

DLR / magazine

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FROM EARLY COMMUNICATIONS SATELLITES TO SWARM INTELLIGENCE

EARTH FROM SPACE: Tandem satellite mission on course for success

REPORTING LIVE: It takes two to tango

STORY: A way around the volcanic ash cloud





Image DLR/Gesine Born

Dear readers,

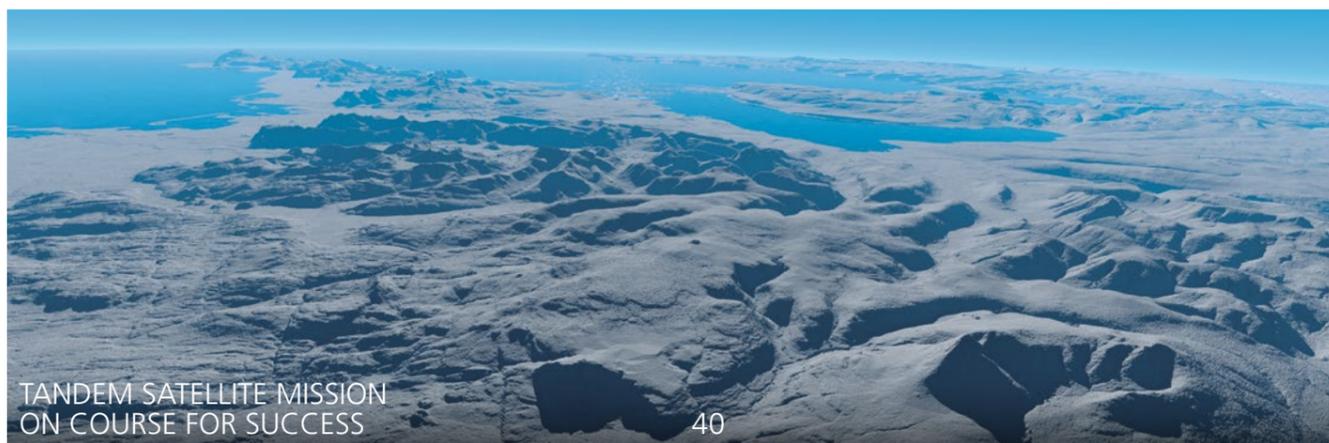
A glance into the past is more often condemned than praised. Confucius once said: "He who only looks back cannot see what is coming towards him." My motto is actually rather similar: "Look ahead, not back!" So taking a more historical approach than usual in the first DLR Magazine of the year might seem rather incongruous. But otherwise, you would not have the opportunity to read about the small but excellent Ries Crater Museum that, with expertise from DLR, explores the meteorite impact in Nördlinger Ries. Even the eruption of the Icelandic Eyjafjallajökull volcano in 2010 would hardly be mentioned. But the ash clouds that the volcano generated back then are the basis for a scenario showing us how, today, we could prevent an air traffic crisis such as the one that occurred from repeating itself. Without a glance back in time, you would not be able to read about DLR's magnificent satellite duo TanDEM-X and TerraSAR-X, whose images from space have changed how we view our planet, and which have paved the way for their successor mission, Tandem-L. What is more, we would not be able to celebrate the 50th anniversary of the Institute of Communications and Navigation and remember how we went from early communications satellites to swarm intelligence.

If we do not stop for a moment and look back, we will not be able to see how much we have progressed. For that reason, I also agree with the German aphorist, Wilhelm Vogel in that: "The sole purpose of the past is to better shape the future."

Sabine Hoffmann
Head, DLR Corporate Communications
Department



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TAILWIND PROPELLING US TOWARDS A CLIMATE-FRIENDLY FUTURE

By Jürgen Trittin, Member of the German Parliament

The German Aerospace Center (DLR) has been a source of fresh impetus for innovations and new technologies for 40 years. With its aerospace research, it not only explores new frontiers but has also made a significant contribution to tackling one of the biggest challenges of our time – preventing catastrophic climate change and transitioning our economy to renewable energy sources.

