidst dozens of monitors and open laptops. Everyone tried to be as calm as necessary, but also as focused as possible. An otherworldly event was about to take place on the other side of the Sun, some 300 million kilometres from Earth. At precisely 03:57 and 21 seconds CEST, an asteroid lander would play the role of its life – and the team back on Earth would not be able to intervene. The microwave-sized Mobile Asteroid Surface Scout – MASCOT – fully equipped with high-tech robotics, would separate from the Hayabusa2 spacecraft at an altitude of 51 metres and begin its descent to the approximately 900-metre-diameter asteroid Ryugu.

The Hayabusa2 mission and the MASCOT lander are breaking new ground in space research

By Ulrich Köhler

"Separation from Hayabusa2 confirmed," announces MASCOT project manager Tra-Mi Ho from the DLR Institute of Space Systems. "The magnetometer telemetry indicates it." Celebration! All is nominal – the magic word all those involved in spaceflight missions want to hear. Silence reigns. The wait for the most important moment of the mission begins. MASCOT has no propulsion system and is descending towards Ryugu in free fall at a speed of a few centimetres per second. Intervention from the ground station is not possible and futile, as it takes a signal over 17 minutes to reach the lander. Six minutes later – and 10 earlier than expected – at precisely 04:03, Operations Manager Christian Krause reports: "MASCOT has a first ground contact." Once again, there is cheer. MASCOT is finally in a place like no place on Earth. A land full of wonder, mystery and danger! This time, however the jubilation is cautious, as most of the team is surprised by how quickly the lander has descended and made its initial contact with the surface. The DLR-developed German-French MASCOT would continue to travel several metres with uncontrolled movements from the first point of ground contact before reaching its provisional final position in the asteroid's minimal gravitational field. That, too, happens nominally.

MASCOT, the box-shaped instrument rack made of sturdy carbon fibre composite measuring 30 x 20 x 20 centimetres and weighing just 10 kilograms, came to a standstill. The gravitational pull on Ryugu is only about one sixty-thousandth of that on Earth, which means that MASCOT weighs less than one gram there. The 'rolling', like dice on a game board, has no effect on the mechanical structure or the technology and the instruments in its interior. The engineers have extensively tested this beforehand. MASCOT carries four experiments. The lander made it to its planned landing site, located at 310 degrees east and 30 degrees south. The scientists spontaneously named it 'Alice's Wonderland', after the eponymous children's book by Lewis Carroll.

It was noon on Ryugu, where both day and night last just three hours and 45 minutes. The radio link to the Hayabusa2 mothercraft, which had ascended to an altitude of 10 kilometres to receive signals from MASCOT, was stable. During the lander's descent, the MASCAM camera system acquired 20 images and transmitted them to the probe. They show an asteroid landscape strewn with angular boulders and sharp stones. MASCOT's first contact with Ryugu was on a five-metre rock. Rubble fills the landscape, but there is no dust in sight – what a surprise! Hayabusa2's three cameras captured the lander's descent in numerous pictures, allowing for MASCOT's free fall on the asteroid and rolling movements to be reconstructed.

Image: JAXA

Hayabusa2 is a very complex space mission. The main task is the exploration of Ryugu, an approximately one-kilometre-diameter, primitive asteroid from the time of planet formation. The highlight will be three samples taken in the coming year. By the end of 2020, a capsule with asteroid material will arrive on Earth.

Landing on its back!

Upon its first contact with the ground, MASCOT bounced and subsequently touched the ground eight more times. It reached its resting position half an hour later. As programmed into the on-board computer, MASCOT immediately started conducting experiments with its four instruments on Ryugu's surface. At the same time, the first housekeeping data from MASCOT started to arrive at the control centre in Cologne via Hayabusa2: state of charge of the battery, temperature of the instruments, memory usage, orientation data, status of the data transmission. Following analysis of the data, the scientists and mission control got a real scare – MASCOT was lying on its back like a turtle. This was not unusual, because the odds that a box-shaped body with six flat sides would immediately end up in the right orientation to conduct the experiments was about one to six. Precisely for this reason, a system was developed to enable MASCOT to automatically change its position – a tungsten metal weight that would be rotated with a swing arm, providing the necessary momentum for MASCOT to flip itself over and even hop across the surface thanks to Ryugu's low gravitational pull.

But MASCOT did not make this swing! A short and intensive meeting took place in Cologne. A decision had to be made fast, since the battery's lifetime was just 16 hours. The signals of the position sensors should have recognised the erroneous position and sent a command to the swing arm mechanism autonomously. But since this did not happen, a decision was made to send a command to the motionless landing device to make it turn 180 degrees. Although this meant losing some valuable exploration time, there was no alternative. The camera, spectrometer and radiometer were just looking into space! Then, there was a big sigh of relief – the manoeuvre produced the desired effect, and MASCOT was now in a favourable position. The instruments then began to carry out their measuring sequences automatically. Meanwhile, the small lander had already been on the asteroid for a full day-and-night cycle. MASCOT's second day on Ryugu began at 09:52, almost six hours after first contact.

Hayabusa2 – Impossible is nothing

Past and future: The Hayabusa2 space probe, which was launched on 3 December 2014, reached asteroid Ryugu in June 2018. The Japanese Aerospace Exploration Agency JAXA's mission is highly complex. Initially, the 'Peregrine Falcon' observed the asteroid from its 'home' position at an altitude of 20 kilometres. The probe is the successor of the Hayabusa mission, which took samples from the asteroid Itokawa in 2005 and, despite considerable technical difficulties, delivered them to Earth in 2010. The second Peregrine Falcon will collect more material, do so from more than one location, and from a Near-Earth Asteroid. The scenario for this is extremely complex and challenging – from the approach of the Hayabusa2 space probe in early 2019 to one metre above the surface, through to touchdown on Ryugu and the activation of its cylinder-shaped sampler horn. A tantalum projectile will be fired from this horn into the asteroid, to stir up the surface material. The dust that rises into the collecting horn will then be fixed and sealed in a container. This will be repeated at a second location.

The third and final sample collection will be truly spectacular. Hayabusa2 will deploy the Small Carry-on Impactor (SCI), a kinetic impactor consisting of a 2.5 kilogram copper projectile accelerating at two kilometres per second to Ryugu's surface by an explosive propellant charge. To ensure that this does not damage the spacecraft, Hayabusa2 will take cover on the other side of the asteroid. A simultaneously deployed miniature camera will record the impact. Hayabusa2 will then approach the artificial crater, where it will touch down and collect the freshly disturbed asteroid material, which has not or hardly been affected by cosmic radiation and the solar wind. Hayabusa2 will return to Earth in 2020, carrying these samples. In addition to deploying MASCOT, eight partially moveable mini-devices will be placed on the asteroid during the mission. These will mark the artificial crater or record the landscape with stereo cameras. No previous exploration mission has ever used such innovative and unconventional technology.

Observing a celestial body up close using a space probe is highly valuable to scientific research, while taking samples and delivering them to Earth is the ultimate achievement. Finally, conducting experiments on the surface really is the cherry on the cake. The MASCOT lander, developed by DLR and the French space agency CNES, embodies a completely new concept for landing on a body with an exceptionally low gravitational pull. DLR's MASCAM camera, which began taking images during the descent, photographed the surrounding area from the landing site all the way to the horizon in high resolution. A total of 120 images were acquired – more than twice as planned – and the light-emitting diodes allowed pictures to be taken even at night. The French MicrOmega infrared spectrometer investigated the mineralogical composition of the asteroid's material through the direct contact of its sensor on MASCOT with the surface. The MasMag magnetometer, developed at the Technical University Braunschweig, collected data on Ryugu's possible magnetic field, which would have been imposed on the small body in the early days of the Solar System. Finally, DLR's MARA radiometer recorded the surface temperature and thermal properties of the regolith.

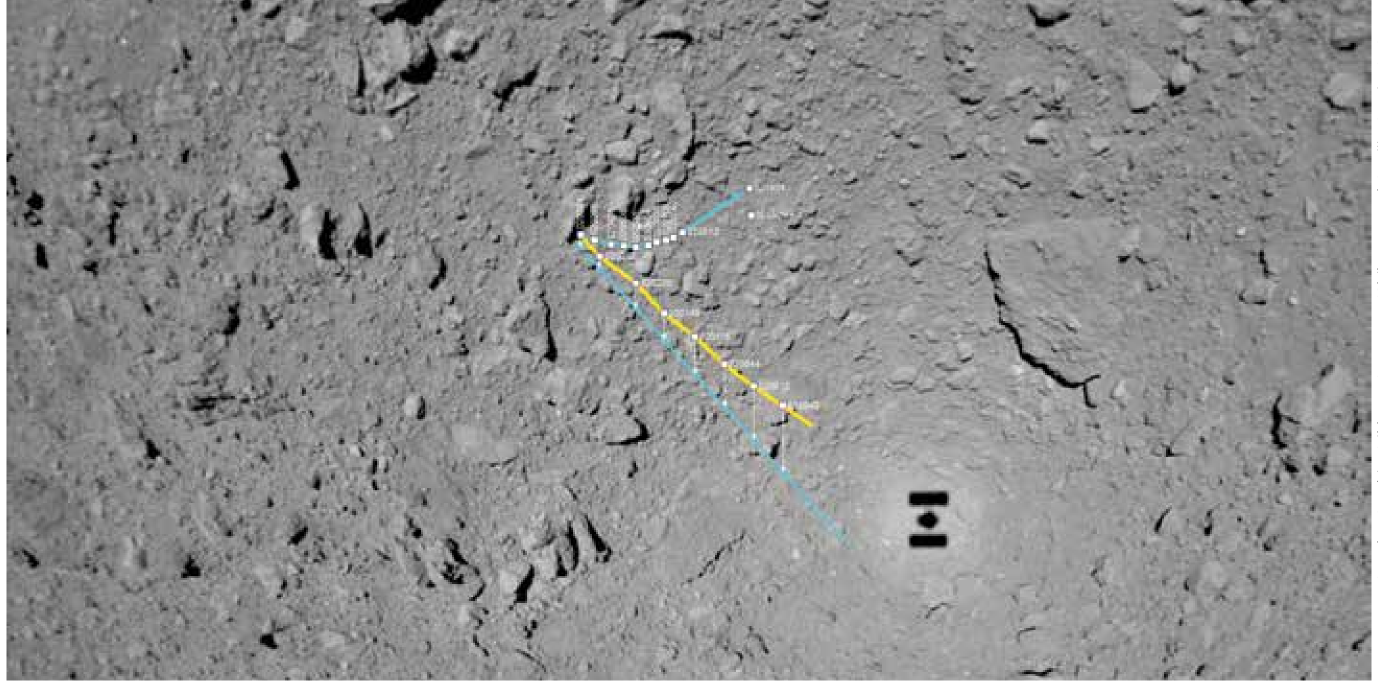
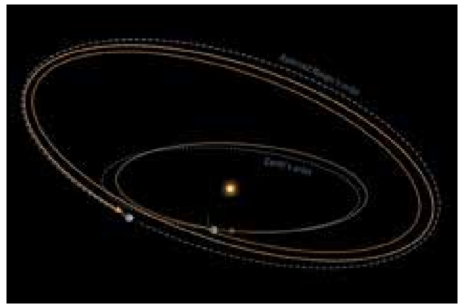


Image: JAXA/U Tokyo/Kochi U/Rikkyo U/Nagoya U/Chiba Inst Tech/Meiji U/U Aizu/AIST

The imaging system of the Japanese Hayabusa2 spacecraft followed MASCOT's descent. The probe's shadow can be seen on the lower right. The dots in the image indicate the times at which the pictures of MASCOT were taken. The yellow line marks the positions at which MASCOT was still descending towards Ryugu. The blue line, below the yellow line, is the projection of these positions onto the asteroid surface. This shows that MASCOT covered a near-straight flight path.



