DLR magazine

of DLR, the German Aerospace Center · No. 162 · October 2019

SHARING THE SKY

ENSURING SAFETY IN A CHANGING AIRSPACE

More topics:

EYES ON THE CLOUDS

SELF-DIAGNOSIS DURING OPERATION

About DLR

DLR is the Federal Republic of Germany's research centre for aeronautics and space. The organisation also completes research in the areas of energy, transport, security and digitalisation. Acting on behalf of the federal government, the DLR Space Administration designs and implements Germany's space programme, together with national and international partners. DLR is also the umbrella organisation for two project management agencies that promote research.

DLR has approximately 8600 employees at 27 locations in Germany. It also has international offices in Brussels, Paris, Tokyo and Washington D.C.

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EDITORIAL

WEBSITE RELAUNCH – REDISCOVER DLR.DE

For Andrea Haag, summer 2019 was a particularly demanding time, but the leader of the DLR website relaunch project proved to be a true all-rounder. The portal manager (whom her colleagues in DLR Information and Communication Technology and their contracting partners will still know by the name of Andrea Schaub) analysed, conceived, planned, conducted training, made telephone calls, supervised, moderated, calculated and presented, and eventually she and her team reached the longed-for finish line when the new DLR website went online, with a completely new editorial system. Together with the design concept, which allows the responsive website to be explored with ease on the go via mobile phone or tablet, the team's pride and joy is the optimised search function. This uses artificial intelligence techniques to automatically assign DLR articles to the research pages for aeronautics, space, energy, transport, digitalisation or security. The ingenious filter concept gives visitors a better user experience, while making the job of DLR editors much easier. For more than two years, the interdisciplinary relaunch team has been filling the new formats with interesting content. DLR's diverse activities are now presented within a new virtual setting featuring interactive fact boxes, mission pages, brief profiles of all 47 DLR institutes and facilities, and collections of thematic content about the more than 140 DLR large-scale facilities in the form of dossiers and overview pages.

Also new this autumn is the project leader's surname. This was not planned at the start of the website relaunch project, but perhaps it gave her a bit of inspiration? Congratulations!

Dear reader,

Autumn brings with it many new things. Before the 2019/20 training year got under way, we met up with Thomas and Thomas, two excellent instructors in the truest sense of the word, at the DLR site in Stuttgart. They are well aware of the value of experience, pedagogical skill and state-of-the-art equipment. As they see it, it is important not only to master the technical aspects of your work, but also to really enjoy it. During autumn 2019, we will be hearing about the seven new DLR institutes. The process of establishing them has only just begun. A double-page overview in this magazine reveals where they are located and what their researchers will be working on.

Also new is the Virtual Product House in Bremen. There, DLR's aeronautics researchers have settled in at the ECOMAT, where they are immediately next door to their industry partners. Together, they can work to make their vision a reality – introducing a new aircraft design without the usual, time-consuming testing. They are preparing the way for virtual certification using simulations on high-performance computers.

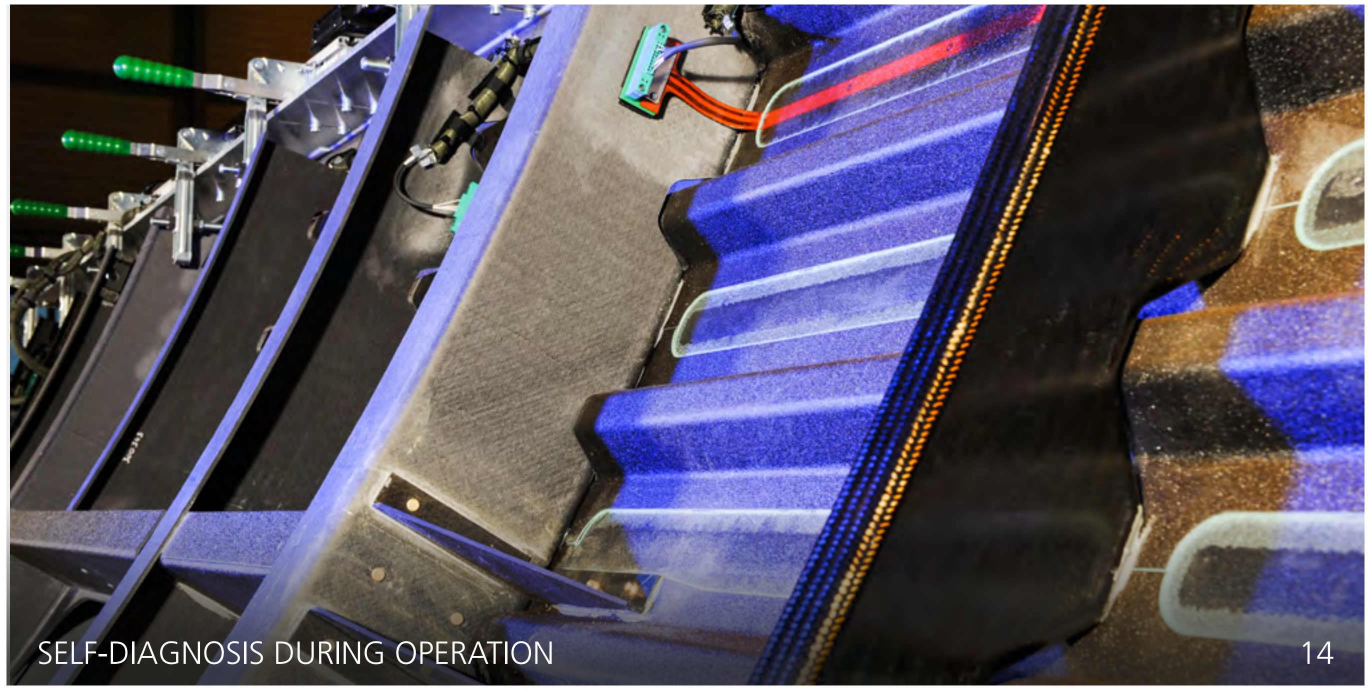
A new mindset is also required when investigating unmanned flight or automated driving. Ensuring safety is a challenging and highly complex issue, but DLR staff from the fields of air traffic management and road transport research are seeking answers.

Anyone reading the DLRmagazine online these days will find themselves on the new DLR website. It features a modern design concept and numerous different formats, including dossiers and themed galleries. It also has its share of new technology, not least the optimised search function, which is supported by a thesaurus specially developed for DLR. Planning, designing and creating the new internet portal for DLR, with its 8600 employees across 47 different institutes and facilities, was a colossal undertaking. Take a look at DLR.de to see how well the team has succeeded.

And, last but not least, the DLRmagazine also has a colourful new look of its own. Let us know what you think about it by writing to **Magazin@DLR.de**

Here's to many more new discoveries this autumn!

Your Magazine editorial team



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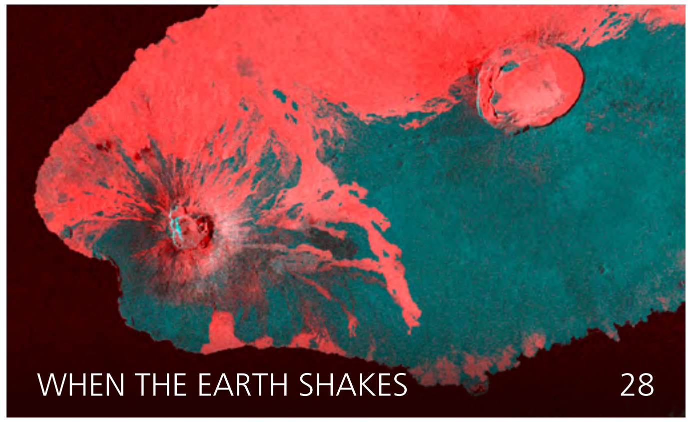

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QUANTUM LEAP

By Robert Axmann

Robert Axmann is Head of DLR Programme Strategy Space

Quantum technologies have been the subject of intense discussion amongst researchers over the last several years. It would seem that a new field of study has emerged. Yet the use of quantum effects – that is, the phenomenon of the superposition of states in the world of atoms, photons and electrons – is not a new area of research. Many decades ago, the development and use of lasers led to applications that have now found their way into numerous areas of life – just think of laser scalpels, microscopes and scales, or laser shows. In the meantime, research has also opened up possibilities for the targeted control and manipulation of single quantum states. This is associated with the term second-generation quantum technologies. New fields of research are emerging for DLR – quantum sensor technology, quantum metrology and quantum communications. These are particularly relevant for the research conducted at DLR. The expectations for such technologies are high. In the field of sensor technology, for example, researchers anticipate significantly improved measurement precision.

DLR is already conducting research in this area. It is currently developing an optical atomic clock that promises even greater timekeeping accuracy. This option is of great interest, not only for satellite technology. We are aiming to qualify this atomic clock on a satellite for the first time within the next few years. To do this, the system must be transformed from a laboratory model into a compact prototype that can endure a rocket launch and work reliably under the harsh thermal and radiation conditions encountered in space. This is the type of challenge to which DLR has become accustomed – the further development of technologies that are still at a low level of maturity into prototypes.

Following a decision made by the DLR Senate, and with funding from the German Federal Ministry for Economic Affairs and Energy, DLR is currently in the process of establishing three new institutes for this very purpose. These are the Institute for Satellite Geodesy and Inertial Sensing in Hanover, the Institute of Quantum Technologies in Ulm and the Galileo Competence Center in Oberpfaffenhofen. The institute in Ulm will focus on the development of new instruments for precision measurement in close cooperation with industry, while the institute in Hanover will concentrate primarily on developments in satellite geodesy. The Competence Center in Oberpfaffenhofen will work on developments for current and future satellite navigation systems.

There are sound reasons for grounding the development of such highly ambitious technologies at DLR. As a major research institution, we have the necessary development expertise, both scientifically and in the form of excellent large-scale research facilities. For instance, we can work together with industry to develop and operate satellites, and thus advance and accelerate the entire development process from the concept up to the prototype. This strengthens Germany's position as a location for space research. In addition, DLR has the required expertise, as well as extensive contacts within the research community both in Germany and further afield. Multinational cooperation will be essential to implement future missions to measure Earth's gravitational field, conduct research into Bose-Einstein condensates on the International Space Station (ISS) or embark on space-based gravitational wave research with international partners.

With these new institutes, we are entering incredibly exciting and forward-looking areas of research and development. Although establishing the institutes will take several years, the future will see scientific achievements that will greatly advance technological research and industry in Germany, particularly in the field of space.

THE FIRST DEDICATED SATELLITE FOR EUROPE'S DATA HIGHWAY

The EDRS-C communications satellite was launched successfully on 6 August 2019. It is a core component of the European Data Relay System (EDRS) – the 'space data highway'. EDRS can transfer very large amounts of data from space to Earth in a short time using satellite laser terminals. Two geostationary satellites act as 'hubs' and transmit data from Earth observation satellites in low Earth orbit to ground stations in Europe. EDRS is the first commercial application of optical satellite communications in space and enables data rates of up to 1.8 gigabits per second.

In 2016, the first communications node (EDRS-A) reached its operational orbit – approximately 36,000 kilometres above Earth's surface. It has already executed over 23,000 intersatellite connections from there. While EDRS-A is a secondary payload on the Eutelsat 9B satellite, EDRS-C has its own satellite. The complete EDRS will consist of four optical communications satellites.

EDRS is being operated under public-private partnership between the European Space Agency (ESA) and Airbus Defence and Space. DLR's German Space Operations Center in Oberpfaffenhofen is responsible for managing the payloads and controlling the EDRS satellites.

© Arianespace

A perfect launch for Ariane 5 and the EDRS satellite

TRAVELLING AROUND THE REGION AND INTO SPACE WITH 'GREEN' HYDROGEN

Lampoldshausen is bringing two major players from the field of hydrogen research together. The DLR Institute of Space Propulsion develops and operates test stands for rocket engines and is a key partner in the European space sector, as well as one of the largest hydrogen consumers in Europe. The biggest wind farm in southwestern Germany, run by ZEAG Energie, is located nearby. In the H2ORIZON project, DLR and ZEAG are working together to create a hydrogen-based, networked energy system using their unique shared expertise and infrastructure. Sustainable 'green' hydrogen will be generated from wind power using electrolysis. There are plans to use this hydrogen locally for energy supply at the DLR site and as fuel for the test stands. The hydrogen can also be made available for applications in the mobility sector and in industry – DLR and ZEAG are already in contact with companies in the surrounding region.

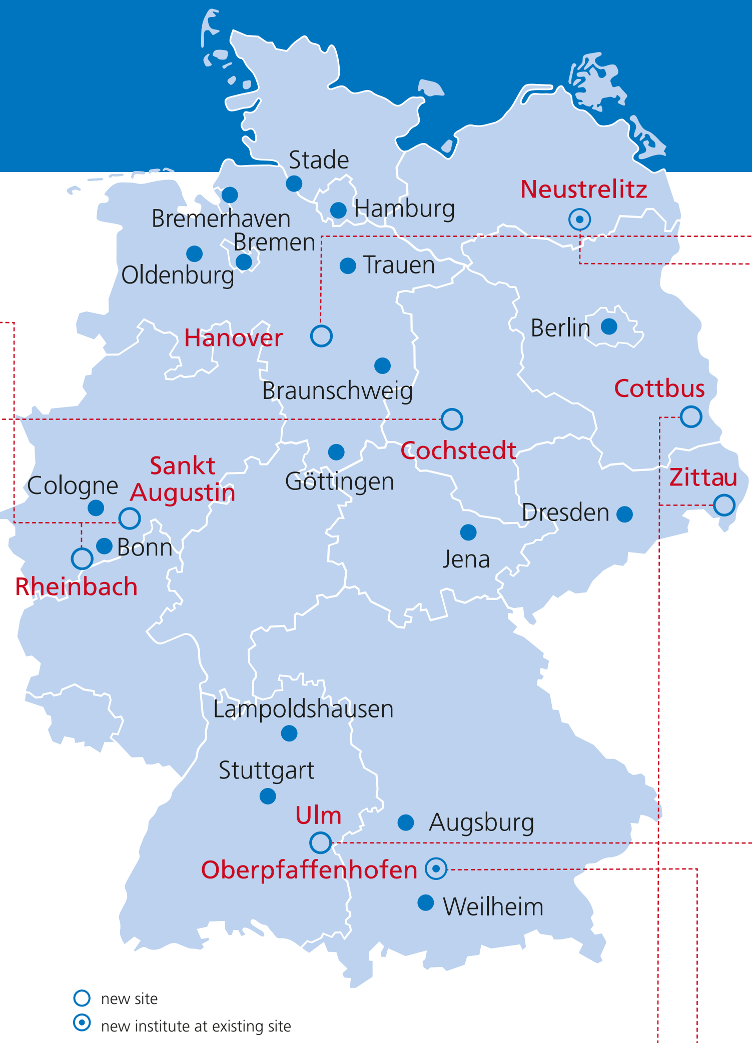
The Baden-Württemberg Minister of Economic Affairs, Labour and Housing, Nicole Hoffmeister-Kraut, and Member of the State Parliament Isabell Huber are interested in this exciting project, which is at the interface between space, energy and mobility. During a visit to the DLR site in Lampoldshausen on 7 August 2019, the two politicians familiarised themselves with the topic of sustainable hydrogen, which is the focus of the H2ORIZON project, and visited the test facilities for European space propulsion research.

DLR Lampoldshausen has 60 years of experience as a European research and testing centre. In this capacity, it will conduct test campaigns for liquid-fuelled Ariane propulsion systems – from development through to qualification and acceptance tests.

Read the site portrait starting on page 48.

PROGRESS, TIMES SEVEN

The German Aerospace Center (DLR) has been shaping the regional appeal for research and technology organisations around Cologne, Oberpfaffenhofen and Braunschweig for decades. However, it has not been connected with Görlitz, Hanover, Cottbus or Zittau. This changed in 2019, when these cities were selected for the establishment of seven new DLR institutes. At these new sites, DLR will build up its expertise and develop cutting-edge technologies. DLR's interdisciplinary approach to research will drive further developments relating to DLR's five strategic themes – mobility, digitalisation, security, sustainability and the strengthening of Germany as a location for research and industry. At the same time, it will reinforce the commercial and scientific appeal of the regions in which the new sites are located.



DANGER DETECTED – DANGER AVERTED

Centralised supply systems, such as those for electricity or water, must function reliably and without restrictions – and not just in industrialised countries. The new institute is conducting research into how such critical infrastructure can be protected. Its experts are developing methods and tools for detecting, evaluating and averting threats at an early stage. To this end, they collaborate with scientists from all of DLR's research areas.

Institute for the Protection of Terrestrial Infrastructures
Sankt Augustin and Rheinbach

Founding director:
Bernhard Hoffschmidt

Planned number of employees:
50

Website:
DLR.de/pi/en

GREEN LIGHT FOR UNMANNED FLIGHT

Unmanned Aerial Systems (UAS) are becoming increasingly important in the civilian sector. The UAS industry is growing rapidly. This test centre – the only one of its kind in Europe – brings together relevant skills and expertise for UAS development. A close-knit and highly innovative research network for all the key participants in this sector has been established. By employing advanced technologies, the test centre will play a leading role in advancing research and commercial progress in the UAS field.

National Experimental Test Center for Unmanned Aircraft Systems
Cochstedt

Founding director:
Werner Etzenbach

Planned number of employees:
30

Website:
DLR.de/ux/en

FRESH IMPETUS FOR THE ENERGY TRANSITION

This institute's mission is to significantly reduce carbon-dioxide and pollutant emissions from industrial processes and power plants over the next decade. Its research focuses on decarbonising energy-intensive industrial sectors, as well as sustainable power generation and energy storage. This includes the development of high-temperature heat pumps, which can enable conventional power plants to be converted into low-carbon energy suppliers (referred to as the 'Third Life for Coal-Fired Power Plants'). The Institute also addresses the provision of high-temperature heat from renewable sources for energy-intensive processes.

Institute of Low-Carbon Industrial Processes
Cottbus and Zittau

Founding director:
Uwe Riedel

Planned number of employees:
60

Website:
DLR.de/di/en

INCREASED KNOWLEDGE ABOUT SPACE WEATHER

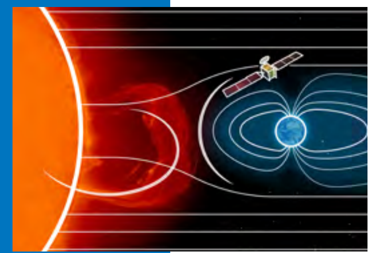
Solar-terrestrial physics deals with the interactions between solar activity and the Earth system. Solar storms can damage communications and navigation satellites in Earth orbit, or even cause them to fail. This phenomenon is referred to as space weather. The Institute is dedicated to the study of this complex topic. It aims to observe and ultimately predict these physical phenomena in a timely, accurate and reliable manner. This will be beneficial for the safety of potentially endangered infrastructure in space and on Earth, such as satellites and power grids.

Institute of Solar-Terrestrial Physics
Neustrelitz

Founding director:
Markus Rapp

Planned number of employees:
30

Website:
DLR.de/so/en



PRECISE INSTRUMENTS AND SECURE SIGNALS

The use of quantum technologies offers great potential for innovation in many fields of application, including quantum computing or modern satellite communications and navigation. The new institute in Ulm is developing instruments for space applications based on quantum mechanical effects in close cooperation with industry. These instruments are expected to greatly exceed the performance of conventional technologies in terms of accuracy. The implementation of quantum communications technologies and quantum cryptography on satellites will make global communications more secure.

Institute of Quantum Technologies
Ulm

Founding director:
Wolfgang Schleich

Planned number of employees:
50

Website:
DLR.de/qt/en

QUANTUM SENSORS FOR EARTH AND SPACE

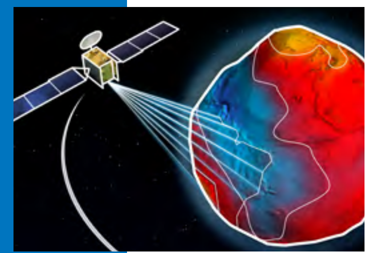
In the context of modern quantum technologies, the Institute is conducting research into novel quantum sensors for terrestrial applications and satellites. The use of quantum-based inertial sensors will deliver new insights into key aspects of the Earth system. For example, the water balance can be investigated using gravitational field measurements. Utilising these technologies on planetary exploration missions will also enhance our understanding of the Universe. Innovative atomic clocks, connected to one another in satellites or on Earth, will enable new navigation systems and a centimetre-precision geodetic elevation grid.

Institute for Satellite Geodesy and Inertial Sensing
Hanover

Founding director:
Wolfgang Ertmer

Planned number of employees:
50

Website:
DLR.de/si/en



NEW IDEAS FOR GALILEO

The Galileo Competence Center is intended to support the day-to-day operation and further development of the current Galileo satellite navigation system. It will also promote the development of future Galileo generations. The Center will work with DLR's other scientific institutes and facilities to analyse the performance of Galileo satellites as well as develop, test and validate new ideas and promising technologies. These will be brought to operational readiness in close cooperation with German and European industry.

Galileo Competence Center
Oberpfaffenhofen

Founding director:
Felix Huber

Planned number of employees:
80

Website:
DLR.de/gk/en

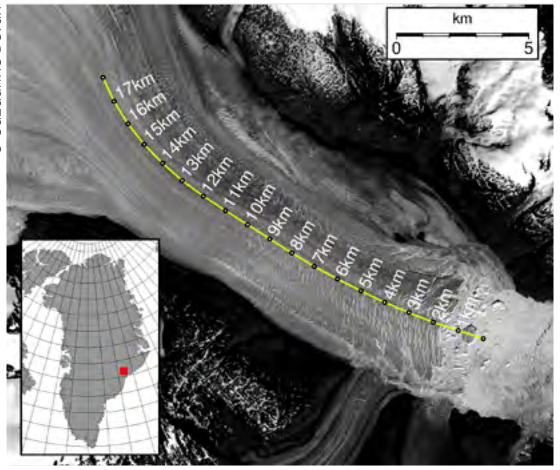
SETTING SAIL – A YEAR DRIFTING THROUGH THE ARCTIC OCEAN

On 20 September 2019, Polarstern, the German research icebreaker operated by the Alfred Wegener Institute (AWI), set off from Tromsø, Norway, on the largest Arctic mission ever conducted. It will drift in the Arctic sea ice for one year and thereby gain fundamentally new data and insights for understanding climate change. The Arctic reacts many times more strongly to climate change than lower latitudes and it has an enormous influence on world climate.

The name of the expedition is MOSAiC (Multidisciplinary drifting Observatory for the Study of Arctic Climate). More than 600 scientists from 19 nations and over 70 institutions address important questions relating to climate and environmental research. Like a mosaic, they are supposed to form a more precise picture of the Arctic system in the same way as the individual pieces of a jigsaw puzzle. The DLR Institute of Communications and Navigation will use a measurement system to receive raw signals from navigation satellites. In the polar region, these are subject to disturbances caused by solar activity. The aim is to detect these and develop countermeasures – thus enabling precise and reliable positioning even in polar regions. DLR's German Remote Sensing Data Center is supporting the mission by providing sea ice maps. The DLR Maritime Safety and Security Lab in Bremen is working to improve techniques for distinguishing between different types of ice. This activity will be supported by ice samples taken during the MOSAiC expedition.

The Polarstern vessel in Tromsø, Norway, days before departure.

© Suzuanne Bevan



Landsat image (18 June 2016) of Kangerlussuaq glacier

TIDAL GLACIERS IN GREENLAND

The Kangerlussuaq Glacier is the largest glacier on the southeast coast of Greenland and flows into the fjord of the same name. The glacier calves approximately 24 cubic kilometres of ice into the ocean every year. This corresponds to about five percent of the amount of ice lost annually by the entire Greenland ice sheet. Using a time series of 150 TanDEM-X elevation models of the Kangerlussuaq Glacier, scientists from Swansea University in the United Kingdom have measured the decrease in the glacier's surface height.

By late summer 2018 – after two years of calving all year round – the Kangerlussuaq Glacier retreated further inland than it has ever done in 80 years of observations. The analysis is based on high-resolution radar data from the German TanDEM-X satellites acquired during 2017 and 2018, and digital elevation models created especially for the research team in Wales by DLR. The maps show that the glacier lost most of its five-kilometre-long floating tongue between 2016 and 2018. In the same period, its thickness decreased by a total of 35 metres, which corresponds to approximately 35 percent.