The researchers at DLR are no strangers to overcoming obstacles. With experiments in a wind tunnel, attempts had already been made at DLR's predecessor in Göttingen to minimise aerodynamic drag in ski jumping, and so calculate the perfect jump. Today, the scientists are helping with the leap into an era with no polluting fossil fuels. During my time as Minister for the Environment, DLR demonstrated that our ambitious goal of an energy transition was achievable and, in so doing, generated support for and enhanced the credibility of this project of the century – to which there was no lack of opposition.

The recent climate conference in Paris – with its national commitments to reducing carbon dioxide emissions – was a major step forward in the fight against climate change. Now, the many promises made must be turned into reality – and this is where both fundamental research and DLR's flagship projects can generate a tailwind. Its scientists were the well-deserved winners of the Descartes Prize awarded by the European Union for a project that involved the use of solar heat for the production of carbon dioxide-neutral hydrogen. Publications, like the recent study – commissioned by Greenpeace – of the possibility of relying entirely on renewables to supply the Canary Islands with electricity not only help persuade critics of the feasibility of a global energy transition, they also demonstrate that it is economically viable.

In the field of solar energy, DLR has also set new standards for the interplay between climate protection, technology policy and industry with the DESERTEC initiative. Although this project, which had the aim to bring solar power from North Africa to Europe's industrial centres, failed for economic and political reasons, we urgently need more initiatives that bridge the gap between applied research, technical expertise and policy.

Whether it is generating energy at the local level, the debate about the design of the electricity market of the future or green energy financing – with its outstanding fundamental research and specific projects, DLR has generated a strong tailwind for the energy transition. I am grateful for this expertise, which will help us to make the leap into a climate-friendly future in the coming decades.



Image: Laurence Chaperon

Jürgen Trittin, born in 1954, is a member of the German Parliament for Alliance 90 / The Greens and a member of the Foreign Affairs Committee. From 1998 to 2005 he was Federal Minister for the Environment, Nature Conservation and Nuclear Safety. During this time, he supported many DLR energy research projects.

INTELLIGENT STRUCTURES DEFY WIND TURBULENCE

Smart Blades – new ideas for stable and lightweight rotor blades

Rotor blades capable of adapting to the wind have been developed and tested at the Forschungsverbund Windenergie (FWWE, wind power research association). Nowadays, the rotor blade of a wind turbine can be up to 85 metres in length, and the turbines themselves can reach heights of over 200 metres. This places tremendous strain on the material. Rotor blades that are able to adapt their geometry to local wind conditions would be an ideal solution. In order to create a rotor blade that will respond to strong wind in such a way that it presents a smaller surface to the airflow, two possibilities were investigated – a crescent-shaped geometry and a special construction technique for the rotor blade. In the structural approach, the fibreglass from which the rotor blade is constructed is designed so that it is able to bend and adjust its angle to suit different wind speeds. This has the advantage of allowing for lighter blades. Another approach is active mechanisms that alter the trailing edges of rotor blades, enabling plant operators to control the aerodynamic loads on the blades. The concept is derived from aviation and is similar to the flaps on an aircraft's wings. The researchers also investigated whether movable slats on rotor blades can improve the efficiency of wind turbines under heavily fluctuating, turbulent wind conditions. The concept of a movable slat has been tested in a wind tunnel and yielded promising results for further developments.



Rotor blade trailing edges that change their shape and flaps that divert wind – very large rotor blades equipped with such mechanisms can correct gusts and reduce performance fluctuations.

At the FWWE – founded in 2013 – researchers from DLR, Forwind (the centre for wind energy research of the Universities of Oldenburg, Hannover and Bremen) and from IWES Northwest (the Fraunhofer Institute for Wind Energy and Energy System Technology) are working with representatives from industry and government, together with other partners, on large-scale wind energy research projects.

QUALIFICATION LABORATORY FOR SOLAR POWER PLANTS

An example for energy providers in India

DLR is supporting the Indian energy provider NTPC in establishing a research centre to test and further develop solar power plants and their components. DLR researchers are providing facilities, measuring equipment and expertise. The DLR test and qualification centre in Cologne, QUARZ, will act as a model for the Indian research centre. There, industrial providers will be able to test components for solar power plants, such as parabolic mirrors and absorber tubes. DLR has developed internationally recognised measuring procedures and has also established quality standards, which are now being implemented in the testing facilities. These include facilities for measuring mirror form and reflectance for photogrammetry and collector qualification. Software developed by DLR will also be used to optimise the power plants and ensure they produce the maximum possible amount of power.