The orbit of asteroid Ryugu approaches Earth's orbit to as close as 95,000 kilometres

Seventeen exciting hours in the MASCOT control centre at the DLR site in Cologne

Image rechts: MASCOT/DLR/JAXA

DLR's MASCAM camera reveals a big surprise; stones, rocks and boulders everywhere – but no dust.

Primordial material with a latent threat

Asteroids are the remnants of planetary formation. More than 750,000 such bodies are known, most of which orbit the Sun in the Main Asteroid Belt, between Mars and Jupiter. Above all, there are asteroids whose paths cross that of the Earth around the Sun. Today, around 17,000 such asteroids have been catalogued. Most of their orbits are sufficiently well known and pose no threat to Earth. One of the major topics of exploration is the characterisation of these near-Earth objects (NEOs) and the avoidance of collisions with Earth through the use of technology. With Hayabusa2 and MASCOT, scientists are hoping to achieve two objectives. Firstly, they aim to obtain information from Ryugu – a representative of a particularly 'primitive', carbon-rich class of asteroids that originates from the earliest period of the Solar System – about the formation of planets. Secondly, the scientists want to know exactly what asteroids crossing Earth's orbit are made of.

MASCOT's third day on Ryugu began on 3 October 2018 at 17:30 local time in Cologne. At this moment, the lander made a small movement on command – a 'mini-move' – to optimise the position of the sensors. And the measurements continued. At 20:04, the last jump is commanded to MASCOT from the control room. Rationally, as engineers can sometimes be, they announced the End of Life phase of the mission. The lander began at the beginning … and continued until the end. Yet the measurement programme continued through to 21:00 that evening in Cologne, far into its mission – and its maximum battery life. Contrary to the calculations, the battery continued to provide power until contact with MASCOT was broken off by radio silence and imminent nightfall. Instead of 16 hours, the experiments were conducted for 17 hours and seven minutes, a highly valuable full hour more than planned.

The palace of the dragon god

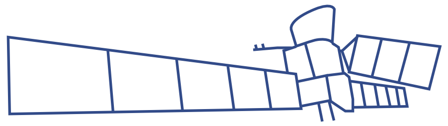
In Japanese mythology, Ryugu is the underwater palace of the dragon god. Legend has it that a brave fisherman was once rewarded with a visit to the magnificent building. He brought back a treasure chest with a secret hidden inside it. Indeed, MASCOT's findings together with the dust samples that Hayabusa2 collects from the asteroid Ryugu, which will reach Earth in a hermetically sealed landing capsule, could well be considered a scientifically valuable treasure from the asteroid realm. Exploring Ryugu from up close, confirming and enhancing these insights with the small MASCOT lander, and analysing the samples will revolutionise observations of this type of asteroid. Hayabusa2 could thus become the standard on which future telescopic observations, in particular, are based.

Ulrich Köhler is a planetary geologist at the DLR Institute of Planetary Research and was present during NASA's Jupiter Galileo probe flyby of asteroid Gaspra in 1991, when an asteroid was photographed up close for the very first time.

MASCOT – BORN AT DLR

The DLR Institute of Space Systems in Bremen was responsible for developing and testing the lander in collaboration with France. The DLR Institute of Composite Structures and Adaptive Systems in Braunschweig was responsible for the lander's stable structure. The DLR Institute of Robotics and Mechatronics in Oberpfaffenhofen developed the swing arm that allows MASCOT to hop across the asteroid. The DLR Institute of Planetary Research in Berlin contributed the MASCAM camera and MARA radiometer. The asteroid lander was monitored and operated from the MASCOT control centre at the Microgravity User Support Center (MUSC) at the DLR site in Cologne.

A WANDERER WITH AN IRON HEART



Planets – wanderers, restless nomads in the firmament. At least, that is how the ancient Greeks looked upon these peculiar celestial bodies, whose positions change ever so slightly each night against the fixed position of the stars. Mercury, the innermost and smallest of the eight planets in the Solar System, displays this unsettled behaviour more than any of its fellow planets. Although rarely visible at dawn or dusk, Mercury is truly something special. As such, there are many reasons to investigate the Sun's nearest neighbour more closely. The European Space Agency's (ESA) BepiColombo spacecraft was launched on 20 October 2018, with the mission of bringing two space probes into orbit around Mercury and to observe the planet from December 2025 onwards. The ESA orbiter carries 11 experiments, two of which are DLR instruments. The Japanese orbiter that will examine the planet's magnetic field has five more instruments. In addition to funding from the institutes involved, the German part of the BepiColombo mission was coordinated and largely financed by the DLR Space Administration using funds provided by the German Federal Ministry for Economic Affairs and Energy (BMWi).

Europe and Japan bound for Mercury with the BepiColombo mission

By Ulrich Köhler

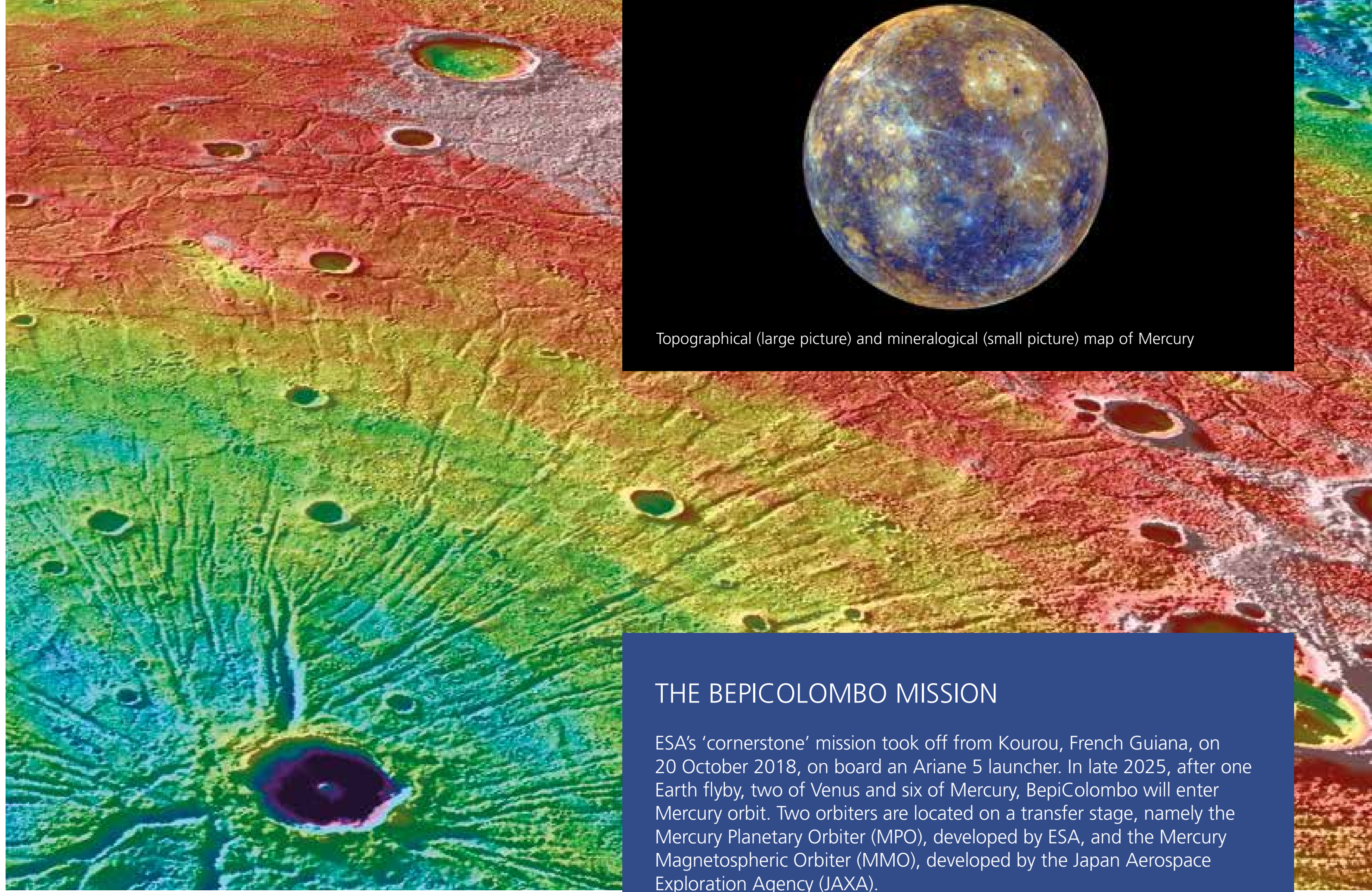
What exactly happened to Mercury? Planetary researchers have been asking themselves this question for decades. Every big family has members that stand out from the rest – and the eight-planet Solar System family is no exception. Mercury is markedly different from its four closest neighbouring rocky bodies – Venus, Earth, the Moon and Mars. It is an 'oddball'. On the outside, it does not seem particularly unusual. In fact, at first glance, Mercury looks a lot like the Moon – its surface is dotted with thousands of craters from the early days of the Solar System, when impacts from asteroids of all sizes were part for the course. And, as in the case of the Moon, its scarred rock crust is testament to the fact that, over the past three or four billion years, this planetary body has not been subject to geological forces within its interior that would cause changes on its surface. Even the expanses of thin, solidified lava – which cover thousands of square kilometres – are pockmarked by countless craters, indicating that these areas are significantly more than three billion years old – ancient even in geological terms.