THE OZONE HOLE, AMAZON FIRES AND GRAVITY WAVES

The German High Altitude and Long Range (HALO) research aircraft will be exploring the atmosphere in the southern hemisphere and its impact on climate change during September and November 2019 as part of the SOUTHTRAC (Transport and Composition of the Southern Hemisphere UTLS) mission. The main objective of the first phase of the campaign is to investigate gravity waves at the southern tip of South America and over Antarctica. In the second phase, the scientific focus will shift to the exchange of air masses between the stratosphere and troposphere. During the transfer flights between Europe and South America, the researchers will investigate how current burning of biomass in the Amazon rainforest is affecting the climate, among other things.

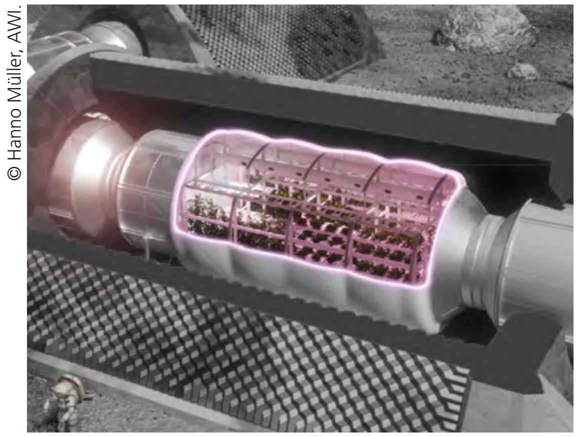
Trace gases, such as ozone and water vapour, are effective greenhouse gases and play an important role in climate change. A very large hole has formed in the ozone layer over the Antarctic region. It will take many decades for the ozone layer to fully recover. The importance of this for climate change in the southern hemisphere is now being investigated in detail by researchers as part of the SOUTHTRAC campaign. Innovative remote sensing techniques will be combined with highly accurate local measurements on the aircraft and compared with satellite data.

© DLR/Minikin

HALO arrives in Rio Grande, southern Argentina.

VEGETABLES 'MADE IN ANTARCTICA' FOR THE MOON AND MARS

© Hanno Müller, AWI.



New design concept for a greenhouse in space

Future food production in deserts and cold regions, as well as under the inhospitable conditions of future space missions to the Moon and Mars, is providing the stimulus for research in the DLR-led Antarctic greenhouse project EDEN ISS. DLR researcher Paul Zabel spent one year on the perpetual ice cultivating vegetables under artificial light and without soil. He was there as a member of the overwintering crew at the Alfred Wegener Institute's Neumayer III Antarctic research station. On 23 August 2019, the EDEN ISS team presented the results of the project, which included 268 kilograms of food produced in an area of only 12.5 square metres over 9.5 months.

The operation of the Antarctic greenhouse is currently ongoing and is open to research groups across the globe. From the results and experiences of the EDEN ISS project, a new greenhouse concept for the Moon and Mars has emerged – deployable, compact and suitable for launch using a Falcon 9 rocket. Future, long-term crewed space missions will require locally grown food. EDEN ISS has proven the feasibility of a space greenhouse in the Antarctic and thus demonstrated that this technology could also be used to produce food on the Moon and Mars.

CIMON BACK ON EARTH AFTER 14 MONTHS ON THE ISS

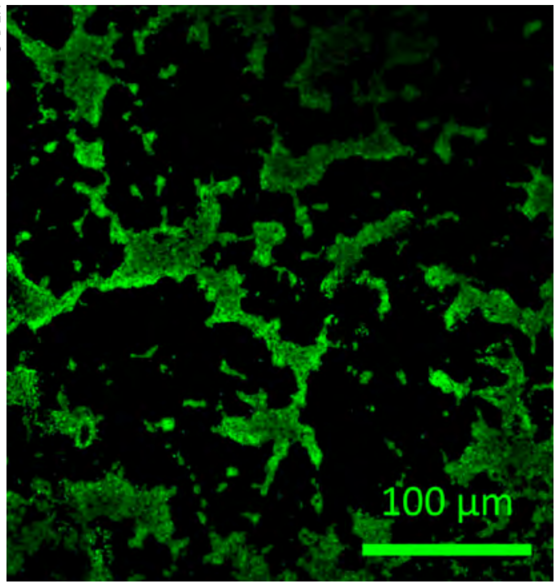
The Crew Interactive Mobile CompaniON (CIMON) mobile astronaut assistant, which is equipped with artificial intelligence (AI), came back to Earth on 27 August 2019 on board the SpaceX CRS-18 Dragon spacecraft. CIMON is expected to return to Germany at the end of October. This technology demonstration has completely met the researchers' expectations. During its initial operation in space – a 90-minute mission with the German ESA astronaut Alexander Gerst on the ISS in November 2018 as part of the horizons mission – it showed that it functions well in microgravity conditions and can interact successfully with astronauts. This is the first time that AI has been used on the ISS. CIMON has laid the foundations for human assistance systems in space to support astronauts in their tasks and perhaps, in the future, to take over some of their work.

A successor to CIMON will be built by Airbus in Friedrichshafen and Bremen on behalf of the DLR Space Administration with funds from the German Federal Ministry of Economic Affairs and Energy (BMWi).

© ESA

CIMON and ESA astronaut Alexander Gerst on the ISS

© DLR



Bacillus subtilis biofilm grown on a membrane and stained with a fluorescent dye that binds to nucleic acids.

BIOFILMS AND MICROBIAL MINERAL EXPLOITATION IN SPACE

The ESA BioRock experiment was carried into orbit, bound for the International Space Station (ISS), on 25 July 2019. The experiment will investigate the growth of biofilms and their ability to extract minerals and use them as nutrients in microgravity conditions. This will be directly compared with results obtained under Mars and Earth gravity conditions simulated using a centrifuge on the ISS. The findings will contribute towards a better understanding of the growth of microorganisms in space, which is key for the development of bioregenerative life support systems.

Three species of bacteria are being investigated in the BioRock experiment: Sphingomonas desiccabilis, Bacillus subtilis and Cupriavidus metallidurans. "Our research focuses on Bacillus subtilis," says Petra Rettberg from the DLR Institute of Aerospace Medicine. "We are curious to see how well this bacterium can extract nutrients from the minerals of the basalt that was inoculated with Bacillus spores for the experiment."

DIGITAL STREET MAP FOR DUSSELDORF

A test field for automated and networked driving has been operating in Dusseldorf for two years. In future, networked technologies will enable traffic in the city to flow more freely, and vehicles will inform drivers in real time about disruptions along their route. DLR has developed a highly accurate digital map for this purpose. It contains information about the infrastructure – for example, traffic lights – parking guidance systems and electronic warning and speed information from dynamic display panels.

Such maps are an important part of highly automated driving, and they also support anticipatory route planning. The DLR research vehicle drove around the test circuit to demonstrate how an automated vehicle will move through urban areas with networked technologies in the future. The test field will remain in place even after completion of the KoMoD (Kooperative Mobilität im Digitalen Testfeld Düsseldorf) project and will continue to be financed by projects in the fields of automation and 5G technology.

The Dusseldorf mobility project vehicle fleet


One of the three unmanned aerial systems from the HEIMDALL project, equipped with cameras and thermal imaging sensors.

CAMERA SWARM DETECTS FOREST FIRES

A swarm of Unmanned Aerial Systems (UAS) can be used for forest fire detection. This was demonstrated during flight experiments conducted by a team from the DLR Institute of Communications and Navigation as part of the HEIMDALL project. The drones, which were equipped with cameras and thermal imaging sensors, autonomously explored a defined area and exchanged data between swarm members. They were able to detect forest fire hotspots with diameters of only 15 centimetres. Over the course of 19 flights, the drones successfully analysed 37 different hotspots from heights of between 30 and 130 metres above the ground. In future, autonomous robotic swarms will collaboratively generate a map of their surroundings – without human intervention. For this purpose, DLR researchers are developing new algorithms and methods for swarm exploration and testing them under realistic conditions.

MASCOT MISSION REVEALS FRAGILE ASTEROID MATERIAL

The evaluation of image data acquired by the DLR MASCAM camera as part of the Mobile Asteroid Surface Scout (MASCOT) mission has produced surprising results. It has revealed that the target asteroid, Ryugu, which is almost one kilometre across, is a fragile 'rubble pile'. It consists of two different, almost black, types of rock with little internal cohesion. The results were published in the journal 'Science'. The researchers believe that a large part of the asteroid's volume must be traversed by cavities that make the diamond-shaped body extremely fragile. Surface temperature measurements performed by the DLR MARA radiometer confirm the porosity of the asteroid material. With an average density of only 1.2 grams per cubic centimetre, Ryugu is only a little 'heavier' than water ice and resembles carbon-containing, 4.5-billion-year-old meteorites found in collections on Earth.

The German-French MASCOT lander descended onto the surface of Ryugu on 3 October 2018 as part of the Japanese Hayabusa2 mission and sent spectacular images and physical measurements from its surface back to Earth.

The surface of Ryugu, imaged from a distance of a few metres by the MASCAM camera on the MASCOT lander.

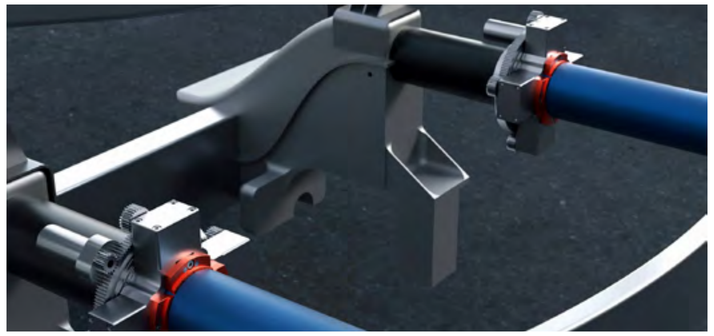
PLATE LINES REDUCE TURBULENCE DURING LANDING APPROACHES


An Airbus A380 approaching Vienna Airport

Small and medium-sized aircraft currently have to maintain a safety separation of approximately 10 kilometres from larger aircraft flying ahead of them. The reason for this is wake vortices and the resulting turbulence, which can be dangerous for a following aircraft, particularly just before landing. A DLR-patented configuration of parallel ground plates causes these wake vortices to dissipate more quickly near the runway.

At Vienna Airport, DLR, together with the Austrian company Austro Control, installed a system of such panels arranged in parallel one behind the other – each nine metres long and 4.5 metres in height. Using a laser measurement system (lidar), the researchers recorded the behaviour of the wake vortices to demonstrate the effectiveness of the plates at a busy airport during normal operations.

SMART STRUCTURES REDUCE ACCIDENT DAMAGE


Visualisation of the crash absorber. In the event of a collision, the telescope-like tube (blue) in the front car is severed by an annular cutter (red) and thus absorbs a large part of the kinetic energy.

A small car that collides with a Sport Utility Vehicle (SUV) often sustains more damage because it has a smaller 'crumple zone'. A 'smart' impact structure would increase the safety of those involved in such situations. Once sensors detect that an unavoidable accident will occur, the structure adapts and reduces the collision energy. The active energy absorber uses the possibilities offered by digitalisation, networking and artificial intelligence. With the aid of image recognition and extensive sensor technology, the system determines vehicle type and weight in a fraction of a second and determines where the other vehicle has structures that can best withstand the energy in a crash. In an emergency, the system intervenes in the last few metres in order to use this information as the basis for a minimised accident outcome. DLR researchers from Stuttgart have been able to demonstrate that this technology works.

MEET DLR AT:

INTERNATIONAL ASTRONAUTICAL CONGRESS 2019
21 - 25 October 2019 • Washington D.C., USA
Founded in 1951 to foster the dialogue between scientists around the world and support international cooperation in all space-related activities, the IAC to this day continues to connect people involved in space from all over the world. Acting as organiser, the International Astronautical Federation is the world leading space advocacy body with 300 members, including all key space agencies, companies and institutes across over 60 countries. At this year's IAC in Washington D.C., DLR will be represented by its Chair, Pascale Ehrenfreund – at the same time incoming IAF president – as well as other members of the Executive Board, numerous experts and an exhibition stand.

AGRITECHNICA 2019
10 - 16 November 2019 • Hanover, Germany
The AGRITECHNICA trade fair is the world's leading trade fair for agricultural technology. With its range of leading technology and new developments, the fair is an information forum for all solutions in agriculture and agricultural technology. AGRITECHNICA is the global meeting place for the agricultural machinery sector, where innovations are presented, trends set and visions discussed. This year's theme 'Global Farming - Local Responsibility' stands for a sustainable future for agriculture, in which sufficient food is provided for a growing world population while preserving natural resources. DLR will be presenting 'Science2Business' in Hall 21, Stand B24.

SPACE TECH EXPO EUROPE
19 - 21 November 2019 • Bremen, Germany
Space Tech Expo Europe is the continent's major dedicated supply-chain and engineering event for manufacturing, design, test and engineering services for spacecraft, subsystems and space-qualified components. At the exhibition and conference, thousands of industry leaders, decision makers, engineers, specifiers and buyers have the opportunity to meet manufacturers across the supply chain for civil, military and commercial space. At this year's expo, high-level industry experts, from, among others DLR, ESA, Airbus, and PLD Space will share their insights on the most important developments and challenges currently facing space engineers and manufacturers.

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SELF-DIAGNOSIS DURING OPERATION

Aircraft structure with sensors. They indicate when damage is imminent.

DLR cross-sectoral project 'Condition Monitoring' – algorithms detect damage before it occurs

By Daniel Krause

Fatigue, a need for rest, difficulty concentrating – even before the onset of an illness, the human body sends signals that something is wrong. The nervous system is able to detect changes in the body at an early stage. What if machines and systems were equipped with this kind of sensory capability?

Condition monitoring of machinery and systems is as old as industrialisation itself. In the late 19th century, the newly founded company TÜV began regularly inspecting steam boilers. This largely put an end to fatal accidents caused by exploding boilers. Since then, regular inspections of safety-relevant systems have been common practice around the world. But these inspection activities are expensive and time-consuming, and do not always avoid the need for extensive repairs. Taking plants out of operation in good time reduces repair costs. This is where condition monitoring in its narrower sense is applicable. Sensors monitor the systems continuously to detect changes, independently of inspections. Such monitoring techniques are able to predict, detect and diagnose faults. Ideally, this completely eliminates the need for inspections. As a result, humans only have to carry out maintenance if a potential failure has been identified or predicted, rather than at regular intervals. This makes operation of the facilities and equipment more cost-efficient.

Universal systems

"Anyone wanting to develop and run a condition monitoring system must first overcome a number of obstacles – the complexity of the system, the need for investment, and the sometimes greater weight of the system due to the additional sensors," says Martin Wiedemann, Director of the DLR Institute of Composite Structures and Adaptive Systems. "We can significantly improve the system by making modifications in two areas – the data on which it is based and the algorithms that evaluate that data." Wiedemann is the coordinator of the DLR cross-sectoral project 'Condition Monitoring for Safety-Relevant Structures'. A team of more than 30 researchers from 15 DLR institutes and facilities is working on new diagnostic methods for the safe operation of complex systems. In view of the increasing digitalisation and networking of production processes, data are the most important inputs to their work.

Data – the raw material of the 21st century

Today, smartphones carry more sensors than engineers could have dreamed of 20 years ago. As early as 2012, studies carried out at the Politecnico di Torino in Italy revealed that smartphones can detect potholes in roads or provide information about air quality. The availability and bandwidth of sensors in every price range are greater than ever before. Researchers at the DLR Institute of Aeroelasticity – who until now have had to rely on expensive, specially-calibrated measurement technology, particularly when conducting the vibration tests required for certification purposes – have found something similar. "Our vision is a measurement system consisting of commercially available, mass-produced devices that still delivers usable results," explains Yves Govers, Deputy Head of the Structural Dynamics and System Identification department. Initial tests with standard industrial sensors have yielded promising results. The trend is clear, but there is still a long way to go. Govers says: "Manufacturers will only begin to integrate the measurement technology into their systems when it is sufficiently inexpensive." Proving the reliability of the system could lead to the establishment of completely new business areas with relatively little investment. Although sensors are already integrated into many systems, their data have received little attention until now.

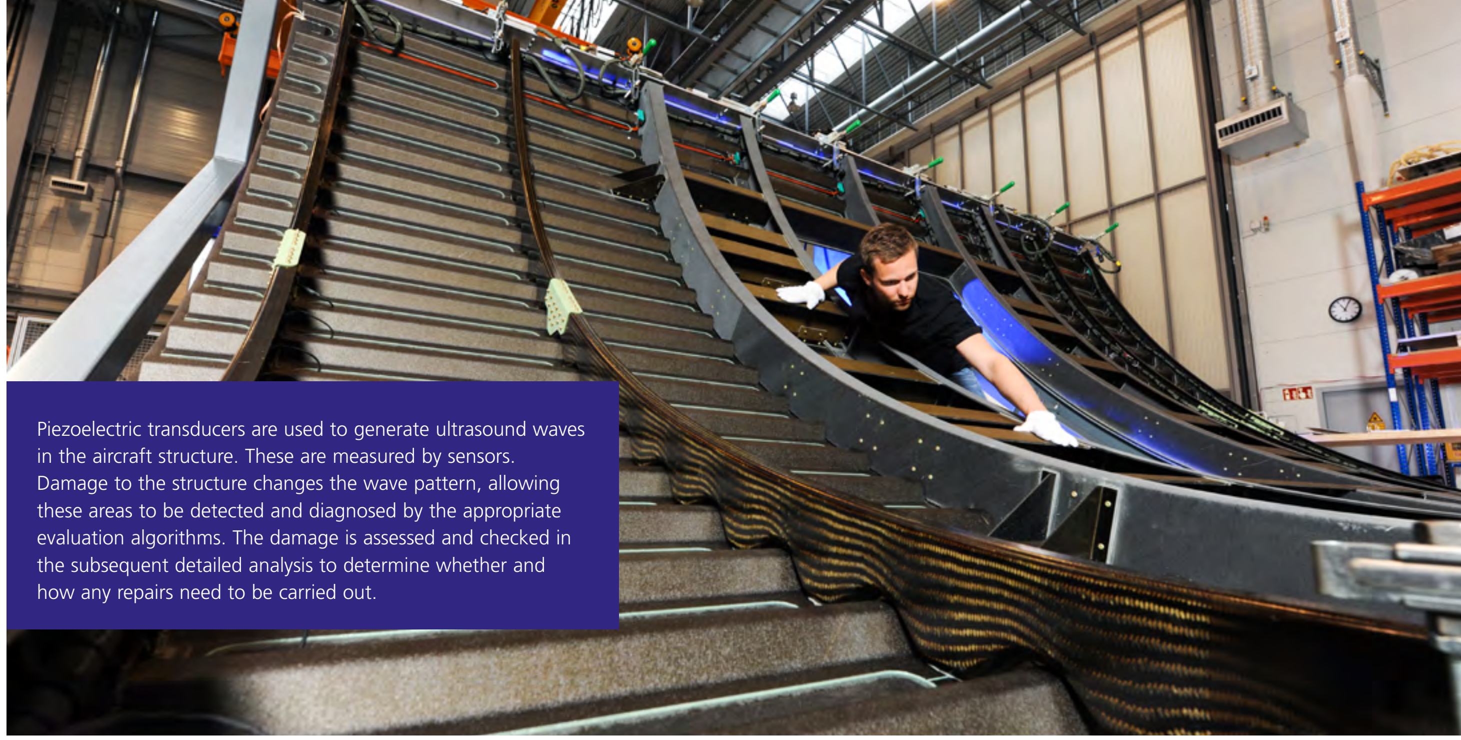
Algorithms that detect anomalies

Improved data evaluation algorithms offer some hope. They are able to sort the information and identify anomalies, searching for the proverbial 'needle in a haystack'. In order to deliver statistically relevant results, the dataset with which the algorithms work must be as large as possible. In addition, the algorithms must be able to cope with the resultant complexity. Suppose, for instance, that a single sensor system on a satellite measures both electrical current flow and temperature. "A condition monitoring system must provide an alert if one of the two factors or the combined data streams deviate from their expected behaviour. For example, it must be able to detect if the temperature drops after the system is switched on, because the temperature usually increases with the current," explains Leonard Schlag, a researcher at DLR Space Operations and Astronaut Training. Schlag is involved in the Automated Telemetry Health Monitoring System (ATHMoS) project – a system for the automated monitoring of satellite data. If this can be done in a reliable manner, it will lead to new business models with the corresponding monitoring systems. One example is the Rolls-Royce 'Power-by-the-Hour' approach. The engine manufacturer 'leases'

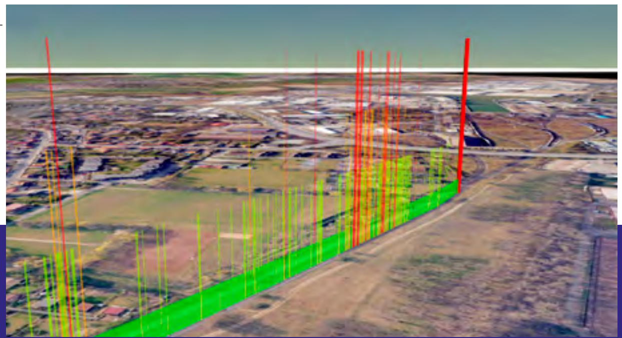
THE DLR CROSS-SECTORAL PROJECT 'CONDITION MONITORING FOR SAFETY-RELEVANT STRUCTURES'

Duration: four years
Total budget: 15.6 million euro
Participating DLR institutes and facilities:
Institute of Composite Structures and Adaptive Systems
Institute of Aerodynamics and Flow Technology
Institute of Aeroelasticity
Institute of Flight Systems
Institute of Maintenance, Repair and Overhaul
Institute of Optical Sensor Systems
Institute of Space Systems
Institute of Solar Research
Institute of System Dynamics and Control
Institute of Technical Physics
Institute of Transportation Systems
Institute of Materials Research
Flight Experiments Facility
Space Operations and Astronaut Training
Simulation and Software Technology

These images show a district heating system – the BTB cogeneration plant in Berlin-Adlershof. The thermal storage reservoir can be seen at the back of the leftmost image. With assistance from the Integrated Positioning System IPS (see the article in DLRmagazine 161), it is possible to generate digital data products for the energy analysis of buildings and industrial plants using optical imaging sensors. These thermal images allow researchers to assess the condition of the plant. Is heat escaping due to a leak, or are there weak points in the thermal insulation? IPS provides thermal images with information about the location, so that researchers can precisely determine where the damage is located.



Piezoelectric transducers are used to generate ultrasound waves in the aircraft structure. These are measured by sensors. Damage to the structure changes the wave pattern, allowing these areas to be detected and diagnosed by the appropriate evaluation algorithms. The damage is assessed and checked in the subsequent detailed analysis to determine whether and how any repairs need to be carried out.



Condition monitoring systems can also be used to examine railway infrastructure, as depicted here with a shunting locomotive at Braunschweig harbour. Sensors in the vehicle's axle bearings continuously measure vibrations. This resulting data give information about the condition of the track.

engines, including monitoring, maintenance and repairs, to aircraft operators. Payment is made when an engine is actually in use. This business model depends on the reliability of the condition monitoring system. False positive reports lead to additional maintenance activities and therefore higher costs (such as compensation for aircraft downtime, or servicing expenses). Failure to detect and report anomalous behaviour leads to unacceptable risks. The algorithms must therefore be sufficiently reliable, without triggering false alarms.

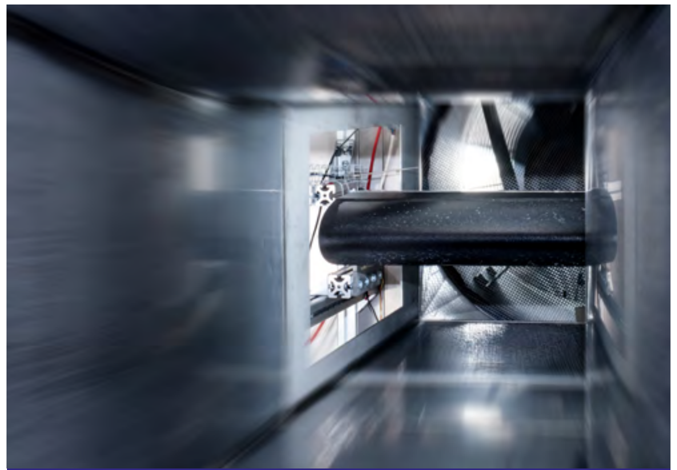
Interconnected research areas

The complexity of data evaluation increases greatly once just a few variables are interlinked. As part of the project, experts from various DLR institutes are exchanging their experiences with these processes in the 'Anomaly Detection' working group and further developing them. In the future, evaluation techniques from the field of spaceflight, for example, could also be applied to monitoring systems for transport infrastructure. "As condition monitoring systems are very complex and often tailored to a particular field, we have set ourselves the aim of interlinking our findings across all research areas and developing universally applicable processes and technologies," says Wiedemann, summarising the project's goals.