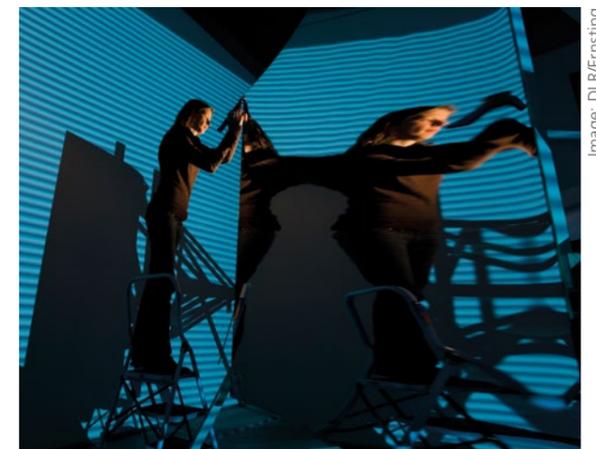


Image: DLR/Ernsting

DLR will also support its partner NTPC by providing an analysis tool that will search the whole of India to identify the best locations for solar power plants. "Although India is located geographically on Earth's Sun Belt, the country has a very heterogeneous and complex radiation potential. Among other factors, the 'Asian brown cloud', a large area of air pollution, sometimes limits the amount of solar radiation that reaches Earth," Christoph Schillings, Head of the Systems Analysis and Technology Assessment Department at the DLR Institute of Engineering Thermodynamics, explains, describing the situation in India. In addition to solar radiation, other factors such as land use, conservation areas, connections to the power grid and proximity to urban conurbations also play a part in the search for suitable locations.

How well does a mirror reflect the Sun's radiation? The testing methods developed by DLR are also able to test mirrors produced by other manufacturers.

s.DLR.de/7xy3

FASTER DETECTION OF LANDMINES USING RADAR

In an effort to aid the reconstruction of war-torn countries, DLR has developed a radar-based method of detecting landmines that is quick, safe and cost-effective. Following a recent Landmine Monitor 2015 report, in which an estimated 10 people fall victim to active landmines and other explosive remnants of war daily, the DLR Microwaves and Radar Institute has developed TIRAMI-SAR, a radar system that allows clearance personnel to examine larger areas of land in a shorter amount of time and in a more targeted way.

TIRAMI-SAR is designed to fit on the loading area of a small truck, and is equipped with multiple antennas that operate at higher frequencies and are angled such that the operators can move on secure terrain while the radar system scans a 'contaminated' area in the vicinity. Using various sensors to generate an 'intensity map,' TIRAM-SAR is able to show what is located both on and under the surface of the ground more quickly and effectively than traditional methods, such as metal detectors, ground-penetrating radars, and sniffer dogs.



TIRAMI-SAR is a part of DLR's security research initiative that has the objective of planning, researching and developing defence and security activities with government, academia, industry, and international organisations.

The system was developed as part of the EU TIRAMISU project. The objective of TIRAMISU is to provide the Mine Action community with a toolbox to help address issues related to Humanitarian Demining, promoting peace, national and regional security, conflict prevention, social and economic rehabilitation and post-conflict reconstruction.

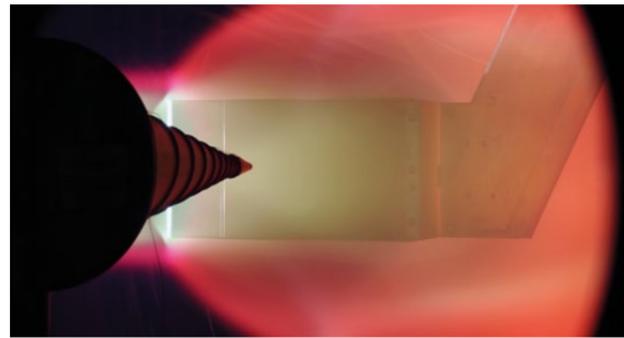
RENEWABLE ENERGY FOR THE CANARY ISLANDS

A study carried out by DLR at the request of Greenpeace shows that the Canary Islands could supply all of its energy needs with renewable energy sources by 2050. DLR systems analysts describe and compare two different development scenarios for the archipelago's energy supply.