So what makes Mercury the odd planet out? Astronomers have long puzzled over Mercury's unusual orbit and rotational characteristics. Its path around the Sun is more elliptical and therefore less circular than that of the other planets. When it is furthest from the Sun, the distance from the centre of Mercury to that of the Sun is barely 70 million kilometres, while at the other extent of its orbit the distance is a mere 46 million kilometres. It takes Mercury 88 Earth days to orbit the Sun, and 59 Earth days to rotate once about its axis. This means that the length of a day and the length of a year are unusually coupled on Mercury in a 3:2 orbital resonance – over the course of two Mercury years, the planet rotates only three times about its own axis. Astronomers describe this as a spin-orbit resonance. Scientists want to understand why.

A tricky endeavour

Until now, only two missions have been sent to explore the Sun's nearest neighbour, which was named after the fleet-footed messenger of the Roman gods. In 1973, the NASA Mariner 10 probe became the first spacecraft to be sent to a celestial body other than the Moon, Mars or Venus. Travelling to Mercury is a tricky task due to the huge gravitational pull of the Sun and the high temperatures involved. The Italian mathematician Giuseppe 'Bepi' Colombo (1920–1984) calculated the ideal 'braking distance' for Mariner 10. He is being acknowledged for his great achievements with the name 'BepiColombo' for the current ESA mission. In 1974 and 1975, Mariner 10 passed by its target three times, photographing half of the planet and carrying out basic physical measurements. Among other things, the planet's magnetic field was discovered. The second mission to Mercury – MESSENGER – only followed in 2011. Mercury was now fully mapped, but due to the orbital mechanics the NASA probe had to concentrate on the northern hemisphere. As a result, research on the south has long lagged behind. This will change with the BepiColombo mission.

In addition to the planet's geological history and development, one other aspect is of particular interest: Mercury's rotational axis is almost vertical as it orbits the Sun, as is also the case with Earth's Moon.



Topographical (large picture) and mineralogical (small picture) map of Mercury

Image: NASA/JHU-APL/ClofW

Both celestial bodies lack an atmosphere, which means that irradiated solar energy cannot be transported from one place to another. Moreover, the poles of both bodies are populated by deep craters, only the edges of which are touched and warmed by sunlight, while the crater floors never get the slightest ray of light, resulting in extremely low temperatures. As such, they are likely to contain frozen water from fallen comets and asteroids. This was first indicated by radar observations of Mercury from Earth. MESSENGER later confirmed this finding while orbiting the planet. BepiColombo is set to provide the definitive evidence.

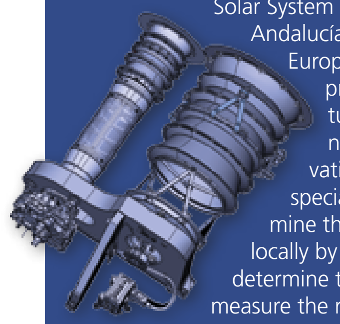
Thin mantle, massive core

But what many scientists find most interesting is Mercury's inner structure. The Solar System's innermost planet is unusually heavy, with a mass that is excessive in relation to the other planets. This is reflected in its average density of 5300 kilograms per cubic metre – almost as great as Earth's. But given that Mercury has a much smaller diameter, measuring less than 5000 kilometres, if its structure were like Earth's – comprising a core, mantle and crust, with equivalent proportions of metals and rock – it would have a far lower density. Its large mass can only be explained by a very high proportion of metals. Model calculations assume that it is more than two thirds iron with an unknown sulphur content and only one third rock. It is thought that the iron is concentrated in a disproportionately large core that makes up almost two thirds of the planet's overall volume and accounts for over two thirds of its total mass. At only 600 kilometres thick, the siliceous rocky mantle that surrounds the iron core is correspondingly proportioned. Why is this so? BepiColombo will try to shed some light into these and many other questions.

THE BEPICOLOMBO MISSION

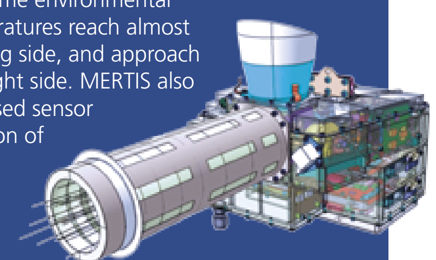
ESA's 'cornerstone' mission took off from Kourou, French Guiana, on 20 October 2018, on board an Ariane 5 launcher. In late 2025, after one Earth flyby, two of Venus and six of Mercury, BepiColombo will enter Mercury orbit. Two orbiters are located on a transfer stage, namely the Mercury Planetary Orbiter (MPO), developed by ESA, and the Mercury Magnetospheric Orbiter (MMO), developed by the Japan Aerospace Exploration Agency (JAXA).

The ESA orbiter will explore Mercury using 11 experiments, including BELA (BepiColombo Laser Altimeter) for measuring the planet's shape, topography and rotational characteristics, and MERTIS (MErcury Radiometer and Thermal Infrared Spectrometer) to determine the composition, mineralogy and temperature of the planet's surface.



BELA was developed by the DLR Institute of Planetary Research in cooperation with the University of Bern, the Max Planck Institute for Solar System Research and the Instituto de Astrofísica de Andalucía. It is the first laser altimeter to be used on a European planetary exploration mission. Given the proximity to the Sun and the extreme temperatures that prevail on Mercury's Sun-facing and night side, the complex, yet space-saving, innovative construction for the thermal household is a special feature of the experiment. BELA will determine the topography of the surface globally and locally by means of laser altitude measurements, determine the surface roughness and accurately measure the rotation state of the planet.

MERTIS was developed by the DLR Institute of Planetary Research and the DLR Institute of Optical Sensor Systems together with the University of Münster, and built in conjunction with German industry partners. The experiment will provide a global mineralogical map and the first thermal map of Mercury. The MERTIS sensors, which weigh only 3.3 kilograms, were adapted to the extreme environmental conditions on Mercury, where temperatures reach almost 500 degrees Celsius on the Sun-facing side, and approach minus 200 degrees Celsius on the night side. MERTIS also features a compact design, miniaturised sensor systems and a low power consumption of just 19 watts.



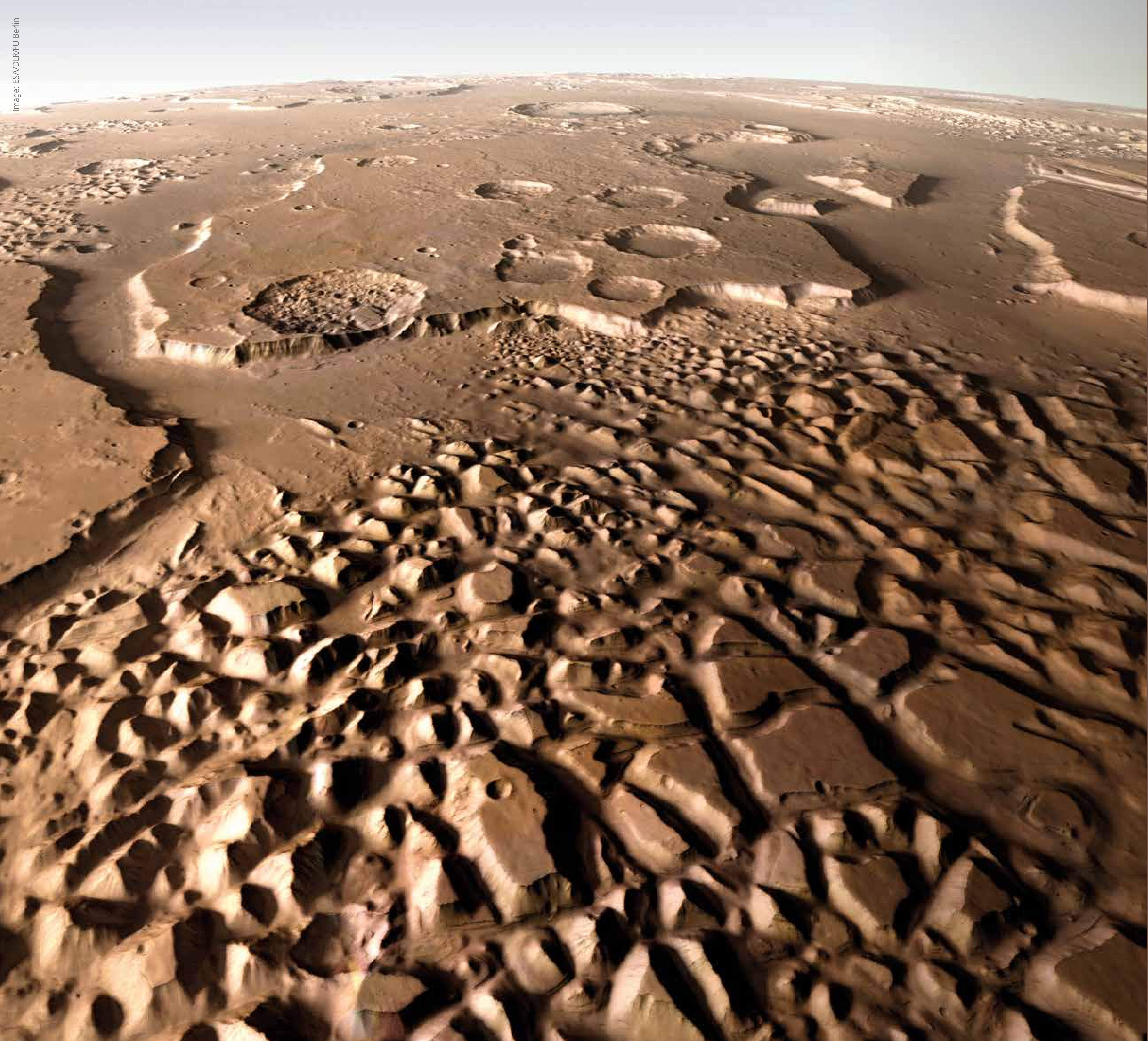


Image: ESA/DLR/FU Berlin

15 YEARS LATER: CHAOS IN A DIFFERENT LIGHT

Mars was in a very favourable position back on 2 June 2003, when a Soyuz rocket took off from Baikonur, carrying the first planetary probe developed by the European Space Agency (ESA) to explore another planet. Just a few hours later, the payload – a satellite with seven measuring instruments on board – was en route to Earth's 'next-door' outer neighbour. The Mars Express mission was under way. Some 205 days later, on Christmas Day, the probe reached its target: Mars' orbit. Despite widespread jubilation, on that Christmas morning no one sensed that this would merely be the prelude to one of the longest and most successful missions to explore a Solar System body. The orbiter is set to circumnavigate and continue to explore the Red Planet until at least the end of 2020. Italian scientists only recently astounded the world with their discovery that a 20 kilometre-wide lake may lie about one-and-a-half kilometres below the ice cap of the Martian South Pole, according to radar data captured by Mars Express. The High Resolution Stereo Camera (HRSC) developed by DLR has also been providing a plethora of valuable insights into the geological development and climate history of Mars for the past 15 years.