While some partners are conducting research into almost complete condition monitoring scenarios, others are developing building blocks. Specialists from the DLR institutes of Solar Research, Optical Sensor Systems and Technical Physics are jointly investigating the early detection of damage to buildings using 3D surveying data. Meanwhile, a team from the traditionally aeronautics-oriented Institute of Aeroelasticity is collaborating with experts from the Institute of Transportation Systems to reveal the extent to which vibration analysis methods from aviation are suitable for monitoring the condition of rail vehicles. In other areas, data are collected during flight tests, using both research rockets and aircraft. These data serve both as a basis for the development of new technologies, and for their qualification and certification. For example, they might be used to test a system that detects unsafe ice conditions on an aircraft. The pilot can be warned in good time and initiate countermeasures. The DLR team is also working on monitoring and assessing damage to fibre-composite structures in aircraft and detecting anomalies in satellite data. In addition to these processes, researchers are looking at various technologies that could form part of condition monitoring systems in the future. These include sensors that draw energy from their surroundings, and therefore require no other power supply, or sensors for detecting micrometeorite impacts on spacecraft.

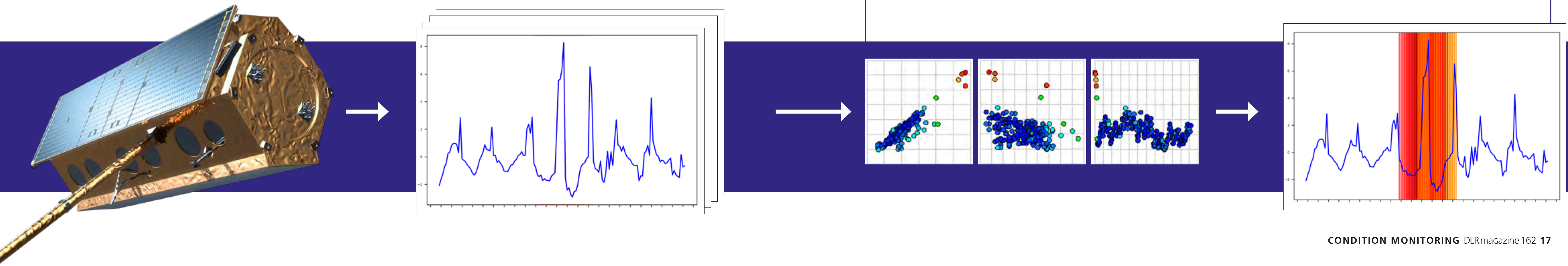
Technology that reliably predicts when functional failures are likely to occur – before they happen – is an interesting prospect for a wide range of industries and areas of life. At DLR, bright minds from a range of disciplines are working to make this a reality.

Daniel Krause is an aerospace engineer. He is a researcher at the DLR Institute of Composite Structures and Adaptive Systems and leads the cross-sectoral project Condition Monitoring for Safety-Relevant Structures.



An innovative technology is able to detect and combat icing on aircraft wings before it becomes a problem. Now that tests in the icing wind tunnel have been successfully conducted, researchers will test the technology under real flight conditions.

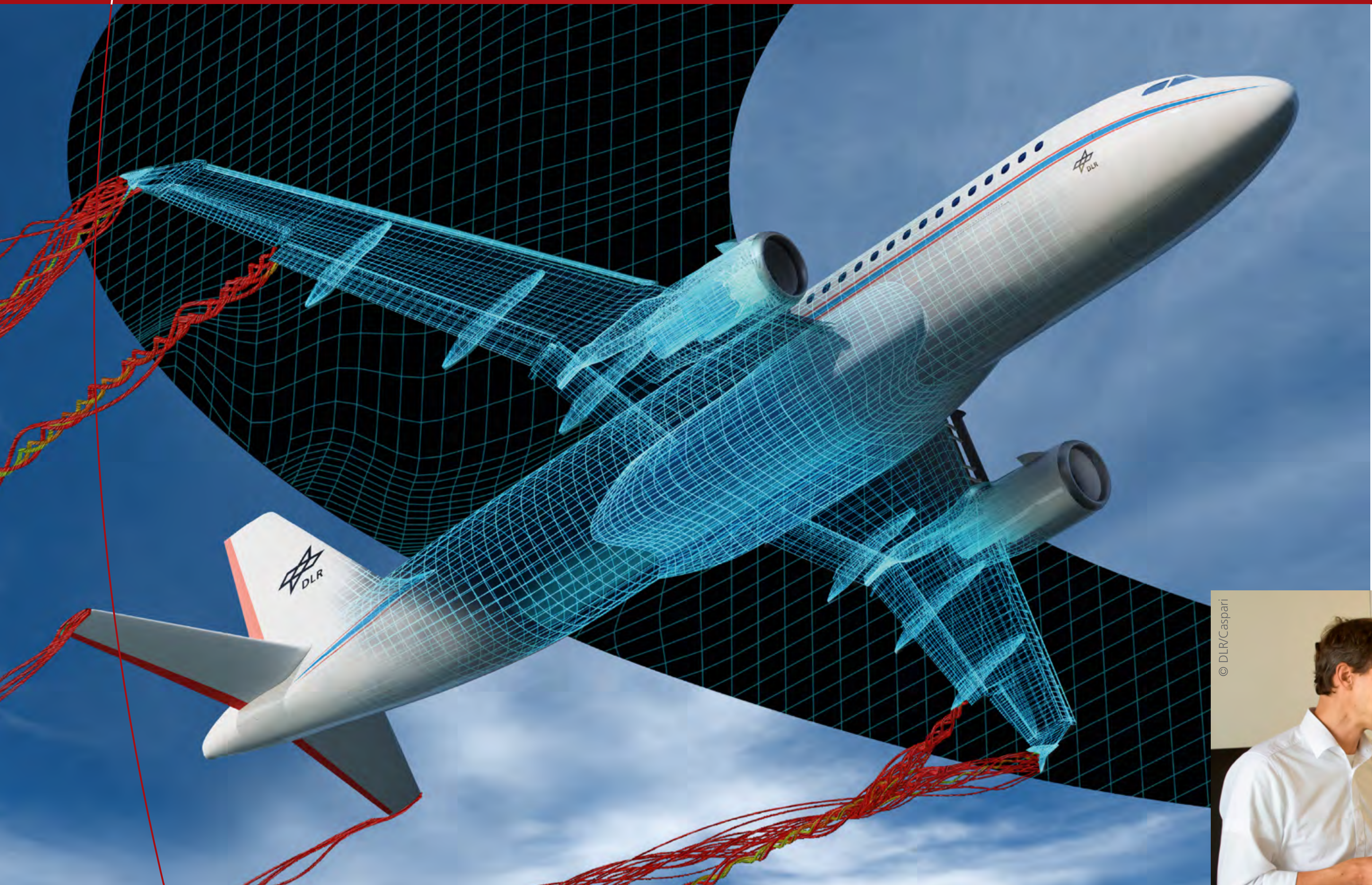
The ATHMoS system supports the monitoring of satellites by acquiring a large number of statistically relevant parameters for all measured variables and sensors on the satellite and continuously comparing them with its previously learned behaviour. In addition to simple limit value violations, short- and long-term trends are evaluated and then presented graphically, so that the status of the satellite can be seen at a glance. In this way, no unexpected change remains unobserved by an engineer at the operating console, even with thousands of measured variables to be monitored.



VISIONARY GATHERING

Industry, research organisations and regulatory authorities are working together on virtual aircraft development in the Virtual Product House.

By Uli Bobinger



The development of the aircraft of the future is increasingly being made possible by computer simulations. DLR and its partners are researching the 'virtual product' – from calculating airflows, to determining the resilience of materials, and through to investigating the effects of structural changes on flight behaviour.

Conference calls, email and WhatsApp groups, communicating in the cloud – teamwork has been virtual for a long time. But in Bremen, researchers have rediscovered the charm of planning the future of aeronautics in person over a cup of coffee.

Filter size – four; colour – white; year of manufacture – unknown. Cost when new (which must have been a long time ago) – less than 30 euro. Yet the value of this device at the new Virtual Product House (VPH) in Bremen is not measured by its price. At this new research platform, DLR researchers, Airbus engineers, aircraft testers from IABG and other partners all gather around an analogue coffee machine. The Center for Eco-Efficient Materials & Technologies (ECOMAT) in Bremen is home to the VPH, led by DLR. Kristof Risse is responsible for this new initiative at DLR: "Being able to just have to call across the corridor when you want to discuss something over a cup of coffee is incredibly convenient." And while that might not sound out of the ordinary, working on future aircraft with partners from other organisations every day – and under one roof – is actually quite extraordinary.

There is certainly plenty to discuss. There are no simple answers to the issue of simulating new developments in aircraft construction with such accuracy that virtual certification of a completely new aircraft becomes possible. Industry partners such as Airbus, Liebherr-Aerospace Lindenberg, FFT Produktionssysteme and the analysis and test engineering company Industrieanlagen-betriebsgesellschaft (IABG) are all participating in the VPH. They are joined by partners from the University of Bremen and, of course, the DLR research institutes involved in this topic. "The digitalisation of aviation is opening up huge possibilities, but it also represents an enormous challenge for research. DLR will be working on this with its partners in the Virtual Product House," says Rolf Henke, DLR Executive Board Member for Aeronautics Research. "DLR has thus taken on the role of integrator at VPH."

© DLR/Caspari

Daniel Reckzeh from the Research and Development Department at Airbus in Bremen (left) and Kristof Risse, responsible for the Virtual Product House at DLR, appreciate the short distances in the new building in Bremen.

'Research Hub' or 'Shared Science Space' – the Center for Eco-efficient Materials & Technologies (ECOMAT) near Bremen Airport has already received a number of nicknames. In an otherwise highly diversified research landscape, the basic idea is to conduct aeronautics research cooperatively and under one roof. The main tenant in the 22,000-square-metre facility is the aircraft manufacturer Airbus. The ECOMAT project was initiated by the City of Bremen and offers space for 500 experts. DLR officially joined ECOMAT in late June 2019 with the launch of the Virtual Product House.

Knowing what works before the first test flight

Companies that are able to develop and manufacture aircraft not only more reliably, but also more efficiently than their rivals have a competitive advantage. Although this has always been the case, it is becoming increasingly important as market conditions become tougher. This simple idea was one of the primary motivations behind the establishment of ECOMAT in Bremen in early 2019. Here, around 500 people conduct research into the key technologies that will prove to be of great importance in aircraft manufacturing and other areas in the future.

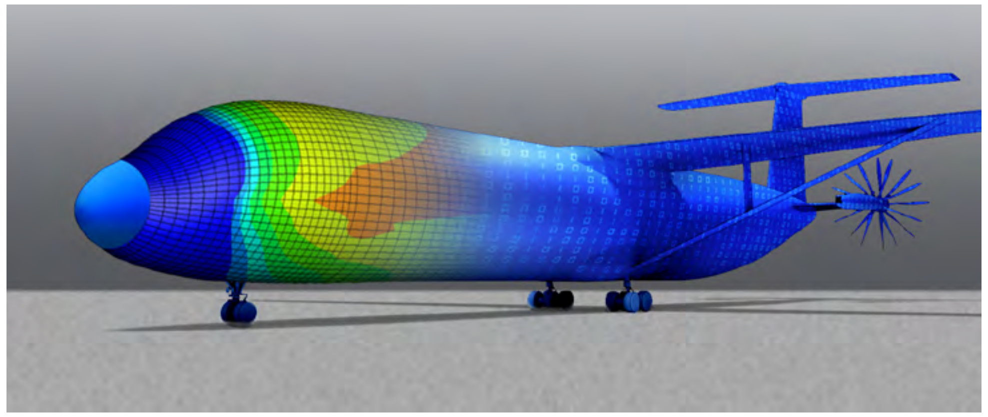
The field of aircraft construction is currently undergoing a radical transformation all over the world. This is not just a matter of moving away from traditional manufacturing techniques and towards an ever-increasing use of composite materials (the fuselage of both the Boeing 787 and the Airbus A350 XWB is made primarily of carbon-fibre composites). Initial ideas for completely new aircraft concepts to be implemented in the second half of this century go far beyond this. For example, designs with forward-swept wings and concepts for making the fuselage and wings a single unit (blended wing body) are being discussed.

One thing is clear – any new technology entails risks. This is why it is becoming increasingly important to determine what works and what does not before the first test flights. In the future, all processes involved in aircraft development – from design through to testing and subsequent series production, operation and even decommissioning – will be simulated on computers. This will be necessary to identify new technologies for even safer, more environment-friendly and cost-effective air transport, to accelerate their adoption and reduce technological risks. Doing this on a large scale, rather than with just a few small components, will only be possible with a new generation of high-performance computers.

This is also where the work of the VPH begins. However, the vision of virtual – that is, simulation-based – certification of an entire aircraft is still a long way away. Willy Sigl of the European Aviation Safety Agency (EASA) says, "This is currently not possible. But this very ambitious goal cannot and should not be ruled out for the distant future. EASA seeks to maintain an agile legal framework that allows for state-of-the-art virtual certification methods."

First, it is necessary to address individual components. The three-year start-up project of the VPH focuses on a multifunctional control surface for an aircraft wing. It is funded by the German Federal State of Bremen and the European Union Regional Development Fund (ERDF). Risse explains: "Our specific application is a moveable, or flap, of an aircraft wing, with the core objective of virtual certification. To this end, we want to link digital design methods more closely with virtual testing and virtual manufacturing, and further develop them with regard to their industrial applicability."

This is precisely what makes Bremen the ideal location for the Virtual Product House. This is where Airbus manufactures all of the flaps for its high-lift systems and also integrates complete wings with these systems for the long-range Airbus models. During cruise flight, these control surfaces were classically not required and retracted. In this way, the wing has the lowest possible drag, thus ensuring maximum aerodynamic efficiency. Nowadays, however, wings are also being assigned new functions during cruise flight.



Highly accurate simulations and virtual testing save time and money. This makes the certification process more efficient.

Cruise flight with variable wing camber

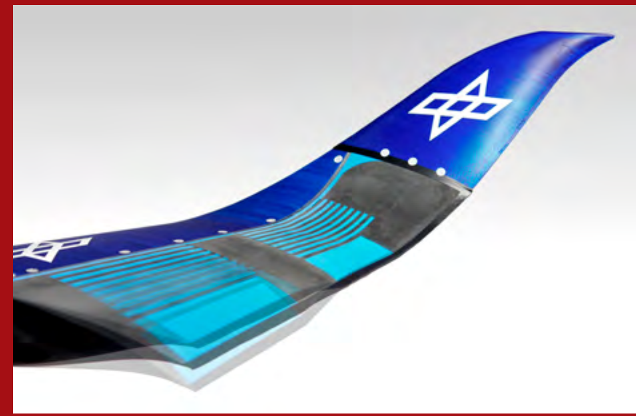
Airbus has already produced multifunctional wings, as its long-haul A350 XWB aircraft uses the control surfaces on its wings in an adaptive way. The shape of the wing can be varied as required to suit the prevailing conditions. All the control surfaces (also referred to as moveables) can be deflected independently of one another and selectively to reduce the structural load, for example in the event of turbulence or while performing flight manoeuvres. The moveables change the wing profile during cruise flight, so that the airflow around the aerofoil, and thus the pressure distribution on the wing, can be controlled. They can also be moved by a few degrees in both directions to change the wing camber. Using this variable camber, the resulting lift force on the wing is moved nearer to the fuselage in early flight phases to reduce the bending moment around the wing root. This facilitates the design of a lighter wing structure. Later in flight, the lift force is shifted further outboard on the wing towards the aerodynamic optimum. The flap system thus enables the adaptation of wing shape and lift distribution to the flight conditions, significantly reducing fuel consumption and emissions.

Daniel Reckzeh, Manager of the Research and Development Department at Airbus in Bremen, is certain: "In future, we will no longer have to choose between different target functions such as flight performance, manoeuvrability, load balancing or redundancy in wing designs." There will soon be no need to pre-assign a function to a flap element in the way we do today. According to Reckzeh: "It is a matter of assembling the individual components of the overall system in such a way that completely new solutions are created."

Compliance demonstration during the development process

The multifunctional wing in Bremen makes an ideal test object for combining the areas of virtual design, virtual manufacturing and virtual test processes all the way up to certification, in cooperation with the DLR institutes and project partners. There is a clear trend: "We are moving away from only conducting the qualification process once the design and manufacturing steps are complete," says Reckzeh. If physical evidence of the suitability of aircraft components is revealed before the end of the development stage through virtual testing methods, a validated digital design can be used much sooner in the development process for reliable testing, not least because the various aircraft design disciplines are integrated into the simulations at VPH.

All partners in the Virtual Product House work on the basis of a 'common source' software architecture – in other words, a protected simulation environment. This is a vital prerequisite for the joint development of completely new processes, with input from a range of very different organisations.



The initial project for the Virtual Product House is a multifunctional flap for an intelligent wing. The DLR researchers are working with their partners to develop virtual design, manufacturing and test procedures that will enable them to better integrate new technologies into aircraft and subsequently evaluate them.

But this is not the end of physical testing. IABG, one of the partners in VPH, operates test facilities covering a total of 18,000 square metres at three sites in Germany. It has followed a complementary approach, combining physical and virtual testing, for a considerable time. According to Gerhard Hilfer of IABG: "Physical tests give tangible results, while virtual tests are more like predictions. Their reliability has to be demonstrated in order to satisfy the high safety and reliability requirements of air transport. However, virtual testing will help us to implement new technologies more successfully and to an ever-greater extent."

More successful – and faster

To survive in this market, one must be fast – especially during the transition period. Established aircraft manufacturers Airbus and Boeing have to devise new concepts for their future aircraft, while the fast-growing Chinese market has already begun moving in this direction. Over the next 15 months, China is expected to establish 200 new general aviation airports, bringing the country's total number of airports to 500. In addition, with its own new aircraft types such as the C919 from the state aircraft manufacturer Comac – which is still very similar to the Airbus A320 – China is entering the market at a rapid pace. Experts estimate that, by 2035, there will be a need for at least 6000 new aircraft for China's domestic traffic alone.

The focus on wings during the three-year launch phase of VPH is thus only the beginning. Once a standardised process has been established for virtual testing and certification of a wing flap, it can be applied to other components, such as a landing gear. The Virtual Product House will therefore serve as both a testing centre and a networking platform – on the long road for DLR and its partners towards a completely virtual maiden flight.

At present, entirely virtual certification of a complete aircraft remains a vision for the future, but the direction that these developments are taking is clear. That is why gathering around the old coffee machine at the VPH to exchange ideas represents such a great opportunity for Kristof Risse, Daniel Reckzeh and the other DLR partners. Three years from now, once the start-up phase is over, they might meet for another exchange – this time around a modern espresso machine.

Uli Bobinger has been working as an aerospace journalist for various German television stations for many years. He is also known in the industry as a moderator of specialist congresses.

SHARING THE SKY

DLR is conducting research to ensure safety in rapidly changing airspace

By Dagi Geister

A freight drone delivers a consignment of goods to the front garden of a detached house. Up above, autonomous air taxis fly commuters to their workplaces in the city. Small unmanned aircraft hover over road junctions in the inner city, detecting traffic volumes and disruptions before feeding the information into a central traffic control system. Although the scene might sound as if taken from a science-fiction film, this futuristic scenario is already becoming a reality – at least partly. In Singapore, drones transport work materials to ships as part of the 'Skyways' project, while in cities like Dubai, Vienna and Ingolstadt preparations are now under way to carry people by air taxi. Yet regardless of what is technologically and economically feasible, one key issue remains to be resolved. How can the safety of air transport users and people on the ground be ensured in an airspace simultaneously occupied by manned and unmanned aircraft?

The integration of Unmanned Aerial Systems (UAS) into the airspace system is becoming increasingly significant. The media often report on dangerous encounters between drones and manned aircraft or helicopters. Several such incidents have also occurred at airports. As a result, Germany's Federal Government made its first attempts to regulate the system in 2017, initiating laws such as the Drone Regulations (Section 21a/21b of the German aviation regulations, LuftVO). These prohibit drones from flying in sensitive zones – near airports or locations where police and fire brigades are on the scene. Yet these measures are limited and do not cover the normal requirements of a growing aviation sector. In particular, operators of small and medium-sized unmanned aircraft (>25 kilograms) are very interested in flying permits. Scenarios range from hobby use to a variety of commercial applications (infrastructure monitoring, parcel delivery, agricultural support), as well as official deployment (civil defence, rescue operations). At present, however, there is neither a fully defined legal framework nor an established infrastructure to enable and safely manage the widespread use of UAS in general airspace.

Today's UAS are used for a variety of missions and applications. To meet the various requirements they vary in size – from quadcopters to medium-sized unmanned helicopters and larger, fixed-wing aircraft – and performance (manoeuvrability and collision avoidance ability), as well as technical characteristics (sensor systems and degree of autonomy). The challenge is to safely plan and monitor the flight movements of UAS with such different characteristics within airspace that includes other air traffic users, such as helicopters, gliders and skydivers.

Looking further into the future, the urgent need for intelligent rules becomes even clearer. According to a study by the SESAR (Single European Sky ATM Research) Joint Undertaking published in November 2016: "By 2050, it is estimated that there will be some 7 million consumer leisure drones in operation across Europe, including a fleet of 400,000 drones offering important services across the agricultural, energy, e-commerce, transport as well as public sectors." Drone fleets for parcel services and infrastructure monitoring will play a major role in this regard, but interest in air taxis is also growing. This requires special safety measures.

As such, the integration of UAS into airspace requires a comprehensive solution. In the long term, it must ensure safe and efficient operation – even for the widest range of air-traffic participants and when traffic volumes are high. Depending on the airspace category and drone's mission area, the airspace under consideration will define specific requirements for those involved. Flight rules and minimum separations must be observed, and aircraft must be equipped with transponders depending on the airspace category. Flight in urban areas requires the consideration of various other aspects. Complex obstacle scenarios place high demands on detection systems and UAS flight capabilities, and there are additional risk factors – such as crowds, critical infrastructure, areas with high probabilities of signal loss, or downdrafts – for which flight restrictions or even no-flight zones may have to be imposed.

Data protection is another key concern. The cameras on UAS acquire data that could be misused –a potential problem that could be detrimental to their acceptance by the general population. Noise, emissions and environmental factors also play an important role. All of these aspects must be considered and used to devise a viable concept that accommodates safety, cost-effectiveness, technical feasibility and societal concerns.

REQUIREMENTS OF AN AIR TRAFFIC MANAGEMENT SYSTEM INCORPORATING UNMANNED AIRCRAFT

The tasks of classic air traffic management (ATM) also apply in unmanned traffic management (UTM). This covers the optimal use of the available airspace (airspace management, ASM), air traffic flow management (ATFM) and operational air traffic services (ATS). As such, UTM should enable safe and efficient UAS operation in lower airspace (below 500 feet) in the medium term and in controlled airspace in the long term. This will require services such as:

- airspace organisation and management, including geo-awareness (notification of prohibited or restricted airspace areas),
- the planning and approval of UAS flights,
- dynamic capacity control,
- route planning and route changes,
- contingency management,
- separation, conflict and emergency management,
- weather and wind restrictions, and
- terrain and obstacle mapping.

DLR expertise for future air traffic management

The DLR Institute of Flight Guidance has been conducting research into concepts and technologies to integrate UAS into airspace for many years. In early 2018, it presented a concept for a flexible, Europe-wide airspace management system, referred to as U-space. This opens up airspace to UAS with both low and high levels of technology. At the same time, it provides incentives for UAS manufacturers and operators to invest in the new technology, but does not prevent minimally equipped and lower-performance airspace users from entering U-space. The concept is based on efficient airspace segmentation and models for UAS performance. Airspace characteristics – population density, land use, geofences, availability of U-space services, and the occurrence of traffic operating under visual flight rules – are used to divide up the airspace into cells with similar use requirements.