The Canary Islands are well suited for the intensive use of renewable energy resources: as well as photovoltaics and wind power, they also have solar and geothermal energy sources. To achieve this potential, an investment of 20 billion euro by 2050 is necessary, which would be offset by the 42 billion euro savings in oil costs. Facilities with a total output of 12 gigawatts will have to be built to ensure that the energy system can be converted. At present, almost all of their demand is met with crude oil.



Image: Greenpeace



SPACECRAFT COMMUNICATION

Entering a planetary atmosphere is one of the most critical mission phases for a spacecraft. The enormous amount of heat generated not only places heavy thermal loads on the material of the re-entry vehicle, it also gives rise to an electrically charged plasma that flows around it. This blocks radio signals, with the result that the spacecraft is unable to communicate with its ground stations for several minutes. In January 2016, a test campaign took place using the arc-heated wind tunnel, operated by the Supersonic and Hypersonic Technology Department at the DLR Institute of Aerodynamics and Flow Technology in Cologne, to search for solutions to this problem. Together with US scientists at Stanford University, realistic test conditions were recreated. The test device, consisting of a heat shield with a transmitter placed behind it, was exposed to a plasma flow heated to several thousand degrees. An antenna was installed outside the hot gas flow to receive the radio signals.

The key to the new approach for preventing re-entry blackouts is a negative voltage field generated in the vicinity of the transmitter's antenna. The negative voltage diverts the ionised plasma flow, thus opening a window for the radio signals. This window cannot be kept open continuously. Therefore, the voltage is pulsed for intervals of a few milliseconds. This is sufficient to allow for data transmission and reception. Until now, the method of using pulsed electric fields had only been developed in numerical simulations. This series of tests represents another step towards future use in space.

NUMBER OF AIR PASSENGERS IS ON THE RISE

DLR scientists estimate that by 2030, 175 million passengers will be flying in Germany (according to DLR's 2014 Air Transport Report). This averages an annual increase of around 3.3 percent. Currently, there are approximately 105 million air passengers per year. But experts do not believe that this will result in a considerable increase in flights taking off from German airports in 2030, because the seating capacity of aircraft is also increasing. The DLR study estimates there will be 1,070,000 take-offs per year, which corresponds to another 130,000 compared to today. The number of take-offs per year would increase by a mere one percent. The volume of cargo – on the other hand – is set to rise significantly: the long-term positive development of the global economy could mean the amount of loaded cargo will increase to 7.3 million tons by 2030.



Image: Flughafen Stefan Reibich

NEW HELMET SYSTEM TESTED IN TRIALS

DLR has developed a helmet-mounted display for helicopter pilots. The display aids pilots faced with poor visibility conditions, especially during landing. Test flights with DLR's ACT/FHS helicopter, which is based on a Eurocopter EC135, tested whether the helmet display could reduce the strain placed on pilots during landing. Sensory data, as well as relevant flight information, is shown directly on the pilot's visor. The helmet system is also fitted with a head tracker that records the direction in which the pilot is looking. Conformal virtual elements – for example obstacles and statistical information – are displayed via a high performance graphing calculator, which gives the pilot an artificial image of the external situation.



NEW FINDINGS FOR QUIETER ENGINES

To get to the bottom of aircraft noise, researchers at DLR dismantled aircraft engines and carried out physical modelling. The aim of the tests conducted was to find out where exactly the noise originates and changes depending on how the engine parts are reassembled. Engine acoustic researchers were able to measure the physics behind the core engine noise and present this data numerically for the first time. With the model they have developed, the processes involved in the formation of core engine noise can be accurately pinpointed. This not only provides a general understanding of noise formation, but it also enables the design of quieter and more environmentally-friendly engines.