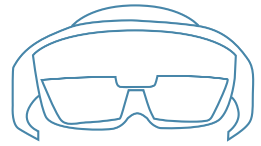
The first image, which was unveiled to the public in January 2004, showed the Hydraotes Chaos region – a labyrinth of mesas created by the eroding effect of masses of water draining away and ground collapsing to form great voids. Since then, the probe has orbited Mars about 18,500 times at different altitudes. As such, global coverage has seen constant improvement, with image resolutions of up to 12 metres per pixel. The image here shows a view recently recorded by the HRSC from the equator looking north over the striking landscape of Hydraotes Chaos, with its more than 2000-metre-tall table-mountain outliers in the foreground. The outflow channels of Simud Valles (left) and Tiu Valles (right), which are up to 80 kilometres wide and more than 1000 kilometres long, extend as far as the horizon.

Evaluating the image data from our neighbouring planet will keep the scientists busy for at least the next 15 years.

Ulrich Köhler

Repairs in space – without a space suit and only with data glasses. DLR researchers in Braunschweig and Oberpfaffenhofen are working on making this possible.

I SEE WHAT YOU SEE



In the last decades, with increasing space activities, a new threat has started to emerge: space debris. Masses of disused satellites, old rocket parts and other debris race through space at high speeds. At present, when satellites break down or are out of fuel, it is generally not possible to repair or refuel them. The famous exception is the Hubble Space Telescope – its incredible visual acuity was restored thanks to several highly complex manned missions using the Space Shuttle. But human spaceflight missions are extremely costly and, of course, entail risks. As such, new solutions are being sought to reduce the number of satellites facing this type of untimely retirement. Researchers at DLR have a vision – to be able to repair damaged satellites using a robot and a pair of data glasses – the Microsoft HoloLens. In addition, DLR engineers have shown that the HoloLens has applications even before the satellite repair work begins – it is already being used as an effective aid in satellite design and training for future repair missions.

Holograms for servicing in space and Industry 4.0

By Andreas-Christoph Bernstein and Sebastian Utzig

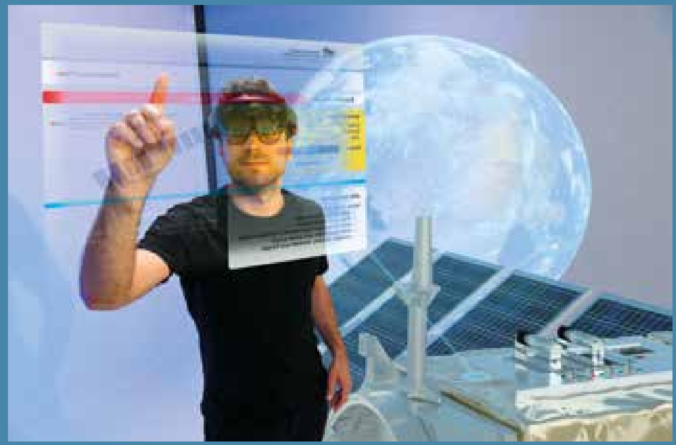
If satellites malfunction during their operational lifetime, the financial damage – not to mention the effect on morale – can be enormous. All that remains is space debris, which presents a risk to other space missions. As such, DLR researchers are working hard on devising solutions for repairing defective satellites directly in orbit. Experts call this On-Orbit Servicing, or OOS.

The high risks and costs of manned OOS missions make them infeasible for recurring maintenance tasks. Defective satellites in orbit will thus be repaired by robots. Such service robots do not only work autonomously, but can also be controlled by a human on the ground. For this purpose, the robot is equipped with a stereo camera that transmits its video signal to Earth. The service engineer on the ground can see the video feed in his or her data helmet and, positioned in an input device, can control the arms of the service robot in orbit. This device – a frame modelled on the robot itself – can also expend force. As soon as the robot comes into contact with a satellite component, the collision forces are transmitted to Earth. The engineer feels them and can react accordingly. In addition, through this force feedback, the forces applied in space can be controlled intuitively. At the teleoperation workstation, the engineer's head movements are transmitted to those of the service robot's camera.

The input device also makes forces perceptible

A service robot like the humanoid Justin can reproduce the arm and head movements of the service engineer

A discussion on the virtual satellite



Menu items can be selected with hand gestures

HOW THE HOLOLENS WORKS

The HoloLens is like a pair of glasses. But instead of lenses, it has two semi-transparent screens that allow the wearer to see the actual surroundings. In addition, these mini-screens can display virtual objects that are superimposed on the real surroundings. The virtual object is displayed from slightly different perspectives on each of the lenses, giving the impression that one is seeing the object in three dimensions. For instance, when wearing a HoloLens, one would see a satellite model floating in space. All of the required components – such as the sensors, cameras and the computer – are integrated directly into the data glasses themselves, so there is no need for a restrictive cable tethering it to another device. With this equipment, the HoloLens continuously records the environment, together with the user's head position and viewing direction. The displayed satellite model is constantly attuned to the user's movement – it floats in space in an almost fixed position. Even hand movements within the HoloLens field of view are detected and interpreted as gestures. Colleagues who are also equipped with the HoloLens system can actively participate in a discussion. If everyone is in the same room and the satellite model is registered in exactly the same position by all of the glasses, interactive discussions can be held about it in the same way as they would be about a tangible component.

Digital twin prototype built into satellite design

In the event of problems in orbit, it is now possible to use the solid knowledge of engineers on the ground. After all, they know their satellites inside out. A detailed virtual model is created during the design phase. Computer models make it possible to discuss and adapt different configurations quickly. The arrangement of all the sensors, drive components and general structure of a satellite are thus specified in precise detail. The HoloLens offers completely new ways of planning the design. Using the 3D visualisation of the satellite model, experts are able to evaluate the position and assembly process for components directly from their workstation. If they need to look inside the satellite, any components that might obstruct their vision are simply faded out. Since the satellite model is displayed in its original size and the user can move around it, a realistic spatial understanding of its structure is achieved.

Seeing what your colleague sees – a new way of working as a team

Interaction with the virtual satellite model without a mouse and keyboard is also possible because the HoloLens recognises hand gestures. The engineer is thus able to take a component out of the virtual satellite, look at it more closely, modify it and then put it back in place. This makes it possible for different designs to be tested quickly and design decisions to be made more rapidly. What is also extremely helpful is that several HoloLens users can simultaneously view, change and discuss the satellite model. And since the HoloLens also allows the wearer to see his or her surroundings, the engineers can see each other and identify which components their colleague is pointing or looking at. Such possibilities for working together offer huge advantages over the traditional PC workstation. It is difficult for even virtual reality (VR) technology to model such intuitive working environments.

Every repair must undergo a planning process

If a satellite suffers damage during a mission, the existing virtual design model can be used to plan a repair process. Virtual models of the service robot and the available tools are also required for such planning. Without these, the repair work cannot be checked. The analysis also determines whether the most important satellite components are easy to access, and whether the robot will be able to grasp and remove defective components without damaging others.

The expert (green in the picture) can be seen as an avatar

The expert draws up a barrier with his hands, and the robot knows it cannot move further.

If all this can be ensured, the sequence of the necessary repair steps is finalised and specified in the form of a repair manual. This takes place on the virtual satellite itself, by attaching virtual notes as information windows with text and image material. The components, screws and connectors used at each stage of the repair are visually highlighted, and operations to be performed appear as animations. Last but not least, voice comments can also be recorded and saved using the HoloLens built-in microphone.

These audio-visual repair instructions provide the basis for repair mission training. The service engineer is positioned at the teleoperation workstation, from which he or she can control the virtual robot remotely using the two-arm input device. Wearing the data glasses, he or she can view the virtual scene from the perspective of the service robot. Now, the engineer can work through the steps of the repair instructions and practice the repair. A trainer wearing a HoloLens, through which he or she can see the real service engineer and the virtual satellite model, observes the process in parallel. Unlike the engineer performing the repair, the trainer is not docked at one end of the satellite, but can move freely around it, checking the execution from all angles and pointing out any problems.

Introducing an avatar

Every movement that the service robot actually makes can be accurately logged and transferred to a virtual model. This allows experts all over the world to follow space servicing missions live and contribute to the repair process if necessary. Again, the sheer potential of the HoloLens comes to the fore: the virtual satellite model and the docked virtual service robot are shown to the expert at his or her own workplace, making it possible to track the robot's movements in real time. As the expert moves freely around the model, he or she is able to view parts of the satellite that are hidden from the service engineer, and is therefore able to point out problems and discuss the way forward. As an add-on to this procedure, the trainer can appear in the repair worker's field of vision as an avatar – a development that could also apply in the actual execution of the repair mission. In this case, the video image captured by the robot would be combined with the virtual avatar.

In addition to the display of avatars (sometimes several at once), notes can be superimposed on the 3D video image. The most important of these is the audio-visual repair manual prepared in advance. Similarly, the components to be repaired on the real satellite can be highlighted in their exact position. Ad-hoc findings by experts can also be visualised as virtual notes. For instance, an expert might want to prevent the robot arms from damaging parts of the satellite that do not lie within the robot's field of view. To do this, the expert can restrict the robot's movement by placing virtual barriers on the satellite model with his or her hands. A virtual touch by the service robot transmits a force to the input device, so that the robot's arms ultimately cannot penetrate this virtual wall. If necessary, the robot's potential movements can be further restricted so that one of the arms, for instance, can only be moved in one plane or along a certain path.

Looking into the future of Space 4.0

The described repair mission is just one of many scenarios in which the HoloLens may be used. As an innovative tool, this new technology opens up a number of fascinating possibilities for design, training and mission execution in all of DLR's engineering-based research activities and beyond. The three-dimensional satellite model, which provides the basis for the 'digital twin prototype' for space, lies at the heart of the On-Orbit Servicing application described here. The new possibilities for working in teams are particularly valuable. As the real environment remains visible – both on Earth and in space – reality and the virtual world are becoming blurred. This is leading to a high level of acceptance for use in future-oriented projects for Industry 4.0, Space 4.0 and further digitalisation, such as in aviation or for advancing vehicle intelligence.

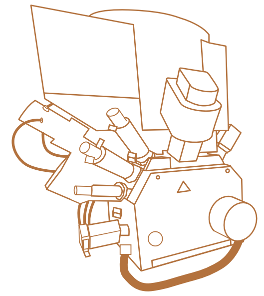
Andreas-Christoph Bernstein is a member of the Interactive Visualisation working group at the DLR Simulation and Software Technology facility. He is researching methods for the photorealistic representation of objects in virtual working environments.
Sebastian Utzig develops and researches new methods of interaction for mixed-reality applications with the HoloLens and is a member of the same working group.

The work described in this article is part of the joint research project VR-OOS carried out by the DLR Simulation and Software Technology Facility and the DLR Institute of Robotics and Mechatronics (RM). The authors would like to thank Maximilian Denninger (RM) for providing the virtual model of the robot Justin.