According to the DLR concept, the lower the overall performance capability of the airspace participant, the greater the safety distance and the bigger the airspace area required for its exclusive use. This means that an airspace area could be used simultaneously either by a few low-performance aircraft or by several high-performance aircraft. The resulting airspace management would offer a great deal of freedom when traffic volumes are low, but little freedom when they are high. This would allow the U-space to be organised safely and efficiently. Conflict-free routes and missions could be strategically planned and monitored – even in dense traffic scenarios.

As part of its national City-ATM project (Demonstration of Traffic Management in Urban Airspace), DLR is working on a concept for the management of urban airspace. It should enable the safe and efficient integration of new air traffic participants, such as UAS and air taxis. This includes defining and verifying operational and technical concepts for airspace management and providing information. Traffic flow management, monitoring traffic for possible conflicts and developing basic concepts for a communications, navigation and surveillance infrastructure must also be considered. A simulation and demonstration platform for an urban air traffic management system is being devised on this basis. This assists with identifying and realising unmanned aircraft configurations that can operate safely in these environmental conditions and in accordance with the new regulations. DLR researchers are hoping that the project will bring together many stakeholders – including UAS manufacturers, urban traffic management system providers, aviation authorities and drone operators – in order to develop a comprehensive solution for the integration of (partially) automated aircraft into the airspace.

The three-year City-ATM project was launched on 1 January 2018. It is based on the European SESAR U-space programme. Ultimately, City-ATM is intended to demonstrate a comprehensive solution for a future U-space.

Dagi Geister heads the research group for unmanned aerial systems (UAS) at the DLR Institute of Flight Guidance in Braunschweig. She addresses research questions concerning the integration of UAS and air taxis into airspace, and is involved in numerous European committees and initiatives for the design of U-space and Urban Air Mobility.

Flight demonstration of the City-ATM system

The first demonstration phase of the City-ATM project was successfully completed in May 2019 in Hamburg. It demonstrated how automated UAS could fly safely together within urban airspace with the help of networked flight planning, registration and identification, as well as flight monitoring, conflict detection and conflict avoidance.

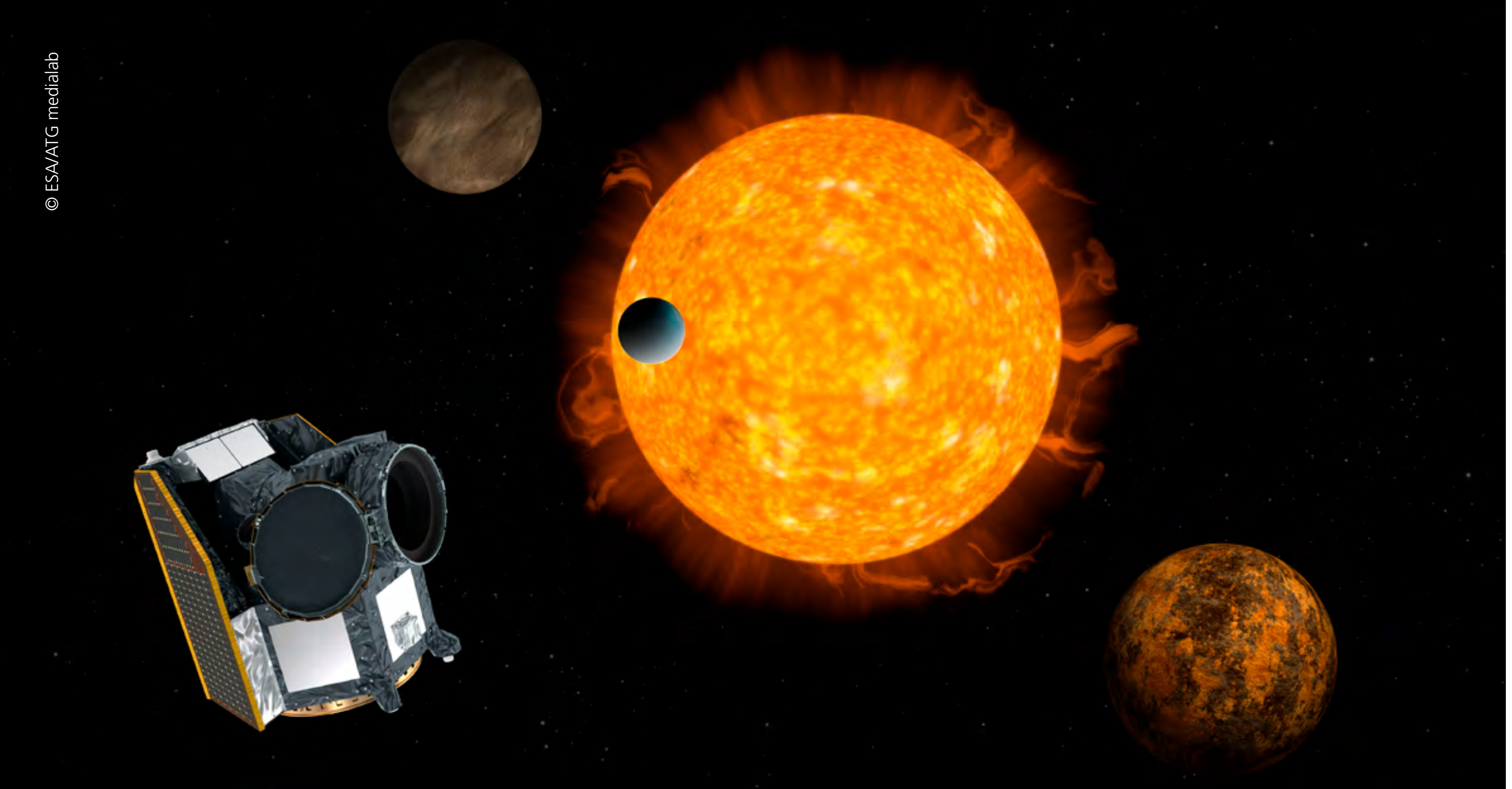
Design of manned and unmanned airspace use (SESAR U-space Blueprint)

REGULATIONS FOR U-SPACE

On 11 June 2019, the European Union Aviation Safety Agency (EASA) published new regulations (DELEGATED REGULATION (EU) 2019/945) aimed at harmonising the rules for drone flights throughout Europe. These are to be enacted as national law by June 2020. In particular, they will replace the current rules for the operation of drones under Sections 21a and 21b of the German aviation regulations (LuftVO). The major changes enacted by these new regulations have a particular bearing on the subdivision of UAS missions into the categories of OPEN, SPECIFIC and CERTIFIED. In the OPEN category, UAS can fly without authorisation in EU airspace areas designated for that purpose under strict operational restrictions. In contrast, the SPECIFIC and CERTIFIED categories have operational and technical requirements due to their respective mission risks, which generally require approval by a competent authority. In addition, all UAS must bear a CE mark following a transitional period of two years.

Other regulations relate to the future use of U-space – the airspace allowed for drone flights (up to 500 feet above the ground). These rules will cover the structuring of the airspace, the different airspace categories and the types of drone flight permitted within them under various conditions. They will also provide for basic services (information and capabilities) to safely and efficiently manage large numbers of UAS within airspace.

An initial draft of the U-space regulations is available and should be presented by EASA in the fourth quarter of 2019. It is important to note that the fundamental idea of U-space in the long term envisages the integration of manned and unmanned air traffic. As such, this will eventually affect the airspace currently reserved for manned air traffic. The design of future airspace and the associated impact on air traffic must therefore be carefully considered now.



EXAMINING EXOPLANETARY CANDIDATES

ESA's small CHEOPS space telescope to deliver great science – DLR participates in the investigation of extrasolar planets

By Ulrich Köhler

This autumn will see the launch of a 'S-class' mission into space. In this case, however, the 'S' does not stand for 'supersize' or 'super performance', but for 'small'. CHEOPS – CHaracterising ExOPlanet Satellite – is the first small-scale mission by the European Space Agency (ESA). Its primary objective is to investigate 'exoplanets' discovered by other satellites, or from Earth-based telescopes using the radial velocity method.

This technique measures tiny changes in a star's light spectrum caused by the motion of the star and one or more planets around their common centre of mass. This oscillation manifests itself in an elongation (redshift) or compression (blueshift) of the starlight wavelengths in a phenomenon known as the Doppler effect, named after the Austrian physicist Christian Doppler (1803–1853).

Investigating promising candidates

The discovery of the first exoplanet orbiting a sun-like star in 1995 spawned a revolution in astronomy. Located approximately 50 light years from Earth, 51 Pegasi b was considered an astronomical sensation. This discovery ushered in a whole new discipline within the oldest of all the sciences. Didier Queloz of the University of Geneva – one of the two scientists who discovered the planetary companion of the star Helvetios in the Pegasus constellation – calls it 'exoplanetology'. The word is a combination of the terms 'planetology' – which until then had been limited to the Solar System – and 'extrasolar planets', or exoplanets for short. These are the new kids on the block.

Today, we know of more than 4000 exoplanets, which have been discovered by ground-based telescopes or by space telescopes such as Kepler, TESS and CoRoT. The Kepler mission has been particularly prolific in revealing planetary candidates, but many of the Kepler 'candidates' still remain to be checked and confirmed. As such, CHEOPS' main task is to determine the size, orbital period and physical characteristics of these planets by measuring the light curves of bright stars during so-called transits – the path of the exoplanet in its orbit when it crosses the star's disc – and their associated dimming.

The key lies in density

The main objective of the mission – which was selected in 2012 – is to investigate the structure of exoplanets larger than Earth but smaller than Neptune, or with a diameter of between 10,000 and 50,000 kilometres. The technique used – transit photometry – is highly precise. The prerequisite is a favourable observation geometry. The planet identified by the Doppler effect must pass in front of its star in the observation plane of the CHEOPS telescope. Only then can a light curve be recorded using the transit method.

The planet's size can be determined by observing the dimming of the starlight during a transit. When combined with the mass – determined from the radial velocity measurements – it provides a measure of the planet's density. This is one of the most important parameters for characterising the star and determining the nature of the planets in orbit around it. For example, it will be possible to distinguish Earth-like planets with solid rock surfaces from gas planets or ocean worlds. The telescope has a spectral range of 400 to 1100 nanometres.

CHEOPS will also observe planets while they orbit their star – and are thus illuminated by its light. The researchers hope that this will allow them to draw conclusions about the existence of an atmosphere, and perhaps even find out whether the exoplanet has clouds. Unlike earlier missions, CHEOPS is not a 'discovery instrument', but rather a follow-up mission that will focus on individual stars that are already known to host one or more planets. ESA's much larger PLATO mission, which will be equipped with 26 individual telescopes and cameras, is tasked with finding new exoplanets, especially Earth-like planets, starting in 2026.

A small telescope on a big mission

The 120-centimetre-long CHEOPS telescope has a 30-centimetre aperture and weighs less than 60 kilograms. Together with its platform, it weighs just 300 kilograms. As such, the space telescope does not require its own launch vehicle for the journey into space. It will be carried to orbit as a 'free rider' together with another payload on board a Soyuz launcher that will take off from ESA's spaceport in French Guiana by mid-December. The telescope platform, which was manufactured by Airbus Defence and Space in Madrid, has a hexagonal basic structure and is only 1.5 metres long. DLR, which is also involved in the scientific evaluation of the data, helped develop the focal plane module for the image sensor, and the sensor electronic module for the underlying front-end electronics, at the Institute of Optical Sensor Systems and the Institute of Planetary Research. The focal plane module represented a particular challenge for the overall system, both in terms of system performance and because of the short development time. CHEOPS is a joint ESA-Switzerland mission. The Swiss organisations lead the consortium of 11 ESA Member States contributing to the mission, including Germany.

Ulrich Köhler is a geologist at the DLR Institute of Planetary Research and, after 30 years of research into the Moon, Mercury and Mars, is now taking the leap towards exploring planets orbiting the millions of stars in the Milky Way.

The CHEOPS focal plane module (bottom, base plate diameter about 40 centimetres). Above it is the module for the sensor control electronics. Both modules were developed and built at the DLR Institute for Optical Sensor Systems in Berlin-Adlershof.

ABOUT THE MISSION

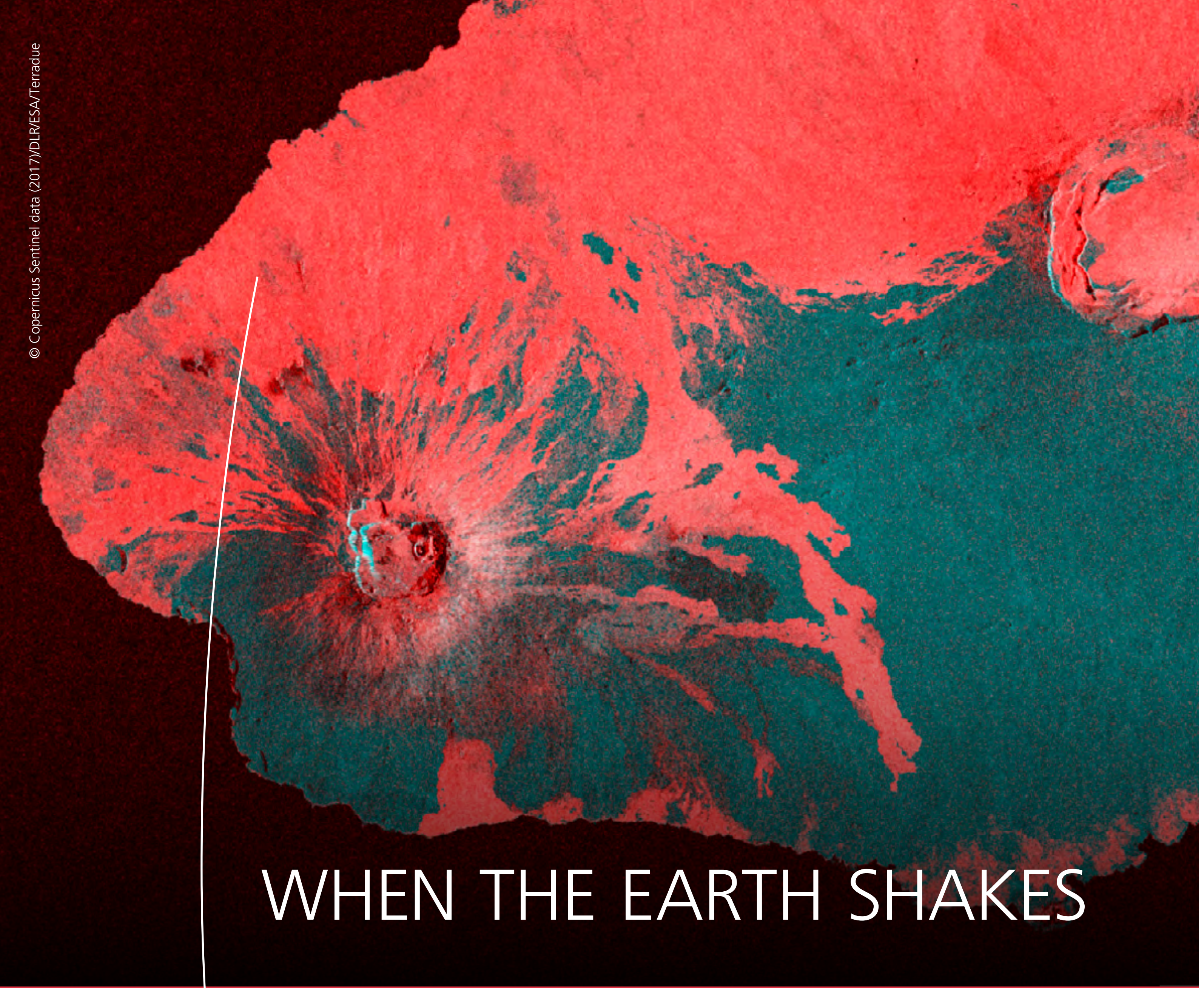
CHEOPS will conduct its observations from a low, Sun-synchronous Earth orbit at an altitude of 700 kilometres and will initially operate for three-and-a-half years, with the option to a five-year extension. The mission will be controlled from the CHEOPS Mission Operations Centre in Torrejón de Ardoz, Spain, which will be in contact with the telescope when it flies over the ESA ground stations in Spain. Around 1.2 gigabits of observation data will be sent to Earth during the five to six transfer phases that take place on a daily basis. The scientific operations centre is located at the University of Bern, Switzerland.

One of the outstanding features of the telescope is that it offers the possibility of maintaining an extremely high target accuracy of 1 arc second over long periods of time. The Sun orbit, orientation and rotation of the space telescope have been configured so that it can be targeted at almost any point in space. A typical observation cycle lasts 48 hours. The high sensitivity and stability guaranteed by the DLR-developed focal plane module are decisive for the success of the mission. In addition to the observations made by the CHEOPS team, one-fifth of the telescope's operating time has been reserved for external scientists.

DLR.de/en/cheops

ESA: sci.esa.int/cheops

University of Bern: cheops.unibe.ch



WHEN THE EARTH SHAKES

A smarter Big Data process – monitoring geohazards from space

By Bernadette Jung

Global change is manifested in many ways and reveals itself in different areas of the living world. With a wide range of consequences for the environment, global change and its interactions are affecting humans in ways that can no longer be ignored. In recent decades, for example, the risk of being affected by natural disasters has increased. Firstly, climate change is resulting in more and more extreme weather events. Secondly, people around the world are increasingly living in urban areas, populating regions ever more densely and getting closer to the areas affected by volcanoes, tsunamis and powerful earthquakes. A single local event can also have immediate consequences in other parts of the world. The eruption of the Icelandic volcano Eyjafjallajökull in 2010 and the resulting flight ban over Europe demonstrated this in a dramatic way. In order to better predict and avoid geohazards, it is necessary to acquire a better understanding of their origins and the complex processes involved. Advanced remote sensing satellites and technologies are indispensable for this. Experts at the DLR Earth Observation Center (EOC) have thus set up a special data service, which is available via the Geohazards Exploitation Platform (GEP).

The Geohazards Exploitation Platform

GEP is a cloud-based web portal developed by Terradue Srl on behalf of the European Space Agency (ESA). The DLR Earth Observation Center (EOC) offers two services on the GEP web portal – up-to-date mapping of the world's most dangerous earthquake zones and monitoring of 22 volcanoes. The first service, the Sentinel-1 Medium-Resolution InSAR Browse Service, operates with a resolution of 100 metres. Fourty percent of Earth's active seismic areas are under its constant observation. The analyses are freely accessible via the data portal. The second service observes the world's most dangerous active volcanoes at a resolution of 50 metres. This Sentinel-1 High-Resolution InSAR Browse Service is also used for expert evaluations following the occurrence of major earthquakes.

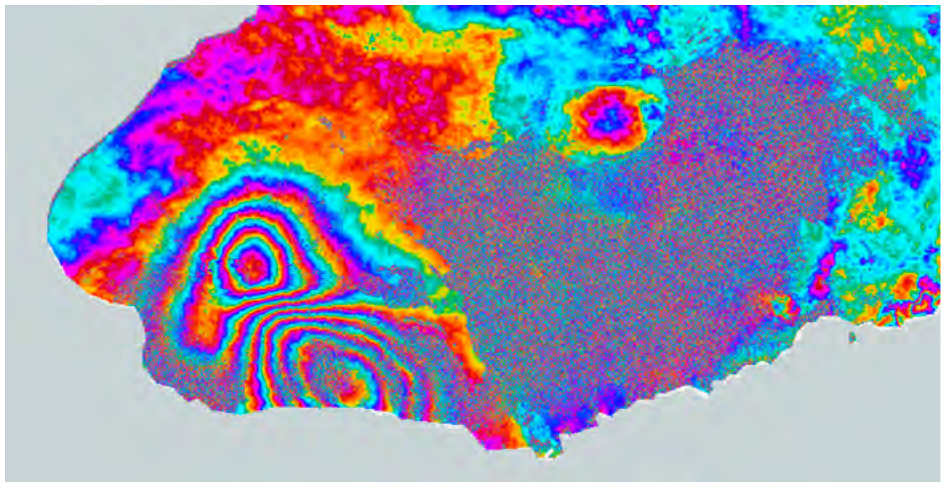
Ramon Brcic – an expert on the analysis of Earth observation data and Project Manager for the Sentinel-1 InSAR Browse Service on GEP.

Both services process radar data acquired by the Sentinel-1 mission. The Sentinel-1A and Sentinel-1B Earth-monitoring satellites have been in orbit since 2014 and 2016 respectively, and can generate images regardless of the weather conditions. They can detect the smallest ground movements, even from an altitude of 700 kilometres. Their radar signals can penetrate vegetation and detect surface elevation changes in the centimetre or even millimetre range. The Sentinel-1 satellites deliver images of Europe every six days, and images of the rest of the world every 12 days. "As soon as we receive the signals, our system automatically processes the Synthetic Aperture Radar (SAR) data from the satellites to derive various data products and uploads these directly to the cloud. These include amplitude images, interferograms and other radar images that make deformations of the Earth's surface visible," says Ramon Brcic, who works at the DLR Earth Observation Center in Oberpfaffenhofen and is Project Manager for the Sentinel-1 InSAR Browse Service on GEP.

"With our InSAR service on GEP, experts can decide immediately which datasets need to be examined more closely. Once they have performed a detailed analysis, they can make statements about the risk of further earthquakes and their expected strength."

Ramon Brcic

The radar products allow geophysicists, volcanologists, seismologists and other experts to draw conclusions about changes to the Earth's surface – from variations in height, ground conditions and topography, through to the smallest movements. This is important for making predictions and mapping risks. For example, time series analyses of hundreds of images over several years can be used to determine exactly where deformations are occurring at tectonic plate boundaries and how fast the plates are moving. It also allows natural events such as earthquakes, volcanic eruptions and flooding to be assessed faster and more effectively. Research centres, measurement stations and monitoring services therefore use the data service provided by scientists at the DLR site in Oberpfaffenhofen. "With our InSAR service on GEP, experts can decide immediately which datasets need to be examined more closely. Once they have performed a detailed analysis, they can make statements about the risk of further earthquakes and their expected strength," Brcic explains. "Normally, these kinds of ground movements have to be surveyed with GPS sensors on site. Thanks to radar interferometry, we can map large areas in detail with a single overflight."



GEP view of the Cerro Azul volcano on the Galapagos island Isabela (Ecuador) at high resolution (50 metres) from the InSAR Browse Service. The interferometric phase shows the ground movement caused by a magma intrusion during the period from 8 to 20 March 2017. The coloured fringes show a drop of 11 centimetres at the summit and a 14-centimetre rise on the southeast flank.

Status at a click

The Sentinel mission is part of the European Earth observation programme Copernicus, so the satellite data are made freely available. Private individuals, researchers and service providers alike can use the raw data to obtain information, conduct research or develop new applications. But before this can happen, enormous amounts of data are accumulated and need to be analysed. Where should we be looking? What information can be derived from the data? Which datasets need to be examined more closely?

"ESA has defined seven subject areas, which effectively act as initial filters so that the various users can access the Sentinel data quickly and in a targeted way. Each topic has its own data portal – the coastal environment, forestry, hydrology, polar regions, the urban environment, food security, and geohazards – for which we at EOC are responsible," Brcic says. As a specialist in SAR signal processing, he knows just how difficult searching for suitable datasets can be.