Image: Laboratorio di Fluidodinamica delle Macchine del Politecnico di Milano

LAUNCH OF EUROPE'S 'DATA HIGHWAY IN SPACE'

On 29 January 2016, the first ever node of the European Data Relay System (EDRS), EDRS-A, was sent to space on board a Proton rocket. This is the start of Europe's new 'data highway in space'. The EDRS represents a milestone in telecommunications. As a Private Public Partnership (PPP) between the European Space Agency (ESA) and Airbus Defence and Space, the data highway is expected to transmit up to 1.8 gigabits of data to Earth per second. Central to the system are the German-developed and built laser communication terminals. The responsibility of monitoring the payloads and controlling the EDRS-C satellite will lie with the German Space Operations Center at DLR in Oberpfaffenhofen.



Image: International Launch Services

MEET DLR AT ...

WONDERS OF NATURE

11 March - 30 December 2016 • Oberhausen
The 'Wonders of nature' exhibit at the Gasometer in Oberhausen follows growth and development on our planet, and celebrates its intelligence and diversity. The highlight of the exhibit is Earth, which is brought to life, glowing in the immense interior of the Gasometer.

A NEW PERSPECTIVE ON MARS

1 April - 1 July 2016 • Colorado Springs, USA
The 3D exhibit 'A New Perspective on Mars' at the Space Foundation World Headquarters and Discovery Center, showcases high-resolution images acquired by the DLR-operated HRSC camera on board Mars Express. Orbiting Mars for more than 10 years now, the mission is providing fascinating insights into the geology of our neighbour, not to mention jaw-dropping images.

SPACEOPS 2016

16 - 20 May 2016 • Daejeon, South Korea
DLR will participate in the 14th edition of SpaceOps, the technical forum for individuals involved in space mission operations, hosted by South Korea at the Daejeon Convention Center. This year's conference will focus on state-of-the-art tools and methods in space mission ops as well as the chance to exchange administrative and technical best practices on various topics including robotics, Earth orbiting and deep space operations.

SUMO 2016

24 - 25 May 2016 • Berlin, Germany
The SUMO 2016 conference, coordinated by the DLR Institute of Transportation Systems, will take place in Berlin-Adlershof. Focusing on road traffic simulation and mobility behaviour, this year's conference aims to facilitate scientific exchange on these topics and is open to individuals interested in traffic, mobility and simulations.

INTERNATIONAL AEROSPACE EXHIBITION ILA

1 - 4 June 2016 • Berlin, Germany
An international favourite of the aerospace industry, the ILA Berlin Airshow will be held at the Berlin ExpoCenter. DLR will be on an impressive display, exhibiting its latest research on space, aeronautics, energy, transport and security, as well as its research aircraft fleet. Celebrating 40 years of energy research, DLR will also host a supporting programme that looks back on highlights of this crucial endeavour.

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AN OASIS IN THE DESERT – FROM SEA AND SUN

By Massimo Moser

A few years ago Marsa Alam, an Egyptian town on the Red Sea coast, was just a small village of humble stone houses. Today, it is experiencing a strong population growth, and numerous tourists have found their way to the hotels along the coast. Marsa Alam is surrounded by desert and sea, but the township has yet to be connected to the national water and electricity supply networks. Rain is scarce in the region: on average, it rains just one day per year, and Egypt's only year-round river – the Nile – is more than 200 kilometres away. As a result, the local water supply is based on groundwater reserves.

The situation in Marsa Alam exemplifies that of many places in the Middle East and North Africa. The region's rising prosperity is generating an increase in the population, as well as the per capita consumption of water and energy. By 2050, water consumption is expected to have nearly doubled compared to the year 2000. Meanwhile, the naturally occurring quantities of water are expected to continue to decrease with time due to climate change. Taking this into account, it is likely that the amount of local rainfall will decrease by up to 40 percent between 2010 and 2050.

Sun and seawater are plentiful in Marsa Alam – the opposite occurs with potable water – so desalination plants seem the obvious solution for meeting the demand of drinking water. It also stands to reason that these energy-intensive processes could be run using solar power. In this way, the limited groundwater reserves could be preserved and protected against overuse. It has been estimated that, in 2020, approximately 30,000 cubic metres of water per day will be required in Marsa Alam and its surrounding areas to support its residents, local agriculture and the tourists, as well as to maintain the numerous golf courses that have been created for tourism purposes.