A view inside the focused ion beam microscope, in which an ion beam can perform miracles.

WORKING WITH A NANO MULTITOOL

Scientific material samples 1000 times thinner than a single hair can be cut or mounted on a special microscope slide with micrometre precision using the Focused Ion Beam Microscope. This edition of the 'Glorious Giants' series on large-scale research facilities unveils a device without which the strongest electron microscopes would not be able to work at full capacity, and thus plays an important role in materials research.



Materials scientists need extraordinary tools and craftsmanship to prepare samples for nanoscale analysis

By Florian Kammermeier

The research facility featured here could well be the subject of an old riddle: 'I can slice, but I don't have a blade. I can file, but I don't have teeth. I can remove layers, but I'm not a shovel. What am I?' The Focused Ion Beam (FIB) microscope is a kind of multitool for working at a micro or nano scale. Its key feature – as the name suggests – is an ion beam. It operates similarly to a scanning electron microscope, but uses gallium ions instead of electrons. These are many times heavier than electrons. If we compare them energetically, an electron smashing into a surface is like a grain of sand being thrown against a wall, while a gallium ion is like a bowling ball. If you shoot enough ions at a sample, you can process them on a micro- or nanometre scale, similarly to a sandblaster. If the person operating the device focuses the beam on a certain spot for a longer time, he or she can mill slices from samples and then thin these out layer by layer. The device can also be used to make and examine cross-sections of material, and combine them in three-dimensional models, known as tomograms.

Learning about microstructures to understand their properties

These thin slices – which scientists call lamellae – provide the basis for the precise examination of materials in a transmission electron microscope (TEM). Thanks to the combination of the thin lamellae provided by the FIB, scientists are now achieving the highest resolutions in the world using a TEM. As such, the FIB and TEM play a key role in research, allowing materials scientists to explore the relationships between a material's microstructures and its properties, for example in alloys and semiconductor materials. Only with these high resolutions can biologists reproduce and study certain viruses, proteins and cell organelles – the components of cells.

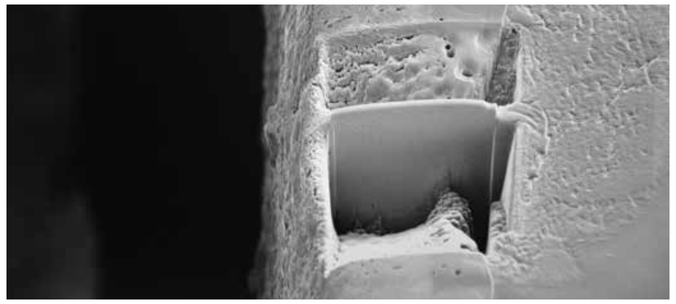
There are basically two types of electron microscopes: the scanning electron microscope (SEM) and the transmission electron microscope (TEM). To put it simply, the TEM shines through a very thin object, like an X-ray device. Here, the electrons that get through produce an image. Alternatively, for thicker samples, the electron beam is scanned over the surface and excites it to throw back electrons itself, as is the case with a SEM. These are detected and used to visualise the surface. The latter procedure can also be carried out with heavy gallium ions. However, this has its price: it slightly alters the surface.

Although the FIB microscope can also be used on its own, it has a lower resolution than the TEM. It provides two options: in addition to the ion beam, SEM electron columns are installed in most FIB microscopes, allowing the material to be processed and observed at the same time. Gallium ions can also be used analogously to electrons to visualise a surface.

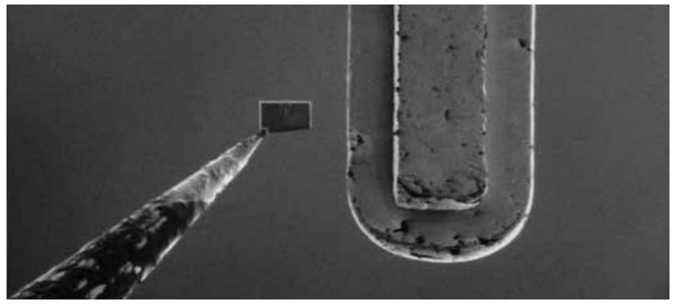
The ions originate from a liquid gallium source. They are accelerated and focused using electrostatic fields. The ions travel to the sample in a high vacuum. The chamber contains a billion times fewer atoms than a space of similar size in a laboratory, and the column sometimes even 10 trillion times fewer. In other words, Alexander Gerst would have an easier time chasing oxygen atoms on the exterior of the International Space Station.

Cutting out lamellae for the TEM is a task that requires precision from both the device and its operator. "Although it is actually a routine job, each step must be performed with precision and concentration," says Frederic Kreps, operator of the FIB microscope at the DLR Institute of Materials Research in Cologne. "If you skip a step or fail to do something exactly right, you will have to repeat hours of work."

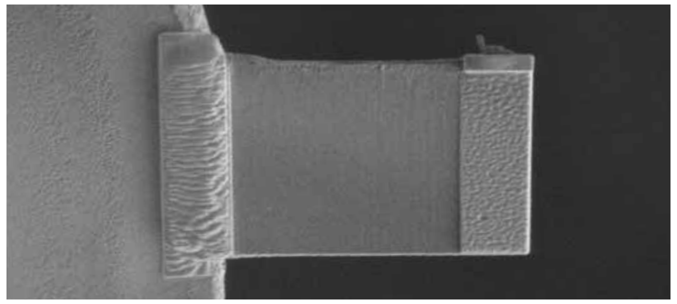
The maximum sample thickness for a TEM analysis is 200 nanometres, or 0.0002 millimetres. To obtain such thin samples, lamellae are prepared using the ion beam. To create a lamella, one must first cut a 'slice' out from a large sample. This slice may have dimensions of around 0.005 x 0.01 x 0.0001 millimetres. If this lamella is removed too quickly, electrostatic effects can hurl it into the vacuum chamber. Therefore, the operator removes all of its connections to the sample, except one, and then introduces a tiny, fine needle. Through the electron microscope, it looks like an oversized insect leg, but it is actually 10 times thinner than a single human hair, and measures around one to two micrometres at the tip. This touches the lamella and is attached to it with platinum. The platinum is diffused over the spot in a gaseous compound and is then irradiated with ions. If one of the ions collides with a molecule in the platinum compound, it dissolves, so the platinum remains attached to the surface beneath. The final connection between the sample and the lamella is then cut. At this point, the lamella is so small that it is no longer visible to the naked eye. The operator then fixes the lamella to the 40-micrometre grid extension – which acts as a kind of slide for the TEM – where it is thinned out layer by layer.



A thin slice, the lamella, is cut out of a sample. At the bottom of the lamella, material can be seen that was left behind when cutting. It consists of other insulating elements, that have deflected the ion beam.



The operator guides the lamella to the micro slide using a needle. It is mounted to it with platinum and then prepared for examination in a transmission electron microscope.



Once the lamella is placed on the slide, the operator starts to thin it. At this point, it is already so small that it can no longer be perceived by the human eye.

THE FOCUSED ION BEAM MICROSCOPE

Name	Dual-beam type FEI Helios 600i
Cost	approximately 1 million euro
Resolution of the Tomahawk ion column	2.5 nanometres at 30 kV
Resolution of the integrated scanning electron microscope	0.8 nanometres at 1 keV
	The gas injection systems (GIS) can inject platinum, tungsten and carbon into compounds.

Basis for three-dimensional representations

In addition to cutting lamellae, the FIB microscope can also be used for many other applications. One example is the creation of three-dimensional models of samples. With the ion beam, it is possible to cut samples into slices, like a loaf of bread, and view each cross-section with the built-in electron microscope. Using software, these images are then combined to generate a 3D model of the material in question.

Although the FIB microscope is a high-tech device, such work is also something of a craft. The operator must be experienced, have attention to detail, and master an array of tricks. To take the removed material as one example, just as when a file is used, such material does not simply disappear, but remains. In the FIB microscope, it may even settle again. "If you do not pay heed to this, you may find that a sample is thinned out on one side, while the material gathers again on another side and the sample hardly gets any thinner. It is like a man digging a ditch and throwing the soil back into the dug area behind him," Kreps says to explain the principle. The very fact that the work has an element of craftsmanship means that there is never complete certainty that everything will work straight away. "For complicated materials, it can take several attempts," Kreps says. This does not present any risk to the material samples, as the lamellae are so small that thousands of them can be cut from a single sample – even if it has a size of just one millimetre.

Operator Frederic Kreps in front of the FIB, as it is referred to at the DLR Institute of Materials Research.

PLENTY OF EXPERIENCE AND SOME INTUITION

A morning of handling delicate material with the FIB microscope

At over 33 degrees Celsius, it is one of the hottest days of summer. Hardly anyone is braving the outdoors unless it is in an air-conditioned car. In Cologne, a few DLR employees can be seen flitting from the shade of one tree to the next. But in the temperature-controlled laboratory of the Institute of Materials Research – home to the Focused Ion Beam (FIB) microscope – it is cold. Frederic Kreps is sitting at the microscope computer, which he uses to control the device. He wants to cut a lamella out of a sample for a transmission electron microscope (TEM) study conducted by one of his colleagues.

"The material is delicate," Kreps says. The sample of a thermal barrier coating that is electrically insulating is in the microscope's vacuum chamber. "The longer I shoot the material with charged particles, the more charged it becomes. Conductive samples transfer their charge to the platform to which they are mounted. Insulating samples retain it." As a result, the charged sample builds up its own electrostatic field and can deflect the ion beam. "If you're not aware of that, you could spend minutes shooting the ion beam at a particular spot without anything happening," Kreps explains.

Kreps releases a small lamella from the sample. He positions the needle on the lamella and begins to fasten it with platinum. There are gentle clicking and hissing sounds as the gas injection systems approach the lamella and release the platinum compound. The image on the computer screen updates every 30 seconds, allowing Kreps to observe the platinum layer becoming thicker over the course of several minutes. He then removes the last connection between the lamella and the sample, before mounting the lamella on the micro slide. The operator must keep a constant eye on the tension within the sample. If the lamella breaks free from its platinum fixings for any reason, it will be lost. "The electrostatic charge will then fling the lamella into the vacuum chamber," Kreps says. As soon as the lamella is attached to the grid and the needle is withdrawn, the operator thins it out, removing material layer by layer. Once again, the tension in the sample is crucial: "Sometimes layers expand in different ways. If you take these away piece by piece, the lamella may bend, which would render it useless," Kreps says. But it is impossible to predict exactly when something like this will happen. The final step is to polish the lamella. Using a fine ion beam, he removes the traces left by the stronger beam. Again, there are distinct echoes of a craftsman, cleaning and polishing the finished piece one last time before presenting it to his customer – only here it is much, much smaller.