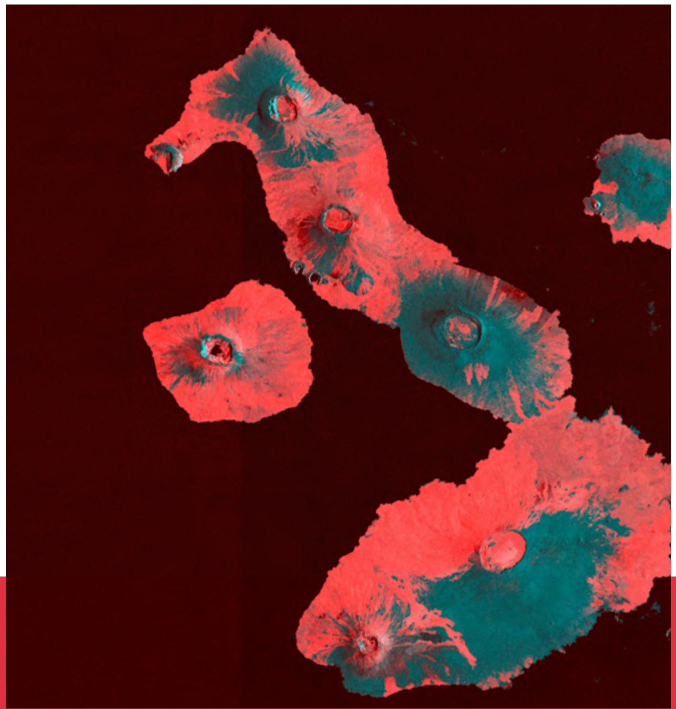
The special feature of GEP is its fully automated processing chain. User-specific data products are made available there, ready for use. Through a search mask, visitors to the web portal can have an immediate overview of all major volcanic and earthquake regions. If required, the pre-defined search area can be adjusted manually. "If I need data about a particular earthquake, all I have to do in GEP is check whether the event was recorded by the satellites and whether an interferogram is available. I can see this immediately and decide whether it makes sense to process the data further. Usually, there are several interferograms of an earthquake from different imaging directions, acquired at different times, so I can select the one best suited to my analysis," Brcic says, describing the advantages of this approach. "I do not have to do anything else – the images are right in front of me."

Automated data processing

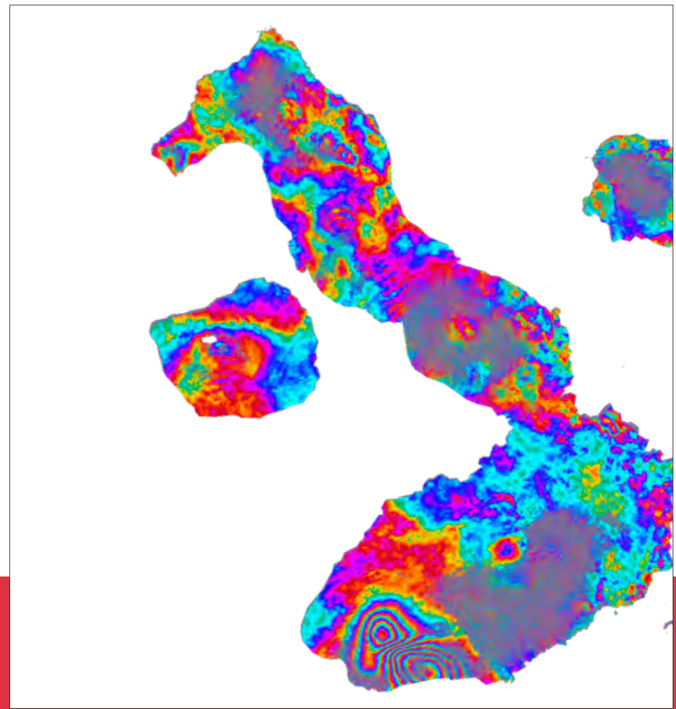
The 'Integrated Wide Area Processor' (IWAP) software is used to process the radar data and generate the images for GEP. IWAP can ingest data from sensors on several radar satellites using various software modules. The system was developed by researchers at the DLR Remote Sensing Technology Institute around 15 years ago. It is constantly being further developed and adapted to meet new requirements. Brcic's team has integrated the proven DLR processor into ESA's portal system for the systematic monitoring of geohazards. IWAP obtains the Sentinel-1 satellites' raw data directly from the Copernicus Open Access Hub – the central data archive of the European Earth observation programme. The processor generates six end products from each image pair. The resulting radar images are made available on GEP at the end of this interferometric processing chain.

Only a few interferograms per day are required for the high-resolution observation of the 22 volcanoes. In contrast, the medium-resolution service for seismic areas covers a total of 15 percent of Earth's land surface. During 2017 and 2018, the system reached peak performance, converting one terabyte of raw data into more than 100 interferograms per day or one interferogram every 15 minutes. Since then, all of them have been available to scientists and other users.

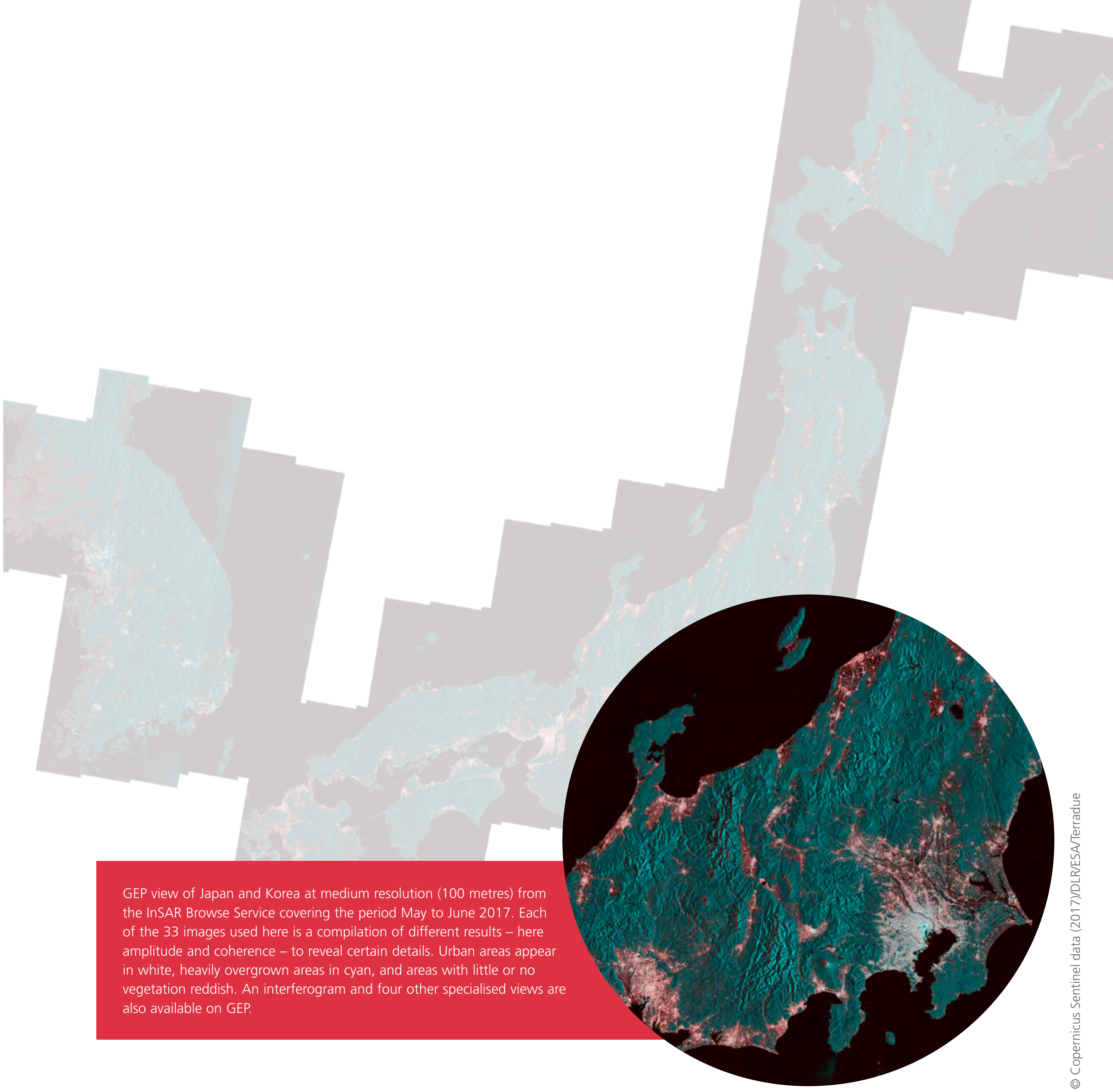
GEP has been online since mid-2016 and has now successfully completed its trial phase. With the processing of Big Data on an operational platform, the SAR team from Oberpfaffenhofen has been able to demonstrate the full capability of its system to striking effect. But the technological possibilities do not end there. In the future, yet another IWAP processor function could be integrated into the data service. For example, the Persistent Scatterer Interferometry



Galapagos Islands – this GEP product combines two different aspects of an image pair, amplitude and coherence, and highlights these properties using false colours. Bare or only lightly vegetated regions (red) can be distinguished from more heavily vegetated regions (cyan) at a glance (High-Resolution InSAR Browse Service, March 8-20, 2017).



Galapagos Islands – this interferogram shows how the ground rises and falls due to volcanic activity. Each coloured fringe represents a change of 2.8 centimetres (High-Resolution InSAR-Browse Service, 8-20 March 2017).



GEP view of Japan and Korea at medium resolution (100 metres) from the InSAR Browse Service covering the period May to June 2017. Each of the 33 images used here is a compilation of different results – here amplitude and coherence – to reveal certain details. Urban areas appear in white, heavily overgrown areas in cyan, and areas with little or no vegetation reddish. An interferogram and four other specialised views are also available on GEP.

(PSI) processing chain takes hundreds of images of an area acquired over a period of years and automatically generates ground deformation velocity maps with an accuracy reaching one millimetre per year. The process is already being used and further developed outside of GEP for earthquake risk assessment.

The necessary technologies and expertise for additional applications and services are certainly available. "If more services are needed, then it is computing power that is important," says Brcic. "One way of saving on computing power and using it even more efficiently is to process the data in a more targeted way. This means that the service only creates an interferogram of an area when a request is made." At present, the team is working on converting the system to an event-driven service. In the future, GEP will automatically search for and process the appropriate Sentinel-1 data in the event of an earthquake or volcanic eruption. The remote sensing experts at the EOC will also continue to develop practical methods and find smart Big Data solutions to protect people from geohazards.

Bernadette Jung is an editor at the DLR site in Oberpfaffenhofen.

geohazards-tep.eu

Measuring, cleaning, taking photographs, documenting – all of the Eye2Sky measuring stations have to undergo regular maintenance. Thomas Schmidt examines a key measuring station on the roof of EWE AG in Oldenburg, where the camera image overlaps with those of other network stations in several directions.

EYES ON THE CLOUDS

DLR is setting up a one-of-a-kind meteorological network for highly accurate forecasting of solar radiation

By Heinke Meinen

The air has that clear, northern Germany quality to it, and a cool breeze wafts over the land. Small clusters of clouds alternate with spells of sunshine in quick succession. The light and shadow change almost by the minute. From the roof, there is a 360-degree view. Thomas Schmidt checks the exact horizontal alignment of the sensors one last time. Everything is fine: the new cloud camera is ready to be used. "Our network is growing," he says with satisfaction. "This is the ninth measuring station that we have put into operation, and it is in the ideal spot."

This ideal spot is in Friedrichsfehn, located about seven kilometres southwest of Oldenburg, Germany, on the shallow-pitched roof of a private bungalow. A brick chimney provides a firm footing for the two-metre-tall measuring station. This location is particularly suitable because it gets so much wind from the southwest. The clouds that scud overhead reach the city, with its scores of photovoltaic systems, just minutes later. Thomas Schmidt is aiming at precisely this kind of short-term weather forecasting. An energy meteorologist, he conducts research into the interface between climate and the energy transition at the DLR Institute of Networked Energy Systems.

"The intensity of the sun and wind has a direct impact on our energy system. This is true today, and it is likely to increase significantly in future," says the scientist, who has been building a network of up to 34 cloud cameras and other measuring sensors with his team for almost one year. Known as Eye2Sky, from 2020 it will be keeping an eye on the sky between Oldenburg, the North Sea coast and the Dutch border. The primary objective of the project is to provide comprehensive solar-radiation forecasting with extremely high spatial and temporal resolution. In future, the energy yields of all photovoltaic systems in the region should be calculated on a per-minute basis. Such data are particularly helpful for grid operators, who have to counteract short-term fluctuations in photovoltaic yield by means of intelligent feed-in and storage management systems. This becomes more necessary as the amount of renewable energy that is fed into it increases. The stability of the power grid is a top priority.

Schmidt looks after the interests of the grid operators. He can offer them solutions – at least in theory. In practical terms, however, he is mainly grappling with organisational issues at the moment. "Every new station presents a real challenge," he says. "It takes weeks, and sometimes months, to set up a station like the one here in Friedrichsfehn, and it involves a great deal of paperwork." There are issues of liability, guaranteed usage times, and assumption of costs. Legal matters have to be resolved, and contracts signed.

The suitability of a site for the grid does not solely depend on geographical location. Its ownership, the load-bearing capacity of the roof, and unrestricted access for maintenance and cleaning are also criteria for selection or exclusion of the site. "Even if everything is in place and the owner wants to support our project," Schmidt says, "we have to check numerous other factors: How can we ensure lasting, weather-proof power supply on the roof, for instance? Does the building have storm-proof mounting options? Does the site have 4G network quality for data transfer? Will the owner of the property allow us to use the Wi-Fi network as an alternative? And most importantly, are there any buildings or trees that might block the view of our cloud camera?"

Conventional weather forecasts are a long way from being able to predict cloud shadow on the ground as quickly and precisely as the Eye2Sky measuring network. This is partly due to the three-dimensional cloud structures, which cannot be detected in satellite images. This gives the network, which views the sky from different locations, a decisive advantage. Schmidt points to the white hood over the other measuring devices at the station and explains: "These cloud

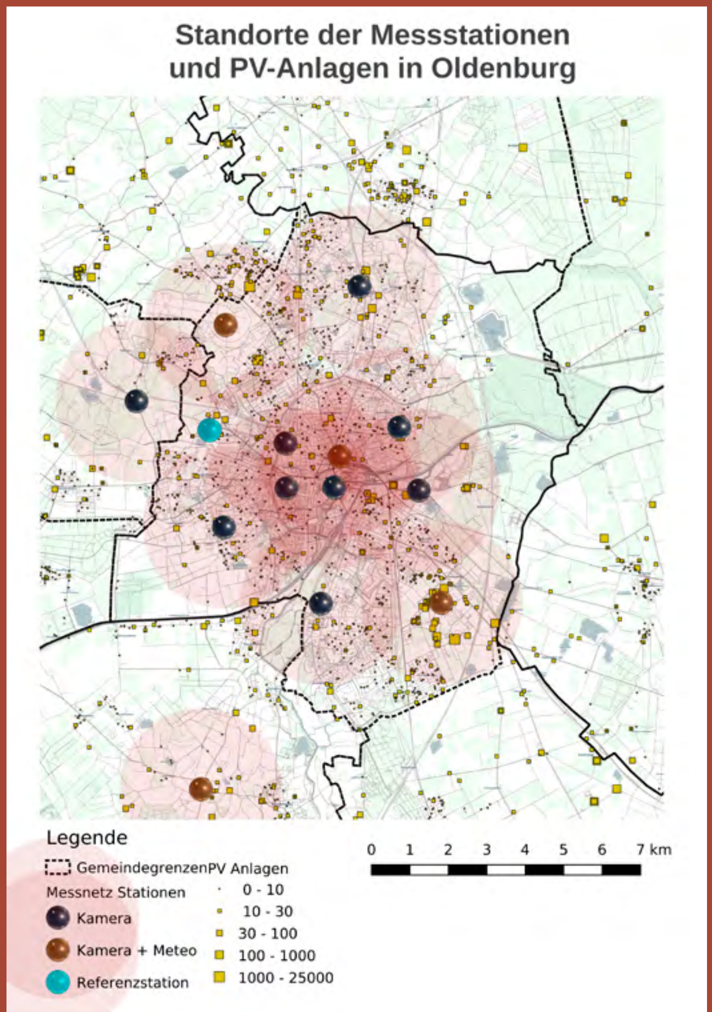
> "These cloud cameras photograph the sky every 30 seconds with a 360-degree view, capturing about four kilometres in every direction."

cameras photograph the sky every 30 seconds with a 360-degree view, capturing about four kilometres in every direction." He continues: "Depending on cloud cover, it can sometimes be further or nearer. Because the images of neighbouring stations overlap in places, we can calculate the altitude of individual clouds. This is key because we are not interested in the position of the cloud, but rather its shadow."

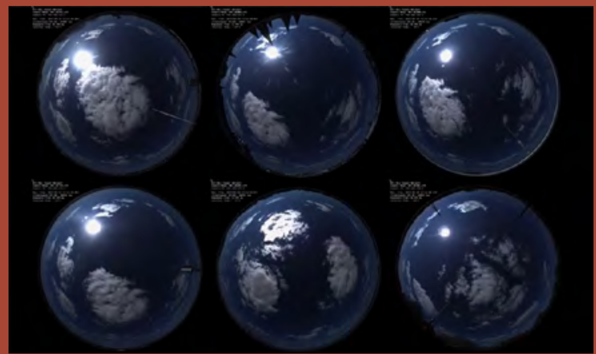
All of the data – which include information about temperature, humidity and diffuse light radiation, in addition to the images from the cloud cameras – are constantly being transmitted to a high-performance computer at the Institute of Networked Energy Systems. This flood of information is processed using software developed by the DLR Institute of Solar Research at its field site in Almería, Spain, where staff are actively assisting the Oldenburg-based researchers with the data evaluation. Only then do the raw camera images – which simply show countless distorted images of the sky at first – lead to usable predictions that can be greatly beneficial to network operators in future.

Whether this will actually happen remains an open question. "It is a research project, not a product that is ready for the market," Schmidt says. "We have to gain experience and continue developing the technology." How the overall package of costs, benefits and outlay looks at the end will be key. To this end, the team of scientists in Oldenburg will build up the Eye2Sky network step by step. Schmidt already has his eye on a promising location for the tenth measuring station: the roof of an old tank hall on the site of the former Oldenburg airbase. Of course, no site is without its complications – but this one is very attractive indeed, as an ultra-modern residential district with innovative energy concepts and countless solar units is being built here. In future, the Eye2Sky network will be able to provide reliable forecasts of their energy yield, including from the measuring station on the bungalow in Friedrichsfehn – at least when the wind blows from the southwest.

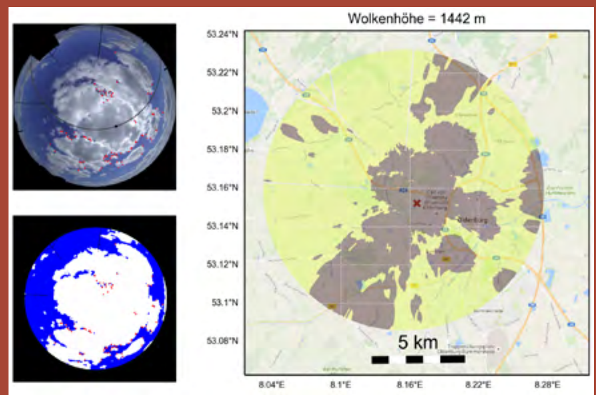
Heinke Meinen is responsible for communications at the DLR Institute of Networked Energy Systems in Oldenburg.



The Eye2Sky network is to be expanded in the Oldenburg urban area in a particularly close-knit way. The need for accurate forecasting is especially pressing here due to the numerous solar units installed on the roofs of private homes.



The sky as seen from different locations at the same time. Software developed by DLR allows comprehensive forecasting of cloud shadow to be calculated for the coming minutes.



The original image from the cloud camera (above left) shows the whole sky above the measuring station, from horizon to horizon. These data only become meaningful once they are rectified and, as here, projected onto the Oldenburg urban area.

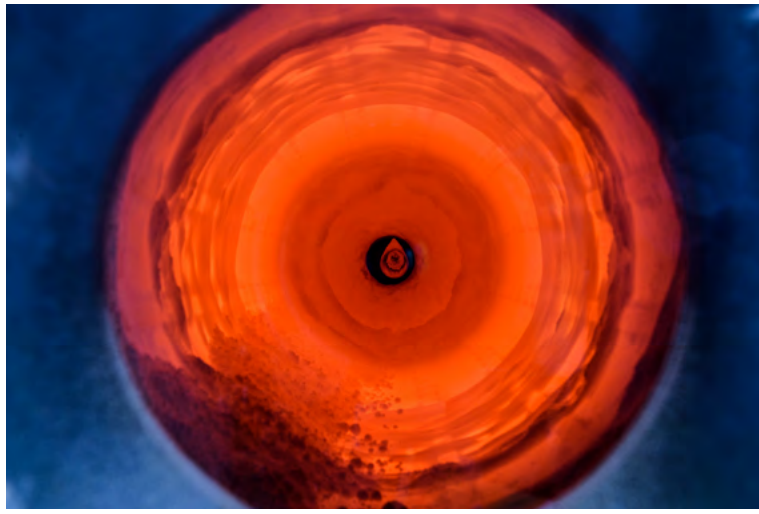
ENERGY NEWS

DRYING ITALIAN PASTA USING SOLAR ENERGY

From 2021, a solar tower power plant will provide process heat for drying pasta at a production facility in Italy. At the 22nd Solar Colloquium in Cologne in July 2019, Eckhard Lüpfert of HelioHeat GmbH showed how the EU-funded project HIFLEX is developing a high-temperature particle system for use in a plant belonging to the Italian pasta company Barilla. The integrated thermal storage system absorbs wind power as well as solar-generated heat, so that sufficient heat can be provided even during times of low solar irradiance.

In general, heat supply using renewable energy sources is lagging behind sustainable power generation. For industrial processes, conversion to low-carbon or carbon-free heat supply is still in its infancy. One reason for this is that industrial processes generally need high-temperature heat to be available around-the-clock. Variable energy sources, such as wind or photovoltaic power, cannot reliably cover these needs due to a lack of large-scale energy storage options. The Solar Colloquium showcased practical cases from industry that demonstrate how high-temperature heat supply from concentrating solar power plants can contribute towards the decarbonisation of industrial processes.

For example, emissions of large quantities of carbon dioxide can be avoided by switching the production of sulphuric acid from fossil fuels to solar-thermal heating. A thermochemical storage system was presented, in which the temperature of the stored heat rises during the storage period instead of falling. The storage system can absorb solar-generated heat and then release it at a higher temperature, thus increasing the efficiency of the conversion from heat to power.



Using the heat of the Sun – a view into a rotary kiln in the high-flux solar simulator at the DLR's Cologne site, with the raw cement powder still glowing.

HYDROGEN-POWERED REGIONAL TRAIN VISITS OLDENBURG

In the summer of 2019, the world's first hydrogen-powered regional train visited Oldenburg. On the initiative of the 'H2OL' interest group, in which the DLR Institute of Networked Energy Systems is also involved, the fuel-cell-powered train developed by the French manufacturer Alstom made a special trip on 25 June 2019 as part of the 'Hydrogen drives us on' day of action. The train has been in service between Cuxhaven and Buxtehude since September 2018.

Particularly in northern Germany, the development of a hydrogen infrastructure is an obvious choice. Here, a large part of the energy from wind turbines is fed directly into the power grid. Surpluses that occur, for example, at night or during times when the winds are strong, could be stored on a large scale in the form of hydrogen. This could be done on a long-term basis, directly on site. Doing so would provide a chemical energy carrier to be used either in the transport sector or for electricity generation to ensure security of supply. This principle of cross-sectoral use is very important element for the success of the energy transition.

Regional transport on the move – the hydrogen powered regional train provides a regular service in the north of Lower Saxony, between Cuxhaven and Buxtehude – low-noise and emission-free.

SAFETY FIRST

DLR scientists are developing methods to enable automated cars to drive safely

An interview conducted by Julia Heil

Jens Mazzega
works in the Automotive Department at the DLR Institute of Transportation Systems in Braunschweig. His work focuses on testing and ensuring the safety of automated and networked vehicles. Mazzega is fascinated by the fact that he can experience the development of the individual building blocks of automated driving up close and can help shape both strategy and content. In recent years, the researcher's ideas have produced tangible results that are now being transferred to series development and secured for product use.

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Trial of the PEGASUS system at the Volkswagen test facility in Ehra-Lessien. All participants are networked to control and synchronise the test sequence.

Driver assistance systems in cars, such as cruise control or parking aids, are by no means unusual nowadays. Cars with traffic queue assistance can stop and start almost automatically in heavy traffic. Jens Mazzega from the DLR Institute of Transportation Systems is convinced that people will soon be able to relinquish control to their vehicles for short periods of time. However, before automated driving systems are introduced into the market, he and his team are asking one question – how safe is safe enough?