THE PALACE OF HORSEPOWER

Journey through time at the Dresden Transport Museum

By Cordula Tegen

The Hillman story. It could be made into a movie, maybe even a road movie. Hillman is an England-native who gets lost in East Germany in the 1960s. His noble countenance does not go unnoticed on the street. Hillman's middle name is Minx, his heart a four-stroke engine. In the autumn of 1960, a doctor from Thuringia took delivery of this remarkable vehicle. Doctors belonged to one of those professions that were considered vital to retain in East Germany, so there had to be some perks along the way. One of these was the sedan built in Coventry, England, with its 1500 cubic centimetre engine and 55 horsepower.

For 23 years, the Hillman carried its owner all over Thuringia, and occasionally to the Baltic Sea or into the friendly neighbouring country, the Czechoslovak Socialist Republic, or CSSR. That was about as far as it went. When the doctor passed away, his widow divested herself of the Hillman. The driver who bought it in 1989 took it on a trip to Czechoslovakia. But his ultimate goal was further west; he crossed the border into the Federal Republic of Germany. His 'getaway' car would not accompany him further. Having now attained the venerable status of a vintage car, it found its way to Ahlen, where a Westphalian car enthusiast offered the rare model to Thomas Giesel, at that time the curator of the Dresden Transport Museum. He accepted and oversaw the transportation of the historic vehicle with the intriguing story all the way from Ahlen to Dresden on a trailer.

The car's technical features were standard for models manufactured from the 1930s to the 1950s, but it was still too early for it to go into complete retirement. Various Dresden-based tradesmen took it upon themselves to track down spare parts with some dogged sleuthing and to restore it to its former glory. By 2014, the vehicle was a veritable showpiece, boasting red leather seats, a column gear shift and the handbrake repositioned on the left-hand side. And then, the Hillman Minx cruised off on another great adventure: the three-day Sachsen Classic vintage car rally.

And it was not its last. The finely polished Hillman can be admired all year round as part of the permanent exhibition at the Dresden Transport Museum. And in the late summer, it demonstrates that it is more than just a showpiece. Indeed, it is still up to bagging a place midway up the rankings. The 2018 Sachsen Classic, held from 23 to 25 August, followed a route from Zwickau to Karlovy Vary in the Czech Republic and back again. Crossing borders still seems to be the Hillman's thing. It then returned to its podium at the Museum, looking so majestic that one is tempted to bow to it – and watch a film about its adventurous story.

The man who sniffed out that story knows of many such tales. Benjamin Otto is Head of Exhibitions at the Dresden Transport Museum. He points out the Baker Electric car, which came from Canada. It is notable for its sophisticated navy-blue paintwork, golden headlamps and trims. But what makes it truly remarkable is that this 1910-built car was powered by electricity. It was easier to operate than cars with a combustion engine, which needed to be cranked in order to start. Combined with its exhaust-free, quiet driving, this made it very popular. This was a time when – believe it or not – almost a third of all cars were electrically powered.

The penny-farthing, however, was propelled by muscle power alone. Try out this late 19th-century bicycle (indeed, you are expressly encouraged to do so) and you will find it rather awkward. According to Benjamin Otto, "In all likelihood, unfortunate cyclists would have occasionally broken an arm or leg while using it. It is no wonder that this type of bicycle was not around for long."

FROM STABLES TO A MUSEUM FOR TODAY'S MOBILE WORLD

In the beginning, it was all about the horse. Anyone who did not fancy walking had to travel on horseback. The Saxon dukes went in for horses in a big way, but their castle in Dresden lacked suitable stables for their mounts, so a stable complex was built at their behest in 1586. This was followed by an armoury, and soon an art collection, which acquired a museum-like character over time. This building became Dresden's first museum (one of more than 50 museums in the city today). In 1876, the stables were renamed the Johanneum in honour of the art-loving King Johann. The building still bears the name to this day, although it is better known as the Transport Museum. In the 19th century, the collections became dominated by technical equipment, as the railway was now on the scene.

Different vehicles began appearing in the newly founded GDR, as the railway was followed by cars and two-wheelers, and soon aircraft and boats. The country needed engineers, and the building acquired an educational function, with the GDR Ministry of Transport moving into the premises. After the ministry was dissolved, the people of Dresden raised awareness about the now splendid collection through car shows and a petition. The Johanneum was refurbished in 2008. Today, the Dresden Transport Museum welcomes more than 200,000 visitors every year. The magnificent building boasts 413,500 exhibits and over 30 collections. In addition, the museum has a packed programme of educational events, comprising guided tours, children's birthday parties, Bobby Car driving licences and workshops. It conducted more than 700 guided tours in 2016.

The Hillman story in the magazine Oldtimermarkt (2/2016)

A 1960s beauty: the Hillman Minx from Coventry, England.

All images: Verkehrsmuseum Dresden

One room further on, in the Railway Hall, visitors are bound to feel rather small when looking up at the Muldenthal steam locomotive. Dating back to 1861, it is the oldest fully preserved German steam locomotive. It was the first major exhibit at the Transport Museum, which was founded just after World War II. The railway itself plays an important part here, as it provided the infrastructure for the post-war history of the museum. The remains of the Saxony Railway Museum served as the premises for the present-day Transport Museum, which opened on 1 May 1952. Four years later, it held its first exhibition, '120 years of Transport History in Saxony,' at the Johanneum building, which had been heavily damaged by the air raids on Dresden in 1945. A shipping exhibition followed in 1959.

Today, this museum is home to almost everything about transport: an early motorcycle and a winged airship; a horse-driven streetcar and coastal rescue boat; a suspension railway and the first monoplane; a rail zeppelin and Lilienthal's glider; a jet engine and an aluminium aircraft. And, of course, a transport collection in Saxony would not be complete without the iconic Trabant. While the sky-blue model on display here (built 1971) still had a two-stroke engine when it was found in a garage, having been used for parts, an attempt was made to fit these quintessentially East German cars with four-stroke VW engines in the 1980s. Spare parts were like another type of currency; you could exchange them for almost anything. Given that this car was ubiquitous for decades, you were bound to need them sooner or later. A Wartburg 1.3 from 1988 is on display on the level above the Trabant. Its built-in VW engine made it 'modern', if only for a fleeting moment.


The oldest completely preserved German locomotive: Muldenthal, 1861, Chemnitz.

Murder on the Orient Express and magnificent men in flying machines

Some of the most fascinating vehicles in terms of engineering are supplemented by images of historical people or by contemporary interiors. Take a look inside the court salon carriage of Princess Mathilde of Saxony, complete with a stove, armchair and vanity, and you will feel as though you have been whisked back in time to the first half of the 19th century. It is reminiscent of the Orient Express, the train on which detective Hercule Poirot investigates a murder in Agatha Christie's 1934 novel.

Peer through the carriage windows to the level above: the aircraft exhibition on the next floor features Hans Grade's monoplane, built in 1909. With its fabric-covered bamboo wings, this fragile aircraft is reminiscent of the flight competition from the 1965 British film 'Those Magnificent Men in Their Flying Machines'. In real life, however, the history of aviation also featured women, who were more than a match for the men when it comes to courage. Hélène Dutrieu was one example. In 1910, at the age of 33, she became the first Belgian woman to be granted a pilot's licence. She had to have airworthy clothing suitable made specially for her. Dutrieu's aviator suit, which was created by a fashion house in Paris, is also showcased; in this case, functionality trumped even Parisian chic.

Glance up again: in addition to Grade's monoplane, a hot-air balloon and a zeppelin, a Super Aero 45 'flies' above the hall, resting on two columns. This plane, made of metal and plastic and dating back to 1954, was among the first aircraft to be used in the GDR. Developed and built in the Czech town of Kunovice, the Super Aero DM-SGE was used until 1964, first for sightseeing and feeder flights, and later as an air force liaison aircraft. However, mainstream use was simply unthinkable, given that there was only space for two or three passengers.

IN THE FUTURE LAB: HAVE A GO AT DESIGNING URBAN TRANSPORT

How will humans get around in future? You can look for and find the answer in the 'Future Lab'. The lab was created by the Transport Museum in conjunction with Dresden University of Applied Sciences to accompany the road transport exhibition 'Right of Way'. It is an interactive digital knowledge station. An enormous interactive scene on the wall can be changed at the touch of a screen. This allows the user to 'recreate' buildings, increase the number of green spaces, add in cycle paths or two-lane roads, and observe how their use of specific means of transport affects traffic events. What is more, users can digitally draw their own futuristic vehicle and drive it around the cityscape. Experts (including figures from the car industry, the ADFC, the ADAC, Dresden University of Technology and local public-transport companies) can also be encountered 'on the road', where they provide soundbites about future mobility at a click.


Exhibition Director and Curator Benjamin Otto shows how it works: create your own car and shape the traffic in your future city.

Small and unprofitable: Super Aero 45, 1954, Kunovice.


All manner of equipment, from driving …

Tell me how you get around, and I will tell you who you are

Describing the Dresden Transport Museum as a technical collection would be only to tell half the story. "The question that we are always asking ourselves is: how does technology change people's lives?" says Director Joachim Breuninger. As such, the charm of the exhibits often lies in the detail: a worn-out ticket or an old timetable; a scenic or jokey postcard; a road sign or badge; a payment token or uniform. A driver's licence, a ticket collector's bag, a suitcase or crockery bearing the emblem of a transport company all have the power to bring the everyday transport of the past to life. "These exhibits show how people's lives changed due to the many vehicles that were travelling on the streets," Breuninger says.

Among the oldest items in the collection of railway timetables is a publication from 1848. It shows the rail and steamboat connections from Copenhagen to Vienna, including hotel advertisements and travel guide tips from the time of the March Revolution in Germany. Yet after the attempt to create a unified German nation-state failed, the dream of establishing free trade and abolishing the restrictive customs policies enforced by the principalities soon came to an end.

In the wake of World War II, various documents became indispensable for everyday life, and not just for buying food. Emma Mammitzsch from the Zschachwitz area of Dresden had to present a 'green bicycle statement' for her second-hand Saxony-brand bicycle. Only when she also presented her certificate of employment was her bike confirmed to be 'exempt from confiscation' – in German and Russian, of course. The exhibition also includes an original postcard of the Trabant 601, built in 1989, featuring the two-stroke engine from different angles. Today, the vehicle still has its first post-reunification registration plate. It belongs to the collection held by the Friends of the IFA, based in Zschopau, Saxony. Instead of the standard greetings, the postcard features affectionate nicknames for the little runaround, such as 'Zwickau slope goat', 'racing cardboard', 'asphalt bubble' and 'escape suitcase'. Indeed, very few of those who managed to cross over to the West would have done so in a Hillman Minx.

The 'escape suitcase' and the Hillman remained faithful to their homeland to the very end. Today, they are telling their story to the next generation.