Mr Mazzega, you work on the safety of highly automated driving functions. What is the purpose of your research?

: Automated driving, where drivers are not required to have their hands on the wheel or their eyes on the road, is getting ever closer. Many manufacturers have already demonstrated applications on the road, with cars that can turn left, others that can drive well in straight lines with an automated system, and others able to wonderfully navigate through bottlenecks. But combining all of these features still does not result in a perfect automated vehicle, as each of them can only handle one situation at a time. Just because a car can drive along a two-lane motorway does not mean that the system will also work on a three-lane motorway.

We wanted to be able to make a statement about when an automated driving function is safe enough to be used in road traffic, so we launched the PEGASUS project. PEGASUS stands for '**P**roject for the **E**stablishment of **G**enerally **A**ccepted quality criteria, tools and methods as well as **S**cenarios and **S**ituations for the release of highly automated driving functions'. In this project, we have carefully considered the questions that need to be asked and the scenarios that must be examined to ensure safe driving. The end product, however, was not a concrete software for testing the driving functions, but rather a methodology that specifies how the test requirements for an automated driving system should be defined and which tests it would have to pass in order to be considered safe.

Can you think of an analogy to explain how it works?

: If a safe driving function were a cake, we could write a recipe for it. We would say, use 600 grams of flour, but would not specify which brand of flour should be used.

ABOUT PEGASUS

The idea for PEGASUS arose from a discussion between the German Federal Ministry for Economic Affairs and Energy (BMWi) and DLR related to getting automated vehicles certified faster and more safely. As a result, the project was born and given 16.3 million euro of funding from BMWi. PEGASUS was set up in record time; in less than a year, the project grew to have 17 partners and a total budget of more than 34.5 million euro. It was jointly coordinated by industry and research – Thomas Form, Head of Electronics and Vehicle Research at Volkswagen Group Research, and Karsten Lemmer, DLR Executive Board Member for Energy and Transport. The project ended in June 2019. In April and July 2019, research work began on the follow-up projects **SET Level 4to5** and **VV Methods** (validation and verification for highly automated driving). These each have a duration of three-and-a-half years and are also funded by BMWi. The total budget for both projects is approximately 75 million euro.

The PEGASUS test manager watches over the situation. He coordinates and controls the execution of the test.

The interior of a robotic vehicle. Pre-programmed, it automatically follows a fixed route on the test site and thus simulates the surrounding traffic. Control and emergency devices enable efficient and safe testing.

Each manufacturer can use its own test program and simply needs to integrate our PEGASUS methodology – as you would do for baking instructions. A manufacturer that wants to manufacture a small car with an automated driving function, which is designed to travel up to 100 kilometres per hour, may simulate tests that are different to those needed for a luxury automated vehicle. With PEGASUS, however, everyone uses the same process and the tests are comparable with one another.

What is the goal of this testing methodology?

: We considered two questions to be of central importance. How good is good enough, and how can we demonstrate that our system is good enough? We are sure that some of today's accident situations will not occur with automated vehicles – for example, a collision caused by illegal overtaking on the wrong side. Otherwise, accidents could occur in circumstances that are not yet apparent to us. Before we introduce such systems, we need to prove that they are at least as good as and as safe as human drivers. We call this a positive risk assessment. For this reason, we have developed a catalogue of criteria that sets out a way of establishing when and whether a particular system is safe. For this purpose, we use measurable data such as fatality statistics, accident figures, and recorded journeys. Ultimately, our methodology is much more comprehensive than the homologation process that occurs later, as a manufacturer has to conduct a considerably greater number of tests than are required by a technical inspection authority. These organisations only check the legally defined minimum safety requirements.

How do you test safety? Do you sit in the car for hours, investigating all sorts of situations with the vehicle at the test site?

: At first, we had the idea of establishing a proving ground, which would allow us to examine automated vehicles comprehensively. However, we soon realised that this was not realistic, as we still lacked any foundation for it in terms of safety measures. Researchers from Darmstadt have calculated that an automated driving system would have to complete more than six billion kilometres of test driving in order to be proven safe in every situation. This does not fit with the development cycle for cars – it is simply too time-consuming and expensive. That is why we are using simulation tools; they are cost-effective and the test conditions can be varied quickly and in many different ways.

How is such a simulation environment created?

: Of course, We did not want to drive through fantasy worlds, so we based our work on actual traffic situations and decided to develop simulation runs that were as realistic as possible. To achieve that, the first thing we needed was a sufficiently large pool of data. So, we began by feeding information from laws, guidelines and standards – such as traffic regulations or the standards for motorway construction – into our simulation environment. The vehicle manufacturers contributed measurement data from their cars and DLR provided, amongst others, the results of driving simulator studies. This enabled us to gradually define a virtual environment in which we could depict numerous driving situations. No one had to do everything on their own; instead, all of the partners collected the information in our joint database. At the end, it was available to everyone. We were able to test a range of traffic situations in this simulation environment to find out which ones were critical for the vehicle and the automated driving functionality. In order to check the results of the virtual tests, we repeated selected different situations and assessed them at the test sites. If, for example, the result of a simulation was that the car came to a standstill only two centimetres from the obstacle in a particular situation, we looked at it again in a real-world test.

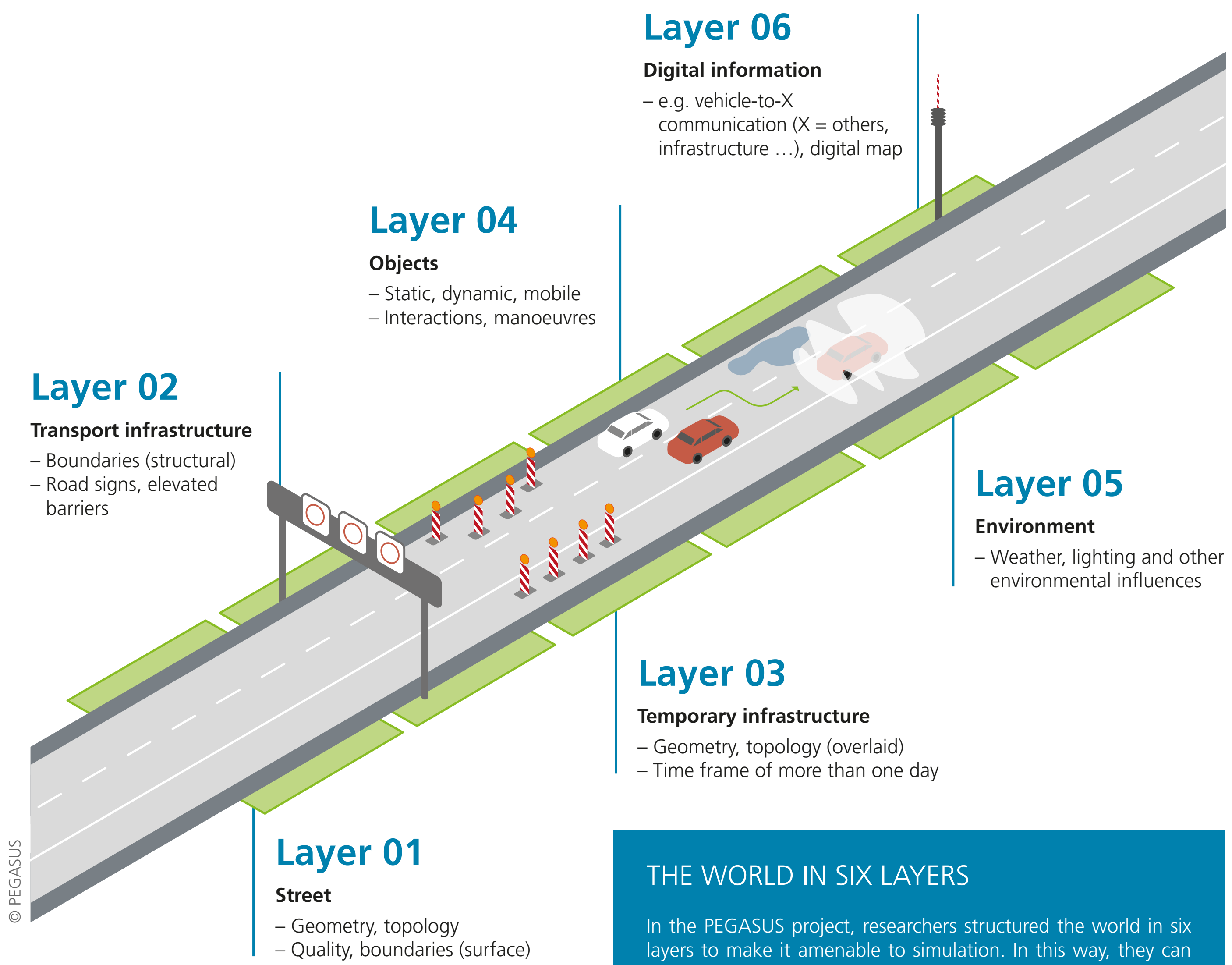
Which issues did you investigate at the outset?

: At first, we focused solely on motorway driving, as we believe that is where automation will first be available. The traffic situation is relatively uncluttered; there are no intersections, and usually no pedestrians. However, our method is scalable, so it can also be used for other scenarios. In the simulation environment, we looked at whether collisions actually occurred, as well as whether the system reacted in time. Overall, we can then make statements about whether the system is safe in road traffic and whether it outperforms a vehicle driven by a human. Nevertheless, we cannot compile any accident statistics at present, because we do not currently have any information on the number of automated vehicles that will be available on the market in future. We can only make predictions. PEGASUS enabled us to build the methodology, but did not provide all of the data.

> "We were able to test a range of traffic situations in this simulation environment to find out which ones were critical for the vehicle and the automated driving functionality."

When will we be able to use automated cars safely?

: Manufacturers are currently integrating the PEGASUS methodology into their environments. One key advantage of our project was that the major manufacturers and the key suppliers were on board, so we were able to use this to achieve leverage for the acceptance and application of the method by the relevant stakeholders. I believe that Level 3 automated driving functions for use on the road will go into series production in 2020–21. For example, BMW has announced plans to introduce its Motorway Chauffeur by 2021. Other manufacturers will certainly not be far behind.



THE WORLD IN SIX LAYERS

In the PEGASUS project, researchers structured the world in six layers to make it amenable to simulation. In this way, they can vary individual conditions and represent a wide variety of traffic situations.

What are the next steps?

: PEGASUS takes care of ensuring driving function safety, which is a key piece in the jigsaw for the automated vehicle as a whole. The interface between sensor technologies and the driving function also requires its own methodology, which is why we are currently working on the VV Methods project. As part of another PEGASUS follow-up project – called SET Level 4to5 – we are adapting the simulation environment for testing so that driving functions can also be trialled and assessed for automation levels 4 or 5. We also want to integrate aspects other than motorway driving, such as city traffic, into our simulation environment. Independently of these projects, issues such as insurance coverage and liability also need to be clarified before automated cars can be used on the roads.

Is PEGASUS also garnering interest at an international level?

: We started out as a German national research project, but we soon received many enquiries from all over the world. We were able to improve our methodology through interaction with other countries, and have since been welcomed as experts at international conferences and by the European Commission. For example, we are also working on transferring our approaches into European regulations. At the moment, parts of our methodology are being converted into a standard by the Association for Standardization of Automation and Measuring Systems (ASAM e.V.). But this will take some time, and there is still much to do.

Will automated systems be able to outperform humans once they are fully developed?

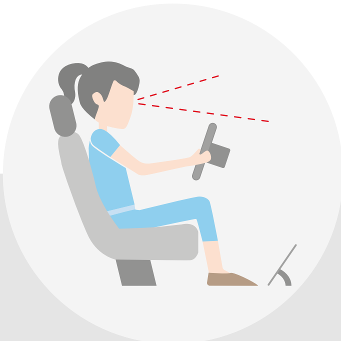
: That is the obvious expectation. We cannot say this with certainty, but with every vehicle that enters the market, we will learn more and be able to improve our predictions. In this respect, much of the responsibility lies with the manufacturers. One question that we cannot yet answer is that of societal acceptance. Society will not necessarily accept automated systems just because they are safe. I am convinced that this topic will continue to command much of our attention in future. Nothing is worse than launching a new, highly acclaimed technology that is then subject to the 'nuclear power effect'. This is when a serious accident occurs, triggering rejection by society. In that case, the reputation of the technology is permanently damaged. Through our projects, we want to work together with industry and government to ensure that automated systems come to market when they are as safe and carefully considered as possible.

To travel safely with automated cars, the driving functionality must be able to contend with all situations. The PEGASUS methodology, which is being tested here, will make this possible.

Special robotic cars driving on pre-programmed routes simulate the surrounding traffic

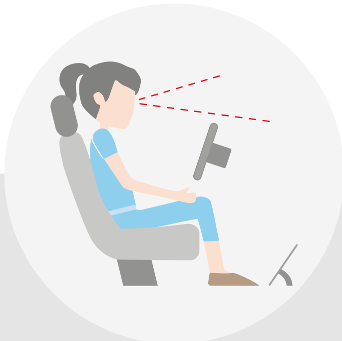
0
No automation

The vehicle does not have any systems that support the driving task. All traffic situations are dealt with under human control.



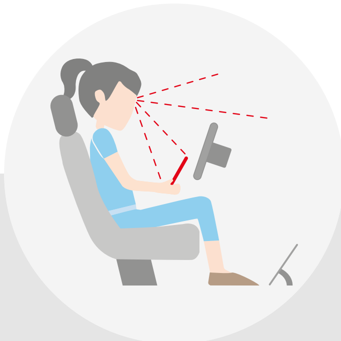
1
Driver assistance

At this level, assistance systems provide support. Adaptive cruise control and lane departure warning systems are already available in many cars today.



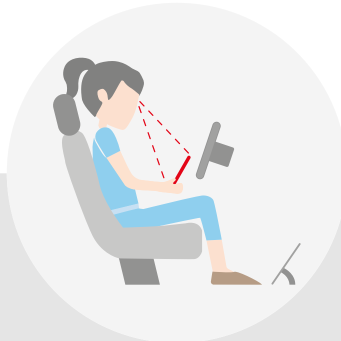
2
Partial automation

Vehicles at this level are able to perform some tasks temporarily and some continuously – for example, keeping in lane or accelerating and braking in a traffic queue. However, the system must always be monitored.



3
Conditional automation

In certain scenarios, the car takes over the driving task independently, without the need for human intervention. For the first time, the driver is allowed to turn their attention away from driving and write emails, for example. In emergency situations, the car acts independently or returns the driving task to the driver, having notified them in a timely manner.



4
High automation

At this stage, a handover no longer occurs, and the vehicle drives completely independently in certain areas, such as on a motorway or in city traffic.

5
Full automation

The car acts independently in all traffic situations and the occupant completely hands over the driving and control task to the vehicle. All the occupant must do is enter the destination data. At this moment, the occupant becomes a passenger.

A TALE OF TWO THOMASES

Heads of technical vocational training Thomas Müller and Thomas Schweizer support technical apprentices as they embark on the world of work

By Denise Nüssle

To paraphrase Erich Kästner, real 'born teachers' are almost as rare as heroes and saints. DLR has a particularly successful duo of teachers at its site in Stuttgart – Thomas Müller and Thomas Schweizer, the two heads of technical vocational training. The two namesakes have been mentoring apprentices in the fields of precision mechanics and system electronics for almost two decades, drawing upon their extensive experience, pedagogical skills, passion, and not least their spirit of fun.

A passion for technology, a secondary school certificate with good marks in mathematics and physics, and curiosity for exciting research topics are the prerequisites for embarking on vocational training in a technical field at the DLR site in Stuttgart. Every year in September, the teams under the two heads of technical training – Thomas Müller and Thomas Schweizer – each look forward to two new recruits. An exciting and challenging three-and-a-half years lie ahead of the trainees. The future precision mechanics learn to use tools, machinery and equipment, and discover how to make components with them. For them, this will entail getting to grips with big, computer-controlled machine tools and diligently practising how to turn, mill, drill and grind. The system electronics technicians will focus on the technical systems, such as manufacturing facilities and test systems that need to be set up, operated and maintained. But in addition to learning the trade itself, they will all experience what it is like to work as part of a team, develop their spirit of initiative and creativity, and – of course – have fun.

The heads of technical training support their protégés as they head along this path. "We are teachers, organisers, points of contact and mediators – you could say we do a bit of everything," Müller says with a smile. It is a full-time job that they have both been doing with plenty of enthusiasm for almost 20 years. "Some marriages do not last that long," Schweizer adds, with a smile. Schweizer is one of DLR's own 'home-grown' talents and has been working at the Stuttgart site since the start of his career in 1989. He says electronics have always been his thing. After completing his apprenticeship as an electrical mechanic at DLR Technical Operations – now known as 'Technical Infrastructure'– he switched to the Institute of Technical Physics, which remains responsible for training system electronics apprentices to this day. He really enjoyed working with trainees, so he took the aptitude test to become a training manager and passed. When the position of head of technical vocational training became vacant in 2000, he took over that role. Since then, he has looked after the junior staff and taken care of IT and electronics at the Institute.

THOMAS MÜLLER:

Age: 47

From: Aichwald

When he is not at work, he enjoys:
spending time with family, cooking
(or learning to)

What he has to say about his namesake:
a doer, a good adviser, reliable

In the same year, Thomas Müller started working as an instructor. From the start of his career, Müller knew what he did not want to do – follow in the steps of his parents and become a hairdresser. After training as an industrial mechanic at a major automotive supplier and graduating from technical high school, he came to DLR. There, he worked for several years as an experimental technician in energy research, completed his master craftsman training and became head of precision mechanics training, which is affiliated with DLR's Systemhaus Technik engineering facility.

Excellent training – in the truest sense of the word

As part of their daily routine, the two Thomases first look at the contents of the training plan. These must be adapted to the specific projects and circumstances of work at DLR, and then brought to life and communicated to the trainees. In addition, there are a multitude of organisational and administrative tasks, such as selecting and recruiting trainees or fostering interaction with vocational colleges and local chambers of commerce. The success of their work is borne out by the prizes and awards they have received over recent years. The trainees and trainers are among the best in their field. DLR trainees regularly earn top places and are awarded prizes in local, state and national competitions. Last year, the Chamber of Trade for the Stuttgart region awarded its 'Lernpyramide' prize to DLR's vocational training programme for its excellent performance in recent years. The key factors in its decision were the high quality of exam preparation and the dedication of the trainers.

"We work in small groups, which gives us the chance to interact with each trainee one-on-one and in accordance with their needs. At the same time, we have access to extensive, state-of-the art equipment," says Müller, who agrees with Schweizer that this is one of the reasons for their success. "In addition, we have more time and freedom than trainers

"We work in small groups, which gives us the opportunity to interact with each trainee one-on-one and in accordance with their needs. At the same time, we have access to extensive, state-of-the art equipment."

Thomas Müller

THOMAS SCHWEIZER:

Age: 48

From: Filderstadt

When he is not at work, he enjoys:
spending time with family, hiking, jogging, travelling

What he has to say about his namesake:
a calming influence, level-headed, down-to-Earth

in manufacturing companies. We can go back over things that trainees have not understood, and in some cases catch up on subjects taught in school, such as mathematics. When they have a practical frame of reference, the apprentices grasp the meaning and understand the connections between things much better," Schweizer says. There is another factor at play, he adds: "DLR works on plenty of fascinating topics. Our trainees pick up on this; it piques their curiosity and gets them to look beyond their horizons and learn new things." Apprentices often say that one of the programme's highlights is being able to work with DLR engineers and technicians on real research projects, according to Schweizer.

Müller and Schweizer treat their protégés as equals. They involve the trainees in decisions, such as selecting the next project or making purchases for the training workshops. It is clear that both trainers still love their work and continue to have fun after 20 years in the job. They are spurred on by the idea of preparing young minds for the future in an ever more rapidly changing labour market. Whether they are dealing with digitalisation, the smart factory or 3D printing, Müller stresses that they foster a learning atmosphere in which: "We stay on the ball, learn the ropes and try out new things together with our apprentices. The motivation and delight that result from this approach go a long way."

Competition for recruiting young talent in the technical sector is fierce. In the Stuttgart region, the competitors include global car manufacturers, a broad-based supply industry and many mechanical engineering companies. Yet DLR is able to hold its own thanks to its fascinating areas of work and award-winning training. When asked about a lack of young talent, Müller and Schweizer answer with an emphatic yes and no. In general, they have noticed that there are fewer people interested in vocational training in technical fields, but they have managed to fill all of the trainee places they have offered. "We used to have around 80 applicants for the two system electronics positions, but today it is roughly 30," Schweizer explains. "We are doing very well, but in order to keep things that way, we are doing more and also actively approaching young people."

Together with the equally well-regarded office management training at the Stuttgart site, the two managers attend career and training fairs in the surrounding region. At these events, they present what DLR has to offer and, with the help of current apprentices, try to interact with interested candidates. Müller and Schweizer are also in contact with young people via educational partnerships with local schools, allowing them to undertake introductory internships during the holidays. Both managers truly welcome female applicants, and they would both like for more women to apply than has been the case until now. Although several female precision mechanics have already successfully completed their training at the DLR site in Stuttgart, the position of the first system electronics technician is still vacant – hopefully not for long.

Denise Nüssle is an editor in DLR's Media Relations Department. She was responsible for communications at the Stuttgart site for many years.

TRAINING OPPORTUNITIES AT DLR:

Assistant chef
(Göttingen)

Chef
(Braunschweig, Cologne, Oberpfaffenhofen)

Electronics technician for devices and systems
(Hamburg, Oberpfaffenhofen)

Electronics technician for industrial engineering
(Lampoldshausen)

Industrial mechanic
(Göttingen, Cologne, Oberpfaffenhofen)

Mechatronics technician
(Göttingen)

Office management assistant
(Bonn-Bad Godesberg, Braunschweig, Göttingen, Cologne, Oberpfaffenhofen, Stuttgart)

Photographer
(Cologne)

Precision mechanic
(Braunschweig, Stuttgart)

Process mechanic
(Braunschweig)

System electronics technician
(Stuttgart)

Technical product designer
(Göttingen, Cologne)

Information and vacancies:
DLR.de/jobs/en

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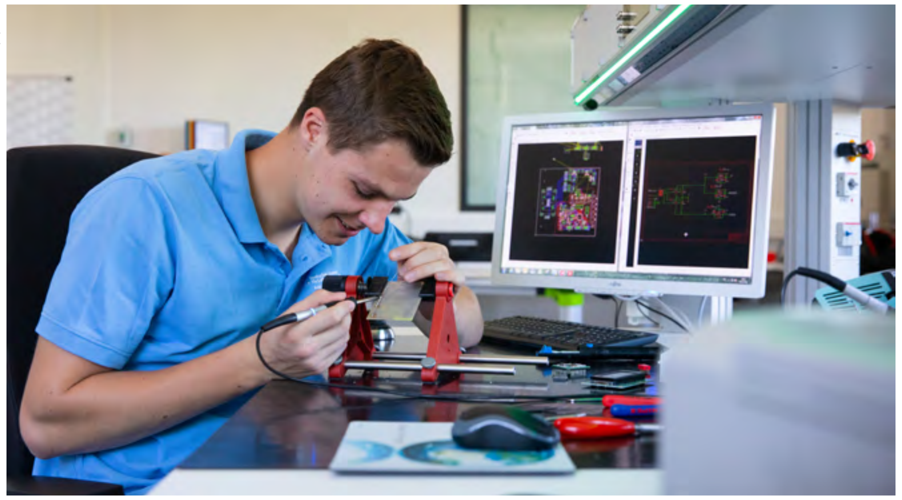

Fabian Staiger, a trainee system electronics engineer, soldering a circuit board.

© DLR/FrankEppler

Precision mechanics apprentice Michael Müller gaining experience in operating large machine tools.

SUSTAINABLE BOOST FOR YOUNG PROFESSIONALS

The German Trainee Programme (GTP)

For some people, the career ladder does not end on Earth, but extends all the way into space. But what does it take to work on space missions? The German Trainee Programme (GTP) has been offering young German professionals a stepping stone into European space research for 10 years. The aim is to encourage them to embark on a career at the European Space Agency (ESA), as well as to train young German talent for the aerospace industry and space science in Germany and the EU. Yearly, the GTP promotes around 20 university graduates and young specialists at the start of their career with one- to two-year traineeship at ESA. From technology development and Earth observation to space launchers, legal affairs and finance, the opportunities are diverse and reflect the interests of German space policy. During their 'on-the-job' training, the participants experience the profession first hand and take on challenging tasks. The GTP trainees are also supervised by DLR. To date, some GTP trainees – 15 staff members and 15 contractors – have been recruited, and eight doctoral theses with the NPI have been launched by ESA. Another 32 have begun working in the aerospace industry, and 22 in the space science sector.

"We want to secure Germany's leading role in aerospace for the future, too. Highly skilled and competent young German specialists are the key to achieving this."

Thomas Jarzombek
Federal Government Coordinator of German Aerospace Policy

THE GTP AT A GLANCE

Duration of training:
max. 2 years

Basic requirements:
– German citizenship,
– Master's or doctoral degree in a relevant subject

Previous trainees:
111 (67 % male, 33 % female)

Number of trainees per year:
about 20

Funding:
German Federal Ministry for Economic Affairs and Energy BMWi

Coordination:
ESA/DLR Space Administration

Contact:
Olivia Drescher-Schwenzfeier (project coordinator)
E-mail: olivia.drescher-schwenzfeier@DLR.de

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"The decision to spend two years as a trainee at ESA's European Space Research and Technology Centre (ESTEC) was simply thanks to my fascination with space exploration. Today I work at ESA, and the network that I built up during the GTP is still proving useful, as my former fellow trainees are spread across the entire European space industry."

Martin Zwick,
Robotics Systems Engineer at ESA

© private

"During the programme, I worked in Navigation at ESA's Galileo Space Segment. I have remained in this field, and today ESA is one of our clients. Thanks to the GTP, I gained valuable insights into the way ESA works, which has given me a better understanding of what it requires."

Sarah Lehnhausen,
Systems Engineer at SCISYS Deutschland GmbH

© Moritz Fontaine

"About four years ago, I stumbled upon the call for GTP applications on DLR's social media channels, applied, and was accepted. As internal vacancies were advertised at ESA during that time, I benefited from the programme by being able to apply for such posts as a GTP trainee. It helped that I had already proven my knowledge and skills prior to my application. We have recently had a new trainee join our team and I am now able to share my knowledge and experience as a mentor."

Dorota Jadwiga Englender,
Legal Officer, ESA Legal Department

Website: DLR.de/GTP

WIN FOR SUSTAINABILITY

The Green Talents Competition

How can we live more sustainably in the face of climate change? How can we protect existing resources? And, most importantly, how can research help? The Green Talents Competition has been addressing precisely this concern since it was launched in 2009 on behalf of the German Federal Ministry for Education and Research (BMBF) by the DLR Project Management Agency.

Every year, 25 young researchers from across the globe are publicly recognised for their efforts in the area of sustainability research. One of the first prize winners was the Indian scientist Saumita Banerjee, who was praised for her work on the production of bioethanol from lignocellulosic biomass 10 years ago. As lignocellulosic biomass can be obtained from tree and paper residues, in 2009 the jury deemed that her research made an important contribution towards greenhouse gas reduction.

Mario Alejandro Heredia Salgado from Ecuador is working in a similar direction. In 2018 he was selected as a winner for his approach to reducing dependency on fossil fuels in Latin America through the use of renewable energies. He is developing energy conversion devices able to use the residual biomass from agriculture to produce simultaneously renewable thermal energy and soil amendments through thermochemical conversion processes.

The Green Talents initiative gives all of the winners access to a unique global network of High Potentials working in the field of sustainable development. The competition invites young scientists to participate in a two-week Science Forum in Germany. Discussions with experts in their field of interest are an important part of this trip, allowing face-to-face contact. This allows the participants to approach particular experts themselves, with the Project Management Agency hosting a kind of 'matchmaking' service. The competition is a building block in the Research for Sustainable Development (FONA) framework programme. The 2019 winners will be announced in autumn. A total of 837 talented scientists submitted applications this year – a new record.

Stefanie Huland, Corporate Communications, DLR Project Management Agency

"Through this competition, the DLR Project Management Agency is making a unique contribution to international research into sustainability on behalf of the BMBF. The up-and-coming researchers will return to their home countries with new contacts and new ideas, ideally making them ambassadors for Germany as a research location."

Klaus Uckel, Head of the DLR Project Management Agency

"Winning Green Talents was a strong evidence of the relevance and excellence of my research. The credibility that came with it has enhanced my impact, within my own organisation and in my field of work more broadly."

Shirin Malekpour, Australia, 2018 winner, is exploring how sustainability goals can be achieved in the long term through strategic processes and tools, despite constantly changing conditions.

"The Green Talents Competition has given me the unique opportunity to get to know people from Germany and all over the world working upon all the different aspects of sustainability. After such an immersion into green research you come back home as a new person."

Yauheniya Shershunovich, Belarus, 2018 prize winner, conducts research into the sustainable development of the electricity industry and waste recycling options in her homeland.

THE GREEN TALENTS PROGRAMME AT A GLANCE

Basic requirements:

- Master's, PhD or at least enrolment in a Master's programme (last degree must have been awarded no longer than three years previously)
- A maximum of three years of professional experience (professional experience acquired during a degree course does not count)
- Focus on sustainability research
- Above-average academic achievements
- Not resident in Germany, no German passport
- Very good English skills

Application deadline for 2020:
expected in spring 2020

Prize winners since the start of the programme:
232 from 65 countries

Funding:
Federal Ministry of Education and Research (BMBF)

Implementation:
DLR Project Management Agency

Contact:
Julia Kirschner, Marc Nettelbeck,
DLR-PT, European and International Cooperation,
Telephone: +49 (0) 228/3821-1886, E-mail: greentalents@dlr.de

Website: greentalents.de

View of the exhibition in the DLR visitor centre. "People who are interested in us need the opportunity to find out directly what we are doing here," explains Klaus Schäfer, Deputy Director of the Institute of Space Propulsion. As coordinator, he followed the construction of the visitor centre from the initial concept through to its inauguration. The exhibition has been visited by 24,600 people since its opening in June 2013.

TEST STANDS KEEP PACE WITH THE TIMES

DLR's Lampoldshausen site turns 60 – modern rocket engine development at a historic space facility

By Anja Kaboth and Julia Heil

A dense forest almost conceals the entrance. Individual buildings can be seen through the greenery. The trees rustle. Suddenly, a deafening, thunderous roar breaks the silence. A short while later, a white cloud of steam rises above the canopy of leaves. The roar is over just minutes later, and the birds resume their singing as though nothing has happened. They seem to be familiar with the hustle and bustle of the Harthausen Forest. DLR's Lampoldshausen site is located 18 kilometres north of Heilbronn, in northern Baden-Württemberg, Germany. The propulsion systems that will launch future rockets into space have been tested here for 60 years.

Anyone who visits the DLR site Lampoldshausen is setting foot in one of the most important places in European space history. The 51-hectare site is a hub of modern engine development with strong historical connections. In 1959, the space pioneer Eugen Sänger established a research institute in the Harthausen Forest. Sixty years after its inception, it still bears the traces of its history, while offering tantalising glimpses of the future. Even if some of the test stands at the Institute of Space Propulsion located here exhibit some patina, they have not become worn out. More versatile than ever before, they are well prepared for the new requirements of European space transport systems.

In the visitor centre, a group of fascinated guests is marvelling at the enormous Vulcain-2 engine, which hangs from the ceiling like an oversized lamp. This is just one of the numerous rocket propulsion systems tested by the DLR team in Lampoldshausen. As the visitors turn around, they see a wall of images showing the history of the site. But they will have to walk a few metres to learn about its establishment.

The early days – 1959

Eugen Sänger could justifiably feel more than satisfied when spontaneous applause broke out in Lampoldshausen Town Hall on 10 October 1959. In a rousing speech, the well-known space pioneer had convinced Lampoldshausen's residents that a test stand site for rocket engines would be very important for the community. A leading space and rocket technology expert, he had returned from France to Germany in 1954 to resume his work into space research. He had overcome an important hurdle and could now begin construction of a test site for the 'Research Institute for Jet Propulsion Physics' – which he had founded in Stuttgart – with the aim of testing liquid-fuelled rocket propulsion systems. Indeed, he had chosen the perfect moment, as the ban on rocket research ended with the revocation of the Occupation Statute in 1955, enabling space research to be conducted once again in West Germany after 10 years. Federal states, universities and industry all wanted to be involved during this 'founding phase'.

The first construction phase of the test site was completed in 1963 – the same year in which the location was selected for the first major European space project. This endeavour would focus on the development of a European launcher. 'Astris', the German-developed engine for the third rocket stage, thus came to be tested in Lampoldshausen. The site was expanded for that purpose, with test stands P3 and P4, developed and constructed for tests under both high-altitude and ground-level conditions. At the same time, the scientists and engineers based at the site in Lampoldshausen were conducting research into high-energy liquid-fuelled engines.

Professor Eugen Sänger (1905-1964), founder of the DLR site in Lampoldshausen.

THEN AND NOW

Protecting flora, fauna and habitats is particularly important due to the DLR site's location in the Harthausen Forest. Utilising the land in a sparing, responsible and resource-conserving manner is a prerequisite for sustainable and long-term development. Approximately 1000 staff members are expected to be working on the 51-hectare site by 2030. Around 70 percent of the area is green space.

1962

2019

Lampoldshausen assists with the birth of European spaceflight

In 1975, work began on the Ariane launcher under the leadership of the newly-founded European Space Agency (ESA). This would allow Europe to gain independent access to space. In order to prepare the launcher for its journey into space, its engines were first tested at the site in Lampoldshausen. Important tests of the Viking engine were conducted here. The success story really began with Ariane's first triumphant launch on 24 December 1979. Today, 40 years on, the researchers are working on Ariane 6, which is earmarked to be launched for the first time in 2020. The DLR site in Lampoldshausen is responsible for testing the Vulcain-2.1 main-stage engine, the Vinci upper-stage engine, and the entire upper stage of the Ariane 6.

In the glass-walled visitor centre, a 1:10-scale model that is roughly six metres in height attests to the close relationship between this site and the new workhorse of European spaceflight. This is the youngest member of the Ariane launcher family and succeeds Ariane 5, which will retire in 2023, after 27 years of service. The lower stage of Ariane 6 is adorned with the flags of the 13 ESA member states involved in the project. These show that such an endeavour cannot be achieved without teamwork, and also demonstrate the site's important position within the space community.

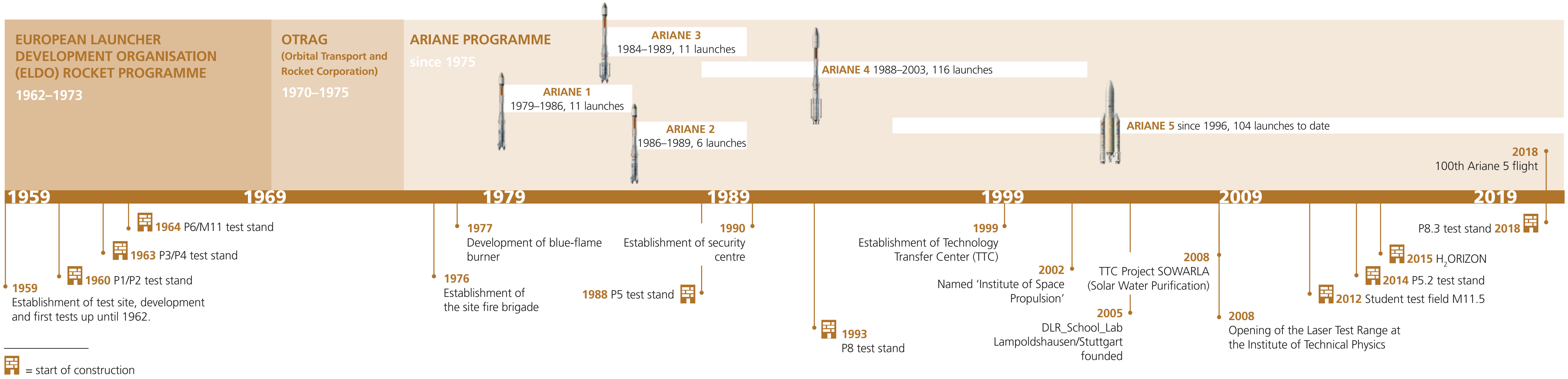
The many facets of future space propulsion – including methane

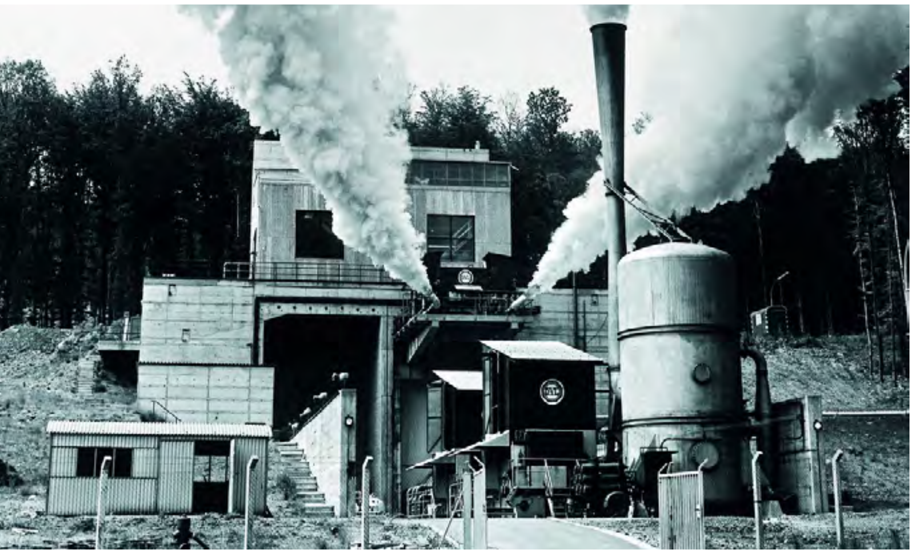
Before a launcher is qualified for launch, its engines undergo several thousand seconds of test firings on purpose-built test stands. In Lampoldshausen, they receive the finishing touches. One of the core tasks of this site over the coming years will be to develop the test stands in a technologically flexible way and to optimise their cost-effectiveness. In addition, DLR engineers are constantly working on developing new technologies for future engine concepts. One example is the propellant combination of methane and liquid oxygen (LOX), which is playing a promising role in the development of new, liquid-fuelled space propulsion systems. In the Prometheus project, DLR researchers are working to ensure that LOX/methane technology will soon be ready for use in European spaceflight systems. It will be tested on the site's P5 test stand, demonstrating that these large structures remain ground-breaking, despite having been constructed during the facility's early years. P5 was originally built for the development of the Vulcain main-stage engine of Ariane 5 and went into operation in 1990. Development tests on the Vulcain-2.1 engine for the new Ariane 6 are currently taking place on this stand.

Behind the scenes, however, a team of DLR scientists is already preparing the test stand for its new task and developing the necessary infrastructure for the Prometheus project. "A LOX/methane technology demonstrator with 100 tonnes of thrust will be put through its paces on the P5 test stand from 2020," says Anja Frank, Head of Test Facilities. "A smooth and swift transition to LOX/methane from the traditional propellant combinations used in current engines – liquid hydrogen and liquid oxygen – is essential to ensure that Europe remains competitive in the launcher sector after Ariane 6." A future LOX/methane engine can reduce the costs of the European main-stage Vulcain engine – which was developed in the 1980s – by a factor of 10 and be reusable.

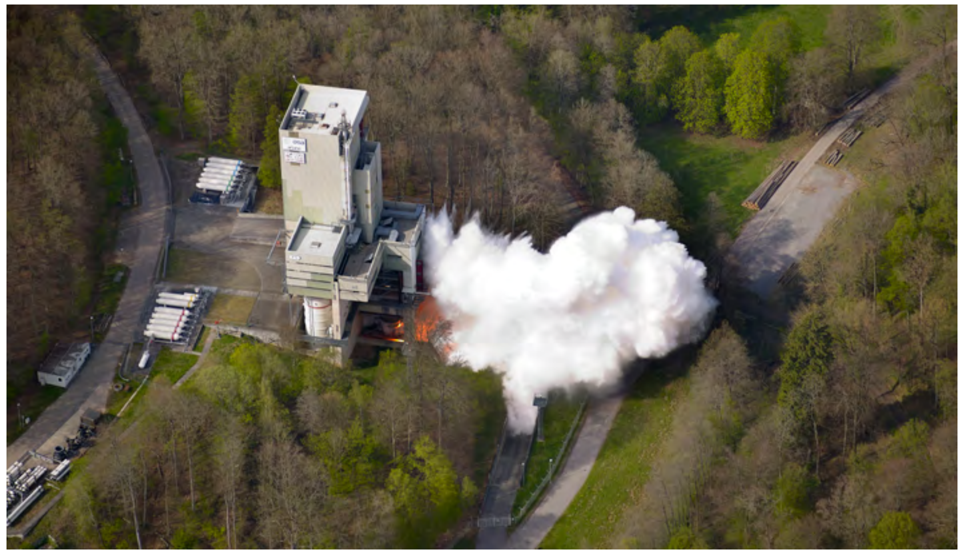
The future of propellants is emerging at DLR Lampoldshausen

Future propellants are also an important part of the research being carried out in the Harthausen Forest. Until now, satellite propulsion systems have used hydrazine. This propellant can be stored for long





From 1966, the Astris upper stage engine was tested under high-altitude conditions on the P4 test stand. The site engineers developed special steam generators for the operation of the high-altitude system. Since the 1970s, the P4 stand has been retrofitted several times for the Ariane programme. Today, Ariane's Aestus and Vinci upper-stage engines are tested there.



Every test on a main-stage engine is an impressive event. A Vulcain 2.1 consumes 600,000 litres of liquid hydrogen and 200,000 litres of liquid oxygen – forming pure water – during a firing duration of approximately 12 minutes. Together with the water used for cooling, this forms the characteristic steam cloud above the test site. Later, this falls back to Earth as rain.

periods of time and works reliably even under space conditions, making it indispensable for space missions today. However, it is also harmful to human health, and handling hydrazine on the ground – during transport, fuelling and launch preparations – is complex and expensive. This is why DLR researchers are now analysing, evaluating and testing new fuels, referred to as 'green propellants'. These are environmentally friendly, cost-effective and easy to handle, and in the future they will be at least as efficient as conventional propellants.

Getting closer to next-generation engines through machine learning

Artificial intelligence (AI) is playing an increasingly important role in the space propulsion sector, in order to accelerate the development of new generations of engines. Machine-learning algorithms can independently develop predictive capabilities using previously generated data, and these can then be used for data-based calculations, decisions and optimisations.

However, these kinds of developments at the site remain invisible to the group of visitors. They are happening on computers in the offices, including those of Jan Deeken and Günther Waxenegger-Wilfing from the System Analysis group at the Institute of Space Propulsion. They are using neural networks as part of the Liquid Upper stage deMonstrator ENgine (LUMEN) project, in which the experts at Lampoldshausen are investigating the interactions between all the components of a rocket engine – from the combustion chamber to the turbopumps and valves. A complete model engine for research in a test stand environment is due to be created for the first time by the end of the project in 2020. "One big advantage is that we no longer have to wait for days to get the results of calculations. The new 'tool' enables us to combine the speed of simple modelling with the accuracy of numerical methods, and provides us with results in seconds. This has given us new insights into the interactions between components in a rocket engine," says Deeken. AI has already proven beneficial in the design of combustion chamber cooling channels. A neural network trained for this purpose is able to predict the complex behaviour of methane – which is used as a coolant, as well as a propellant – and is thus a central component of automated cooling-channel design for the LUMEN combustion chamber.

No downtime

The visitors have now come to the end of their tour. They are one of the many groups that visit DLR each week to get a picture of past and present developments in space propulsion. The future of spaceflight is being driven forward in many offices, laboratories and on test stands across Europe, with DLR Lampoldshausen at the very forefront. "The exciting and unique thing about this DLR site is that scientists can conduct research, develop technologies and carry out tests at different scales," says Stefan Schlechtriem. As Director of the Institute of Space

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>
> Stefan Schlechtriem

Propulsion, he has been in charge of the site for 10 years. Under DLR's Strategy 2030, he is pursuing a clear vision of the future with a focus on innovative test stand technologies and technical expertise. Schlechtriem attaches great importance to stable foundations, both technologically and through strategic partnerships. "For space propulsion systems, there is no other location in Europe where research, development, design, planning and tests on large test stands are so closely interlinked as they are here in Lampoldshausen. This is almost unparalleled in Europe and offers immense potential. We have excellent prospects for exploiting it."

Anja Kaboth is responsible for Communications at the DLR site in Lampoldshausen. **Julia Heil** is an editor in DLR's Public Affairs and Communications Department.

The central element of the visitor centre is the open-plan architecture, which promotes direct communication – both with the international space community and with the surrounding region.

Since the opening of the Laser Test Range in 2008, a team of researchers at the Institute of Technical Physics has been investigating the properties and propagation of laser radiation under real atmospheric conditions. With the help of this facility, which is the only one of its kind in Europe, eye-safe laser systems and laser spectroscopy technologies are developed. One application is the detection of hazardous substances from a safe distance.

RESEARCH ON THE MOVE

Traffic planners need data, and researchers need test participants. MovingLab focuses on improved survey technologies and enlightened users.

Florian Kammermeier spoke with DLR transport researcher René Kelpin

Ever since horse-drawn coaches began travelling on German roads, people have been interested in data on the use of various means of transport. Social research that emerged later had to address such questions, among others. Yet the methods of data collection in transport research have hardly changed since its inception – people are interviewed and survey questionnaires are filled out. But much has changed about transport, its scope, requirements, technologies and problems. The DLR MovingLab is intended to help close the existing gaps by using new survey technologies, and thus provide better data to city managers and transport companies. This information can be used to plan the transport systems of tomorrow. René Kelpin is overseeing the development of the DLR MovingLab large-scale facility. Florian Kammermeier spoke with him about the advantages of digital data collection on behalf of the DLRmagazine. They discussed the difficulties in determining the relevant mode of transport from mobile phone data and why Google data cannot be used for this purpose.

René Kelpin
studied mathematics in Berlin and is overseeing the development of the MovingLab large-scale facility. He is also responsible for the Clearing House for Transport Data, which makes standardised mobility and transport research data available to authorised users on behalf of the German Ministry of Transportation and Digital Infrastructure.

Mr Kelpin, you travel across Berlin every day to your office at DLR in Adlershof, which is located on the southeastern side of the city. How does someone whose professional focus is transport get to work?

: Intermodally! In other words, mixing different means of transport. I cycle to the suburban railway station, and I frequently take my bicycle with me on the train. I ride it the entire way as often as I can. I have found a bicycle path away from the main roads that is perfect. The landscape and the physical activity compensate for the extra travel time.

If you were recruited by DLR for a transport research project with MovingLab, what would the app on your mobile phone do?

: If the app is running, it uses GPS to record every route that I take. I am then asked to check these routes and describe them. I can do that as soon as I have arrived at my place of work or when I get home in the evening. Then I describe my mobility throughout the day within the context of the topic that the researchers have chosen to examine. For instance, I might be asked questions about the risks of riding a bicycle, so I could highlight danger points that caught my eye along the way, such as a high kerb or a sharp turn.

Global Navigation Satellite Systems (GNSS) technology has been available on navigation devices and mobile phones for many years now and is widely used by the general public. With its MovingLab, DLR is one of the first organisations to use GNSS and sensor data from smartphones for transport research. How was data for transport research collected in the past?

: Mobility surveys as a very early form of transport research date back to the time of horse-drawn coaches. People came with questionnaires and the respondents would tick the relevant boxes. Ultimately, this is no different from what happens today, where people fill out an online questionnaire about their mobility behaviour or take part in a telephone interview. In that case, someone sits at a computer and completes a questionnaire. Problems primarily arise when someone undertakes such surveys with regard to a particular day, which might have been two weeks ago. Which route did they take? Why did they go by car, rather than by bicycle? Where were the children? The context within which the mobility has taken place fades from memory. The big difference with MovingLab is that it can display the route that was travelled and the relevant means of transport on the same day or in retrospect and link this information with various surveys. In addition, technical data – such as the length of a route – are no longer estimates, but are precise – down to the nearest metre in some cases.