… to flying …


… and sailing …

DRESDEN TRANSPORT MUSEUM

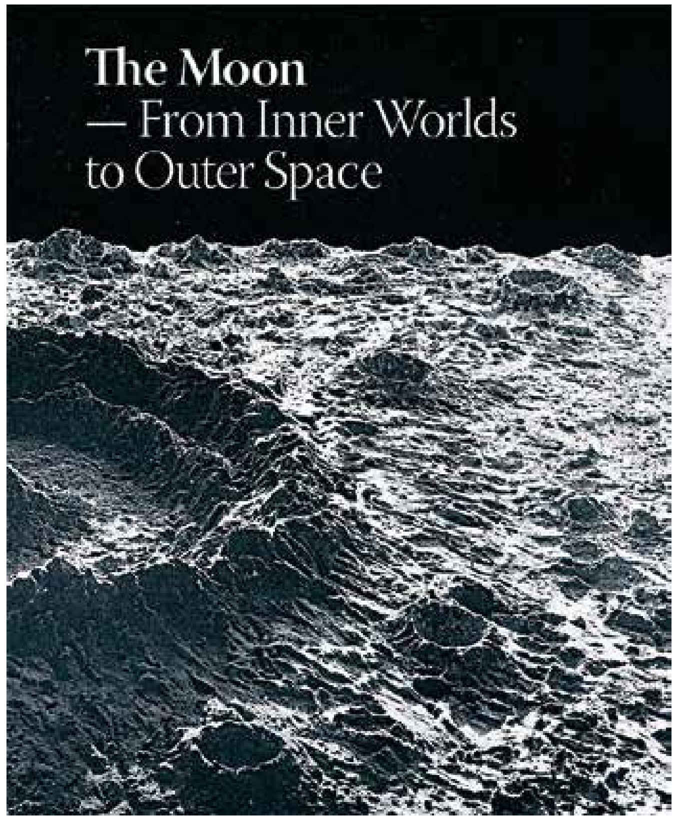
In the Johanneum on Neumarkt

Opening times:
Tuesday to Sunday: 10 to 18h

Entrance fees:
Free for children up to 5 years of age, Adults: 9 euro, Concessions: 4 euro
Small family pass (max. 1 adult accompanying at least 1 child and max. 2 children aged up to 16): 9 euro
Large family pass (max. 2 adults accompanying at least 1 child and max. 4 children aged up to 16): 18 euro
Annual pass: 30 euro, concessions: 14 euro

Special programmes, tours and events:
www.verkehrsmuseum-dresden.de/en

THE MOON – FROM INNER WORLDS TO OUTER SPACE



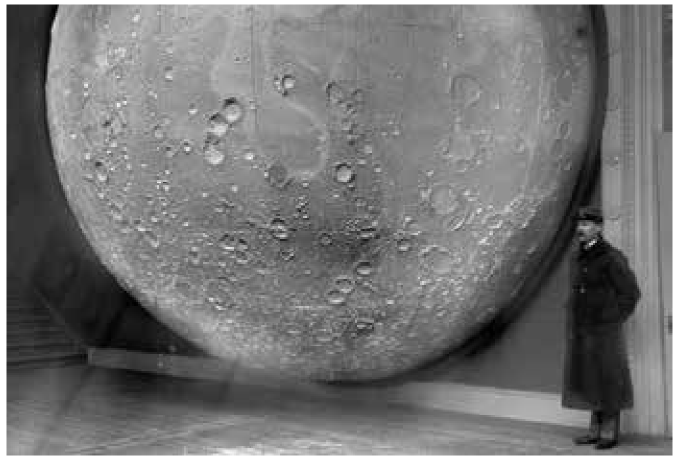
The beautifully crafted catalogue that accompanies **The Moon: from Inner Worlds to Outer Space** exhibition paints a multi-faceted portrait of humankind's fascination with the Moon. It takes the reader on a journey from the first neolithic ceramics to be decorated with crescents through to Galileo Galilei's watercolour drawings of the phases of the Moon, and from there to the first known photograph of the Moon, the Apollo 11 Moon landing in 1969, and contemporary engagement with the Moon and space.

Marie Laurberg, the curator of the exhibition, wrote the first of four background articles included in the catalogue. She introduces various Romantic painters, who saw an opportunity to contemplate sublime nature through the lens of the Moon and the ephemeral nature of moonlight. Laurberg also discusses the rise of scientific interest in the Moon, inspiring detailed maps of the lunar surface in the 1800s, and how several modern artists have engaged with the relationship between man and Moon. In the second article, US astronomer E.C. Krupp dives into ancient depictions of the lunar crescent, as symbolic representations and as embodied in gods and goddesses.

Researcher and writer Stephen Petersen describes how during the 1960s, when the 'space race' was in full swing, artists sough to participate in the space enterprise in their own way. For instance, Fabio Mauri set up an installation called 'Luna' in 1968, in which visitors were guided into a simulated lunar environment (a room with black walls and a foot-deep layer of white styrofoam pellets). Astrophysicist Anja C. Andersen, professor at the University of Copenhagen introduces the reader to some of the logistical difficulties of walking on the lunar surface. She also explains how lunar dust and rock samples have helped to develop theories on the age and genesis of the Moon and the Solar System. The catalogue also includes a number of poems about the Moon (by Sappho, Percy Bysshe Shelley, Sylvia Plath and D.H. Lawrence, among others) and Italo Calvino's 'The Distance of the Moon'.

Although the catalogue makes for an excellent read in its own right, it is also certainly set up to tempt the reader into visiting the exhibition. For instance, only about 60 percent of the exhibition pieces are included in the catalogue, and even less are discussed in the text. An appetiser, if you will. Also, although the reproductions of the artworks are a decent quality, they are of course still best experienced in person.

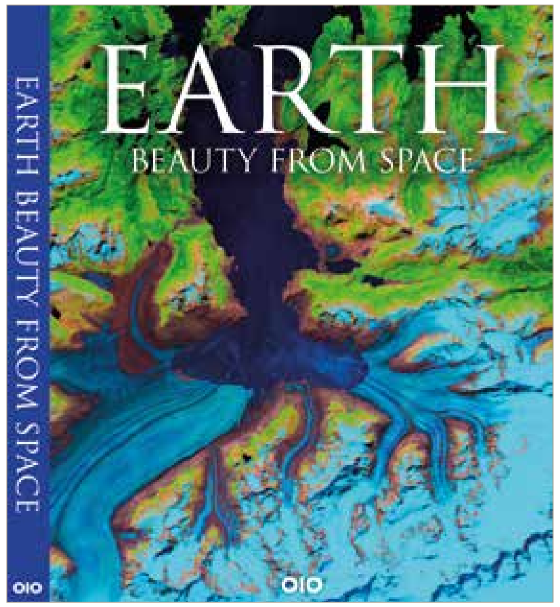
For example, Laurberg describes an installation by contemporary artist Katie Paterson, in which Ludwig van Beethoven's famous 'Moonlight Sonata' is transmitted to the moon in Morse code and reflected back to Earth. The returning piece of music, incomplete because certain parts have disappeared into the Moon's craters, is then played on a grand piano. Camille Henrot's 'October 2015 Horoscope' installation, which features the changing cycles of the Moon rotating in a circular motion over a series of small figurines (described, interestingly, as palpable existential absurdity) can surely only be properly experienced by walking around it. The exhibition also includes Rosa Barba's 'The Colour Out of Space' from the same year, in which images of the Moon, stars and planets (courtesy of the Hirsch Observatory) are projected through discs of discoloured glass. The accompanying soundtrack features observations on the endlessness of the Universe by researchers, artists and writers.



A personal favourite is catalogue entry 61: Leopold Galluzo's illustrations for a series of articles published in a New York newspaper called The Sun in 1835. The prints depict curiously winged humanoid creatures and unicorns living on the Moon, allegedly discovered by British astronomer Sir John Herschel. Just weeks later, the story was discovered to be false; it went down in history as the 'Great Moon Hoax.' Other highlights include Charles Delagrave's European Celestial globe from 1878, Galina Balashova's designs for the Soyuz Orbital Module (1964), the first picture of Earth from the Moon by the Lunar Orbiter I (1966), a Lunar meteorite sample of unknown date and 3D printed plans for lunar settlements. In whichever way you are interested in the Moon, you are sure to find something fascinating to challenge and broaden your understanding in this excellent exhibition and its accompanying catalogue.

Merel Groentjes

BEAUTY FOR ITS OWN SAKE

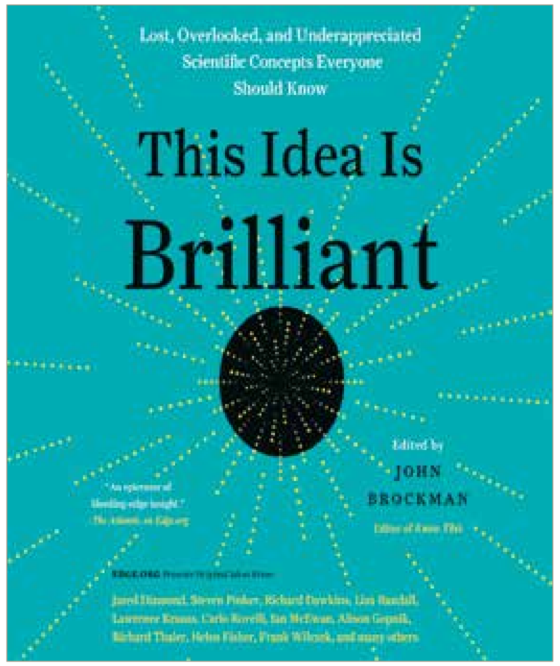


'NASA is the world's best photographer,' reads the last page of the picture book **Earth: Beauty from Space** (oio Books). Over the course of 160 pages, publisher Robert Gabor presents the Earth as it can only be seen from space. He adhered to strict selection criteria when putting it together: the landscapes, which are uniquely captured from the satellites Terra, Landsat 5, Landsat 7, EO-1 and Aqua, appear beautiful, vibrantly coloured and replete with striking geographical features.

The 'Land of Terror' – the Tanezrouft Basin in Algeria – looks like a palette on which different paints have run together. The Okavango Delta appears patterned dark and light green, while the Erongo Mountains seem to consist of dark red and yellow splashes. Each picture is accompanied by a small map of the world that allows the reader to pinpoint the region, as well as a few sentences about the place, and the date on which the picture was taken. Robert Gabor relies solely on his own eye and assessment of the visual impact of the 62 NASA images. The back cover text simply states that NASA cameras were used, and explains the novel colouration process made the picture book possible. Explanations of why certain colours are to be seen and details including the satellite from which image was taken are not given in the book. The foreword by the NASA Science Mission Directorate underlines this pared-back approach: 'These images are not intended so much for scientific interpretation, as to be enjoyed primarily for their beauty'. As such, Earth: Beauty from Space is more of an artistic picture book, and one would be unlikely to quiz a human artist as to how exactly he or she had managed to create such an exquisite combination of colours.

Manuela Braun

THIS IDEA IS BRILLIANT



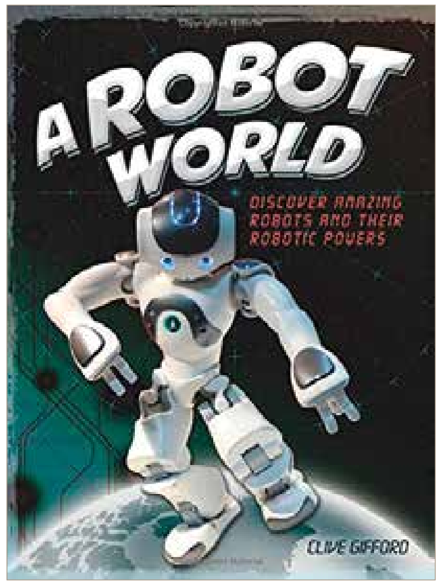
Natural Selection, DNA, Anthropocene, Matter, the Big Bang, Networks, the Scientific Method... These are just some of many terms we hear on a daily basis. But, what scientific term or concept ought to be more widely known? This is precisely the question that John Brockman, publisher of Edge.org, presents in **This Idea is Brilliant**. He poses this question to over 200 experts in their own field - from physicists to philosophers, through to biologists, novelists and even artists.

The book is a large collection of very well-written, concise 2-5 page essays on a variety of topics, including lost, overlooked and underappreciated scientific concepts. Brockmann aims to give the reader a broader view of science as a whole and bring more scientific ideas into general culture. By cutting across many scientific fields, this book can only enrich every mind. The many contributors include Richard Dawkins on using animals' 'Genetic Book of the Dead' to reconstruct ecological history, Yuri Milner on the longevity factor and Ian McEwan on Navier-Stokes Equations.

Once you are done reading, you are sure to ask yourself the question: which of these ought to be more widely known?

Paul Schilperoord

ROBOTS, ROBOTS EVERYWHERE!

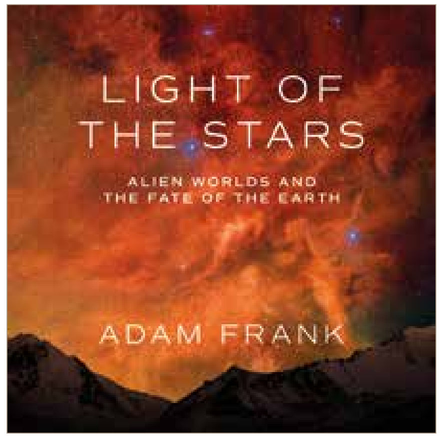


Robots, robots, robots. They are no longer science fiction, but a true part of our daily lives. We have them at home, we can find them in hospitals, and they even help us to explore space. They take on a myriad of forms and their uses are plenty. Do you want to find out more?

A Robot World: Discover Amazing Robots and their Robotic Powers is an illustrated children's book on the ever-growing and fascinating topic of robots. Author Clive Gifford is experienced in the field of youth books, having written many such books on a variety of subjects. Each double-page spread of A Robot World is structured as a kind of infographic with colourful backgrounds and pictures of the 'bots at hand, combined with short descriptions of their components, history and applications in eye-catching textboxes. Every such 'infographic' touches a different subject, including the origins of robots, the marvels of underwater robotics and the Curiosity Mars rover. The book contains 30 such double-pages, which although short, are enough to inform the reader about the basics of robotics. At the back there is a glossary of some of the more difficult words and concepts encountered in the book. It also includes a list of books and websites for further reading. All in all though, the book is a great read for kids around the age of eight to 12, supplying them with enough cool robot facts to annoy their parents for days – they might ask for a robot or insist on becoming a robotics engineer. On a more serious note, the book is a good and fair-priced addition to school or home libraries on the usually complicated subject of robotics.

Ruben Walen

WHERE DO WE STAND?



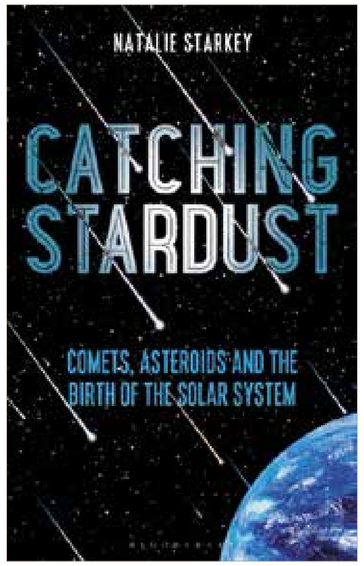
Did you know? There are about 300 billion stars in our galaxy, The Milky Way, alone. If just 10 percent of these have planets, Earth is just one of approximately 30 billion. This means that alien civilisations could exist or have existed – and also that many of them may have driven their own worlds into dangerous eras of change. The big question is: what can this tell us about humankind's fate on Earth, threatened by the growing challenge of climate change? That is exactly what astrophysicist Adam Frank focuses on in **Light of the Stars: Alien Worlds and the Fate of the Earth**.

This thought-provoking book is filled with the inspiring work of, among others, scientists like Frank Drake and Carl Sagan, pioneers of the modern science of astrobiology. With great clarity, Frank illustrates how we can learn from other planets – for example, dust storms on Mars and Venus' greenhouse effect – to broaden our understanding of our planet and our relationship to it. He looks back at humankind's growing awareness of its impact on the habitability of Earth. More importantly, he stresses the fact that, to ensure our survival, we need to manage our own planet and resources intelligently. To be successful as a civilisation, Frank argues, we need to keep looking to the stars.

All in all, this is a great read! The book is very elegantly written and clearly presented. Frank's arguments are compelling and his conclusions powerful. The book is certain to make you think about your place in the Universe.

Paul Schilperoord

CATCHING STARDUST!



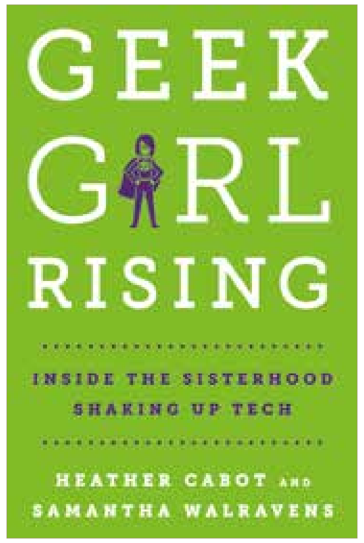
Ceres, Vesta, Ryugu, 67P/Churyumov-Gerasimenko. These are among the oldest inhabitants of the Solar System. Until now, we have been able to study these objects from Earth, from orbit, directly on the surface, and we have even followed a comet – 67P – as it approached the Sun. But why study them? Bodies like these – comets and asteroids – are a treasure trove of information for deciphering the events at play during the formation of our planetary system.

Catching Stardust: Comets, Asteroids and the Birth of the Solar System, by Natalie Starkey is an enjoyable and accessible story of our Solar System. Its clear narrative makes it a great read for anyone. And for those needing a bit of extra help, the book includes a glossary with some commonly used astronomical terms.

How did we come to be, what lies out there, what might await us – and what can we do about it? These are some of the topics that Starkey addresses. She explains the importance of water for life and introduces missions to asteroids, such as the European Rosetta mission and NASA's Stardust mission, and makes a very strong case for the importance of these types of missions to better understand our own planet.

Karin Ranero Celius

GIRLS ON THE RISE



Geek girl rising. Inside the sisterhood shaking up tech by award-winning journalists Heather Cabot and Samantha Walravens is a must-read for every young girl out there wanting to get actively involved in technology and to those with ideas of their own that dream of starting their own company in what is still a male-dominated tech world.

The book introduces us to some extraordinary women innovators and on how they were able to take part and succeed in technology each in their own way. The inspiring stories about these pioneers prove that success is possible in the fast-moving innovation economy.

What is certain is that we still have a long way to go. But books like 'Geek girl rising' will surely encourage women to delve into their potential and find capital to start their own business. And even better, it might inspire girls to choose a career in science and technology.

Dirma van Eck

RECOMMENDED

FROZEN FOR A YEAR
https://youtu.be/69OsRXEO7y4
History's biggest Artic expedition will start in autumn 2019: The crew of the RV Polarstern will freeze the German research vessel at the North Pole and drift through the Arctic, propelled by the movement of the ice. The image film and website at www.mosaicobservatory.org show which challenges lie in wait for the approximately 12-month mission and what the MOSAiC expedition hopes to achieve.

STRAIGHT FROM MARS
twitter.com/NASAInsight
The NASA InSight mission will soon be exploring the Martian surface. On board is DLR's HP^3 - aka, the Mole. Follow @NASAInsight on twitter for the latest news on the probe's arrival on Mars and its investigation of the Red Planet directly from the surface.

WILD RIDE BACK TO EARTH
https://youtu.be/-l7MM9yoxII
"Landing feels like a head-on collision …", says Paolo Nespoli. An ESA video gives astronauts who have returned to Earth on a Soyuz capsule a chance to speak their minds. They talk about precisely what happens on the return journey and how the crew prepares for the task.

ISS PANORAMA LIVE
http://t1p.de/r9q3
Enjoying the sunrise from the ISS, eavesdropping on the astronauts' radio transmissions with Earth and sharing the excitement of spacewalks – the ISS HD Live app offers all of these things. Anyone keen to stay on the ball can enable push notifications to learn the times of the next sunrise or use the app's positioning monitor to search for the ISS in the night sky.

FLYING SPARKS
vimeo.com/88093956
Like fireflies dancing and slowly gathering at a single point – that's what Europe looks like day for day. At least in the eyes of NATS Holding, the largest service provider for air traffic control in Great Britain. The company released a time lapse animation in which the movements of every single aircraft traversing European airspace in 24 hours is shown as a glimmering dot.

DLR in video
youtube.com/DLRde
What is DLR up to? What are the scientists working on? Take a look behind the scenes of DLR's work and find out about the cutting-edge science and missions – from the MASCOT landing through to experiments as part of ESA astronaut Alexander Gerst's horizons mission.

About DLR

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

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

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Cover image
The Japanese Hayabusa2 space probe photographed the asteroid Ryugu in search of a landing site for MASCOT from an altitude of six kilometres. The German-French lander, developed and built by DLR, separated from Hayabusa2 on 3 October 2018 and reached the surface of Ryugu after six minutes of free fall. The four experiments were performed for approximately 17 hours.

Image: JAXA/U Tokyo/Kochi U/Rikkyo U/Nagoya U/Chiba Inst Tech/Meiji U/U Aizu/AIST

DLR
Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

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