“The big difference with MovingLab is that it can display the route that was travelled and the relevant means of transport on the same day or in retrospect and link this information with various surveys.“

Knowing which mode of transport was used for a journey is important. How much progress have you made with this, and what problems have you encountered?

: The detection of modes of transportation and of individual trips is the most important technical challenge for MovingLab. You cannot purchase any software to address this problem. Various companies are working on systems such as this in parallel to DLR. Our software has now been tested in a number of projects. We record the signals from GNSS sensors in a mobile phone once per second, and other data – on acceleration, location and compass direction – twice per second. In this way, it is possible to determine the location of a survey participant. Their chosen mode of transport can be established using their movement pattern and the pattern of their acceleration. The reliability of this method depends on the quality of the sensor data, which is very variable, particularly in urban areas. GNSS signals are frequently subject to disruptions, particularly on underground railways and in 'urban canyons', as well as behind the coated windows of high-speed trains. Unfortunately, we will never be able to achieve a 100 percent recognition rate. In cities, in particular, there is another layer of complexity – routes are not entirely covered by just one mode of transport. In the morning, people leave their homes on foot, board a train on their way to work, change trains at a station, and perhaps

THE MOVINGLAB LARGE-SCALE FACILITY

When MovingLab goes online in late 2019, it will make information on mobility-related issues available to more than just universities and research institutions. As is the case with other DLR large-scale facilities, it will be possible for cities and companies – from car manufacturers to local transport service operators – to 'hire' MovingLab, use its software and receive scientific and technical support.

MovingLab data collection uses the smartphones carried by test participants to automatically detect their route and mode of transport by means of Global Navigation Satellite Systems (GNSS) and other sensor data. Depending on the topic and target group, different questionnaires can then be linked to these routes. As such, the resultant data set will be movement data enriched with subjective information, such as personal impressions of how busy the various modes of public transport were, or whether there are dangerous locations on the cycle paths.

miss a connection. They might therefore spend 15 minutes waiting on the platform. This interrupts their trip without ending it, and the program needs to be able to recognise what is happening automatically.

So the app might also have problems recognising whether someone is on the platform waiting for a train or is one floor below getting something to eat from the bakery?

: Exactly. You cannot determine this from the movement data alone. We want to eliminate this uncertainty by enhancing the data with subjective input, whereby test subjects enter the purpose of their journey, for instance. We are looking to investigate a similar topic relating to shopping in train station supermarkets. How often do people do their shopping at Berlin's train stations, and are previously unseen trip chains generated from this? Or do people do their shopping on their way home? Another project that will apply MovingLab is called 'EVer', which looks at how long people spend at petrol stations. Do the passengers have a coffee? Do they do some shopping at the station's supermarket? Could they also use the stop to charge an electric vehicle? The project should be up and running in early 2020, with 500 vehicles.

One problem is finding the right test participants – and having a sufficiently large number of them. You have pulled back from the initial plan to recruit 10,000 test participants for MovingLab via market research organisations. Why?

: The conditions for social research have changed since the plan was written in 2016. Nowadays, people are requested to rate every holiday, hotel visit and flight – indeed, every single purchase. Our methodological tests showed that people are tired of filling out surveys. Because of this, we only want to recruit and follow 2000 participants – and even that will be very time-consuming. We want to supplement them with local and regional teams. The project requests that we are currently receiving are almost exclusively local – from Berlin, Hanover and Hamburg, to give a few examples.

Would it not be easier to use existing GNSS trackers or to work with Google?

: There are a number of reasons why that would not work. For one thing, Google is unwilling to provide us with its data. In addition, we also have to think about where the data has come from and whether it has always been collected with the users' consent. This is what makes us different – we recruit users, inform them about the research project and clearly show them what we intend to do with the data. We use the information exclusively for research purposes and never pass it on to third parties. We also have research privileges for our work, meaning that we are allowed to do more than commercial organisations and market researchers can. For example, with the consent of the test participants, we can store anonymised data for longer. If we work on the project with commercial organisations or market researchers, we lose these privileges. In addition, MovingLab knows the participants' demographic background, so we can select these people specifically for projects and also ask them targeted questions.

"This is what makes us different – we recruit users, inform them about the research project and clearly show them what we intend to do with the data."

Florian Kammermeier studies economics at the University of Passau. During internships or holidays, however, he likes to broaden his horizons as a journalist. He travelled to Berlin for the interview by high-speed train, tram and on foot, and was amazed at how smoothly his journey went.

The Mayor of Berlin, Michael Müller, visits DLR. René Kelpin (right) and Barbara Lenz, Head of the Institute of Transport Research, demonstrate how MovingLab works.

A large touchtable enables users to visualise the data collected by MovingLab. Different colours denote the various means of transport. Filter functions allow specific queries by categories such as age group or the purpose of the journey.

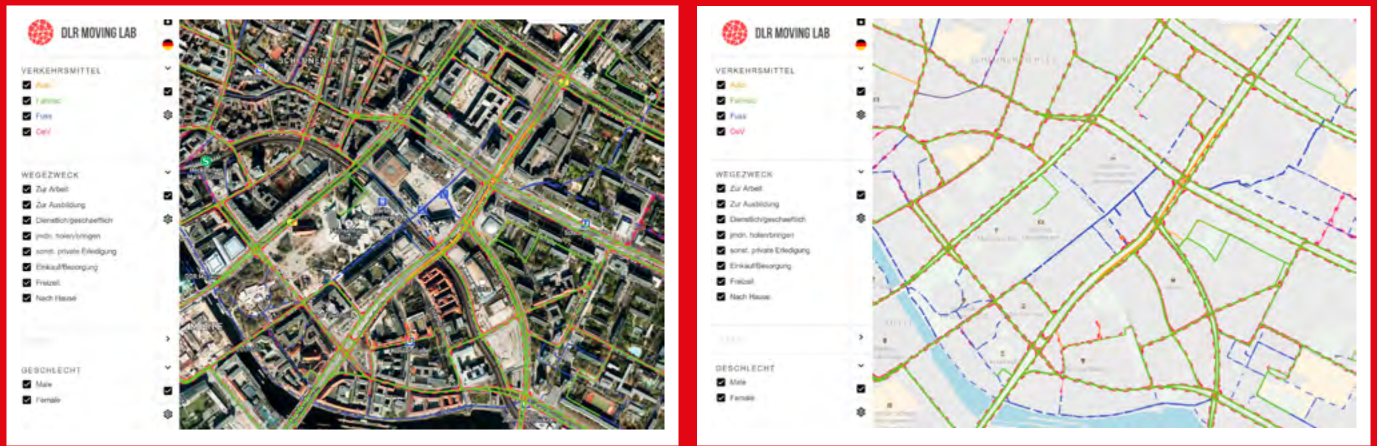
© F. Anthea Schaap

Commuters increasingly use different means of transport to move around the city …

… and travel to a suburban railway station, for example, by bicycle.

The roads can be relieved of car traffic …

… but transport planners need information about changes between means of transport – a challenge for research.



Routes across Berlin, shown in a satellite image and as a road map, arranged by means of transport and purpose of journey (simulation).

PARTICIPATING IN MODERN TRANSPORT RESEARCH

If you would like to take part in transport survey using MovingLab technology, you can find out more and register at **movinglab.dlr.de**. If you do not own or want to use a smartphone, you will be given a GPS logger the size of a large Smartphone. All of the surveys can be done via the app or online using a personal computer.

TECHNOLOGICAL MARVELS IN A PLACE OF WORSHIP

The Musée des arts et métiers, Paris

By Jana Hoidis

Technology Hall of Fame in the former Church of Saint-Martin-des-Champs. The steel scaffolding that spans the entire church almost up to the roof offers a new perspective on both the exhibits and the vaulted ceiling. Experience the Statue of Liberty, the Blériot XI airplane, Ariane's Vulcain engine or Scott's steam machine from new heights.

Our lives are simple. In the morning, we get into our cars, go to the metro station or ride our bicycles to commute to work. At night, we switch on the lights. And we can watch films in full HD on our smartphones. What a luxury! Some still remember black-and-white TVs or travelling by steam train – technological achievements that paved the way to our globalised, on-the-go multimedia world. Who ever thinks of how today's modes of transport and high-tech communication devices developed? Who can picture the beginnings of technology in the 16th century, or the time of the Industrial Revolution? The story about the forerunners of today's high technology is impressively told at the Musée des arts et métiers in Paris.

The exhibits breathe history, as does the building that houses them. Today, we can marvel at a whopping 80,000 exhibits carefully laid out across the 6000-square-metre Church of Saint-Martin-des-Champs and its former abbey buildings – partly thanks to the French Revolution of 1789-1799. In the 12th century, this place of worship – which combines Romanesque and Gothic stylistic elements – was built near the eponymous abbey. Excavations in the 1990s confirm that a funerary temple lay on this spot during the Merovingian period from the 6th to 8th centuries. In short, this has been a magical place since time immemorial. The abbey was dissolved during the French Revolution, and its premises were handed over to the newly founded Conservatoire national des arts et métiers. A church that is a museum is certainly not an everyday occurrence, but offers space for an even four-dimensional arrangement of the exhibits. More about this later.

Is it a bird? Is it a plane? Is it a bat?

The venerable abbey buildings make up the main section of the museum. The ground floor houses the striking transport collection. Passing bicycles and vintage cars seen in black-and-white silent movies, we reach the museum's first highlight piece: Clément Ader's 'bat'. In the stairwell, the aircraft – officially named Avion III – seems to float beneath the beautiful Baroque ceiling. Like the German aviation pioneer Otto Lilienthal, when developing his invention, Ader was inspired by nature. He modelled the wings on those of a bat. Powered by a steam engine, his first aircraft managed to make a 50-metre hop. The Avion III, however, tragically crash-landed during its maiden flight.

t1p.de/pm7j (The museum's virtual exhibition about Clément Ader)

The mechanics of entertainment versus retro communications

The opulent staircase beneath the Avion III leads me to the first floor. Four fascinating collections are displayed here. They address the topics of energy, mechanics, communications and construction. The most unusual element on this floor is the Théâtre des automates, which you can watch while sitting on benches in a darkened room with a small stage. From here you can enjoy the wonderful goings-on of the mechanical images. The scenery resembles the inside of a terrarium, but here everything is made of sheet metal. For a more interactive experience, you can activate the images and puppet shows by pushing buttons along the short route around this section. The tin figures suddenly start moving and music plays. As a first time spectator, I wonder what it must have been like to see this same scene every day in a 'sheet metal TV', bearing in mind that in those days there was no television, let alone Netflix. We can only assume that such ultra-modern entertainment was reserved for wealthy and fashionable Parisians at that time. The communications technology exhibit is also quite fashionable – some of the televisions, record players and telephones made after the 1950s are displayed in colours and designs that are no longer available, even in the trendiest retro-chic shops.

Pioneers of science

The scientific instruments and materials on the third floor are bound to enthuse anyone interested in the history of science. For one thing, this area of the museum is home to a replica of Antoine-Laurent Lavoisier's laboratory. From 1785 to 1787, the chemist built two gasometers with which he was able to conduct experiments on water synthesis and analysis. The gasometers were used as precision scales to determine the weight of hydrogen and oxygen. Lavoisier thus demonstrated the Law of Conservation of Mass in chemical reactions and laid the foundations of modern chemistry.

The display cases contain numerous small exhibits that will surprise visitors, such as the golden microscope designed in Rococo style by Michel Ferdinand d'Albert d'Ailly, the fifth Duke of Chaulnes. I imagine how this ornate instrument, made in 1750, would have looked in the Duke's magnificent study in Paris and how, fashionably dressed and complete with a curly white Baroque wig, he would have peered through it. I close my eyes for a moment and think of today's high-tech electron microscopes, with their LED displays. I am amazed at how far we have come in almost 300 years! The museum's three floors are packed with technological time capsules from the 18th century to the present day – steam engines, weaving looms and sewing machines, aircraft, cars, bicycles and locomotives, TVs and radios, and even satellites, rockets and planetary exploration rovers. Construction machinery and bold building designs are also showcased.

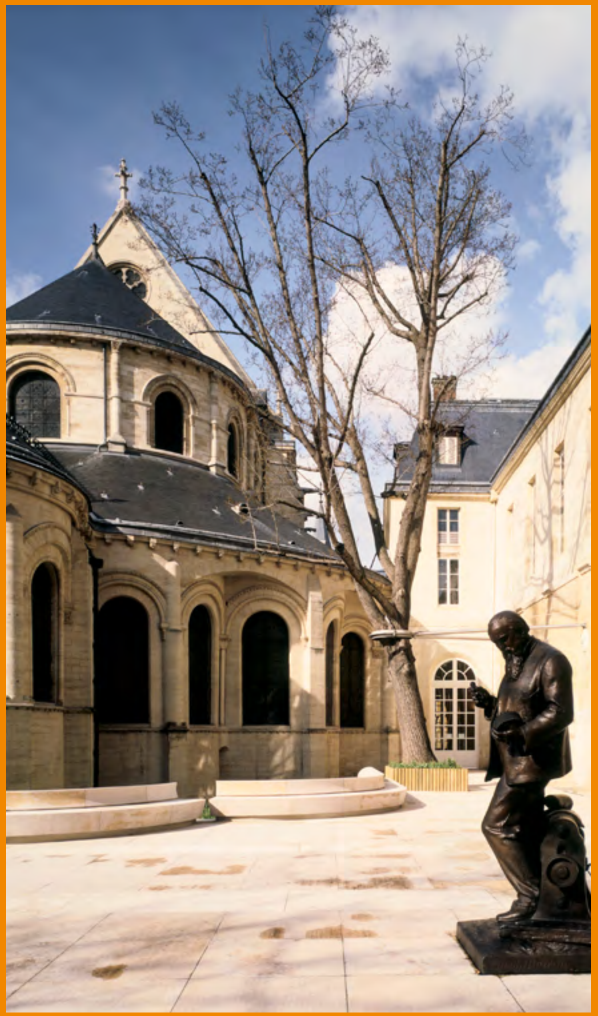
A church for more than prayer

The most impressive sight of all comes at the end – the church itself. The route through the museum is designed in such a way that the visitor enters the church from above. A Foucault pendulum hanging from the ceiling of the Romanesque chapel welcomes all visitors. In 1851, Foucault used it to demonstrate Earth's rotation without reference to observations of the heavens, for the very first time. Further to the right in the nave is a modern steel construction that takes you past a model of the Statue of Liberty, a range of vintage cars and other means of transport, to reach the aircraft floating between the arches. The most glorious of them all is the Blériot XI. The French aviation pioneer Louis Blériot devoted several years of his life to developing an operational aircraft. After a number of experimental models, his dream came true in 1909. He broke countless records with his Blériot XI and achieved international fame for his first flight across the English Channel. One hundred of these extremely powerful aircraft with a 25-horsepower engine were sold. Some airworthy models are still in use today.

t1p.de/0sqk (The museum's virtual exhibition about Louis Blériot)

For all who have already visited Paris's most famous attractions, a trip to the Musée des arts et métiers comes highly recommended, particularly for those interested in science, technology and their history. The countless exhibits relating to the history of technology and industry are not only informative, but also beautifully presented. What is more, the buildings also have a typically Parisian charm. The steel structure within the church allows four-dimensional movement through time and space. You can get remarkably close to the aircraft, the vaulted ceiling and the colourful stained-glass windows, giving you a completely new view of things. It literally broadens your horizons!

Jana Hoidis is in charge of communication at DLR's northern locations (Hamburg, Bremen, Bremerhaven and Oldenburg). In her free time, she likes to go on journeys that combine technology and art.



The museum's garden has a charm of its own

Technological wonders of the past in a row

Clément Ader was inspired by bats when he built the wings of his Avion III

MUSÉE DES ARTS ET MÉTIERS

60 rue Réaumur – Paris, 3rd arrondissement
Tel.: +33 (0)1 53 01 82 00
Metro: Arts-et-Métiers (3, 11) and Réaumur-Sébastopol (4)
Bus: 20, 38, 39, 47

Opening hours

Monday to Sunday 10:00 to 18:00
Thursday until 21:30

Prices

€8, students €5.50
Free admission for EU citizens under 26, non-EU citizens under 18, people with a disability card + 1 accompanying person, and with a range of Paris tourist passes (inquire in advance)

Additional information

The museum offers various audio guides for €5 – including one tailored to children – in different languages. The museum is barrier-free and has a restaurant (Café des techniques).

Special exhibitions are held on a regular basis.

arts-et-metiers.net

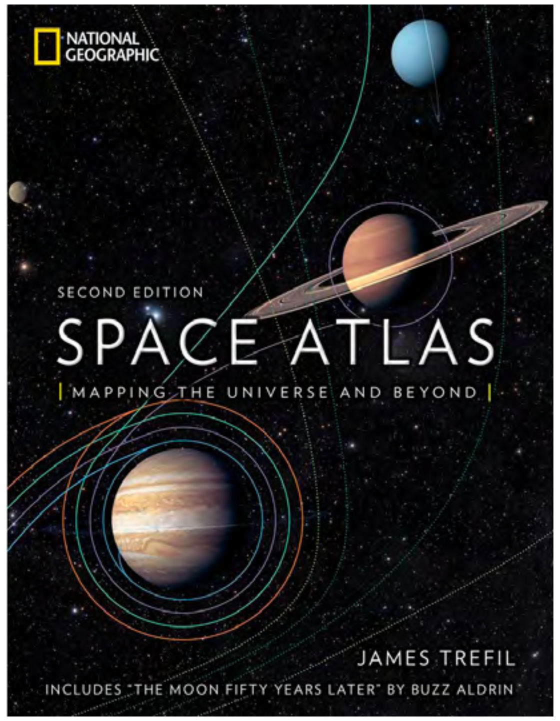
REVIEWS

WHAT DO YOU SEE IN THE STARS?

In the beautifully crafted **What We See in the Stars, an Illustrated Tour of the Night Sky**, artist and illustrator Kelsey Oseid invites the reader on a journey to explore the night sky. It is packed full of fun and interesting facts about the constellations, planets, comets, nebulae, as well as other familiar and less familiar features of space. For example, Oseid explains where the 48 Ptolemaic constellations get their names, what the difference is between an equinox and a solstice, and when you can expect to see meteor showers. Likewise, the reader can find out where in the Solar System we might find liquid diamonds, why Halley's comet came to be named after Edmund Halley (1656-1742) although its first recorded sighting was in 240 BC, and who named constellations after 18th century inventions (including Antlia, the air pump and Horologium, the clock). Personal favourites include the size of the Great Red Spot, Jupiter's giant storm, and that Mars is home to Olympus Mons and a crater named after Star Trek creator Gene Roddenberry.

If you want a practical guide for stargazing, this volume is not what you need. For more technical or in-depth material, you will have to look elsewhere. However, if you would like a striking and picturesque introduction to the cosmos, this is the book for you. Enjoy!

Merel Groentjes



COSMIC ATLAS

With stunning images from the latest missions, **Space Atlas** takes the reader on a tour of the Universe from the Earth to the furthest reaches of time and space. While little in it is likely to be new to space enthusiasts, having up-to-date information compiled in one book gives a sense of the overall structure, dimension and interconnectedness of the Universe. DLR devotees will appreciate that it features visuals and information from many of missions DLR has been and is involved in, including Cassini, Rosetta, MESSENGER and Venus Express. Science writer and physicist James Trefil explains what we know about the Milky Way and other galaxies, and provides clear explanations of the basics of astrophysics, including Dark Matter and gravitational waves.

The book would make a perfect gift for anyone with a sense of wonder at space. It is beautiful enough to draw the interest of even less space-enthused friends and family but has enough scientific detail for children (and adults) looking to learn about the Solar System and the Universe. Make sure to buy an extra copy, though – you will probably want one for yourself.

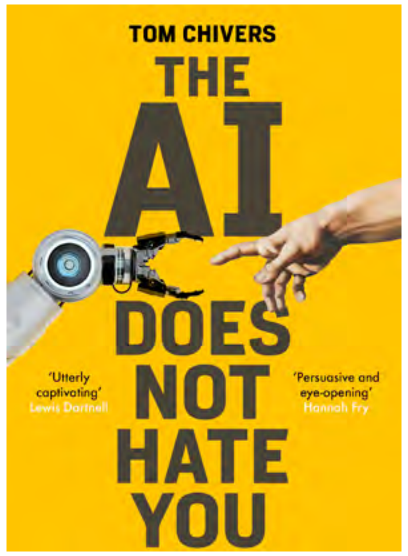
Sarah Leach

IS A SUPERHUMAN AI GOING TO DESTROY US – AND SHOULD WE EVEN CARE?

Security can mean many things and accordingly, various people are working on security problems from different perspectives. One key aspect of security research is the question of what we are trying to defend ourselves against. **The AI Does Not Hate You: Superintelligence, Rationality, and the Race to Save the World** by Tom Chivers is about a group of people who believe that the development of Artificial Intelligence (AI) with superhuman general intelligence could pose a catastrophic threat to the survival of humanity in the not-so-far future. Sounds hyperbolic – I'm not entirely convinced it isn't – but the book tries to explain the point of view of these thinkers, and they raise some good points. It does away with the stereotype of a Terminator-like robot gone rogue, and instead focuses on the more realistic threat of human errors and carelessness in developing such a powerful and apathetic entity.

This isn't just a book about AI though – in fact, it is more about the perspectives and the quirks of the Rationalists, the aforementioned group of thinkers who see advanced AI as a threat. At its core, this global and mostly internet-based community is comprised of individuals who seek to acquire knowledge and make decisions based purely on reason. Rationalism has existed for centuries, but this community seems to desire explaining everything from within their new framework of reasoning, of which core tenets include Bayes' law in statistics as the fundamental unit of decision-making, and utilitarianism as the one and only true moral philosophy. From this framework, they argue that an advanced AI poses a major existential risk for humanity as we know it, and that preventing such a catastrophe is their moral obligation.

The arguments, concepts and group dynamics of these Rationalists are complicated, but the book does a good job of explaining them in an accessible style and the author really took the time to get to know these thinkers. What I'm less enthused about is that it often feels as if the occasionally strange arguments and viewpoints of the Rationalists are presented as facts, with potential criticism from external sources immediately being met with refutations from the Rationalists, who nearly always have the final say. In this way, the argumentation can feel rather one-sided. Nevertheless, the book provides an interesting, modern and accessible perspective on why a superhuman AI may present a global risk, and on the people working to avert this problem.



Ruben Walen

RECOMMENDED LINKS

AN EPIC JOURNEY
twitter.com/MOSAiCArctic
Ever wonder what it's like in the Arctic ocean? As of September 2019, the icebreaker will drift through the Arctic for an entire year as part of the MOSAiC Expedition. On board are researchers from 17 nations studying the Arctic climate. Embark on the largest polar expedition in history on board the Polarstern research vessel by following the journey on Twitter.

FOLLOW EUROPE'S SPACE MISSION COMMUNICATIONS
estracknow.esa.int
The European Space Agency (ESA) operates seven ground stations – all around the world – in order to communicate with its various space missions. The new 'ESTRACK now' website allows you to see – in real time – which spacecraft is communicating with each of these ground stations. The website also provides facts and figures about the communications activities of numerous European missions.

MORAL DILEMMAS
moralmachine.mit.edu
The question may be grim, but in reality it could inevitably be asked: Who should a self-driving car run over? The pensioner or the family who crosses the road in red? In this online game, the players have to decide who will survive the accident and when, and who won't. The website was developed for a scientific study by the Massachusetts Institute of Technology. The project was completed last fall. But anyone who wishes to can still use the moral machine.

WE ARE DLR
DLR.de/WeAreDLR
This video takes you on a journey through DLR. It leads through 40 institutes and facilities, as well as more than 20 locations and field offices worldwide. The three-and-a-half minutes show how much enthusiasm DLR has for cutting-edge research and demonstrate the diversity of the approximately 8600 people who work here.

CALLING ALL SPACE EXPLORERS!
solarsystemscope.com
Want to explore the Universe from the comfort of your own home? Now you can do just that! Solar System Scope is a model of the Solar System, the night sky and outer space in real time, with accurate positions of objects and lots of interesting facts.

Cover image

When freight drones and air taxis enter service, they will have to share the airspace with existing traffic. How can the safety of transport users and people on the ground be guaranteed? DLR is researching a management system for air transport that includes both manned and unmanned aircraft.

DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center