Using Marsa Alam as a case study, the Department of Energy Systems Analysis at the DLR Institute of Engineering Thermodynamics investigated the feasibility and economic viability of combining a renewable energy power plant with a plant for the production of drinking water. This proposal was explored using the INSEL simulation tool – Integrated Simulation Environment Language – a graphical programming language to simulate energy systems based on renewable energies. INSEL can be used to simulate smaller energy systems (such as that of a small town) based on input data (such as electricity demand or solar radiation) and the stored algorithms for the respective plant components. The commercial software already accommodates a broad spectrum of models, including those for photovoltaic modules and wind turbines. As part of the study, it was supplemented with newly developed models for solar power plants (CSP, Concentrated Solar Power), thermal energy storage units and desalination plants.



Image: Fotolia

The up-and-coming Egyptian town of Marsa Alam has Sun and seawater in abundance. What it lacks is fresh water. A DLR study set out to determine to which extent the desalination of seawater might solve this problem.



Image: VA TECH WABAG
Al Ghubrah desalination plant in Oman. The plant supplies the city of Muscat with drinking water.

The study focused mainly on two desalination technologies: reverse osmosis (RO) and multiple-effect distillation (MED). Osmosis is a natural phenomenon that involves the spontaneous flow of a liquid – such as water – through a selective membrane towards the solution containing the higher concentration of dissolved substances, such as salt. In desalination, what is important is the reverse process – in other words, the flow of water from a concentrated solution (seawater) to an almost salt-free solution (drinking water). Reversing the natural phenomenon requires energy in the form of an applied pressure of up to 80 bar, which is supplied by means of a set of pumps. In contrast, MED is a thermal process based on a series of evaporation and condensation steps at different temperatures. This process requires thermal energy, such as the waste heat from a steam turbine with a temperature of around 70 degrees Celsius, as well as some electrical power for the feedwater pumps.

While thermal desalination processes, including the MED process, which is mainly used in Saudi Arabia and other countries of the Arabian Gulf, have been employed for decades, reverse osmosis has started to play a more dominant role in the world market in recent years. The improved salt rejection rate and longer lifespan of the membranes, as well as its lower energy consumption and lower capital costs have all added to this growing trend. The analysis conducted by DLR has concluded that, in the Marsa Alam region, reverse osmosis would be the more economical option. Nevertheless, the MED process is still a competitive option on account of its simple and robust operation, particularly when the seawater is of low quality and has a high salt content, as is often the case in the Arabian Gulf, for example.

When used on a large scale, desalination can significantly increase the consumption of fossil fuels and, by extension, the emission of greenhouse gases. Therefore, the second focus of the study was to investigate how desalination can be combined with the use of renewable energies. To this end, the simulation tool was used to calculate the costs per cubic metre of water for various scenarios. The input data used in the analysis included electricity and water demand in the region, the available resources (sunshine duration, wind speed, air temperature and water quality) and technical and financial parameters (including capital and operating costs of the plants, fuel cost, etc.). The scenarios were calculated on an hourly basis. A subsequent feasibility analysis took the total lifetime of the facilities into account.

The above-calculated scenarios demonstrate that desalination plants can make an important contribution to supplying Marsa Alam with drinking water. The energy requirements for desalination can be met by using both fossil and renewable energy resources. The costs of water treatment depend on the type of energy used; if the plants are supplied purely by fossil energies, the cost of water is currently approximately 0.70 to 0.80 euro per cubic metre, although this does not take into account the fact that many countries in the region heavily subsidise the use of fossil fuels. This causes a distortion in the competition between fossil and renewable energies. If the market price of fossil fuels (stand June 2014) is taken as a basis, the water price increases to about 1.20

euro per cubic metre. On this assumption, supplying Marsa Alam with power from renewables would be less costly than with fossil fuels – even at the present time. The findings of the study also show that if approximately 75 percent of the energy came from renewable energy sources, a water price of approximately one euro per cubic metre could be possible by 2020. The energy mix in this scenario consists of renewable energy sources such as wind power and photovoltaics, as well as adjustable output power plants based on CSP, which use efficient thermal energy storage to be able to produce electricity on demand.

The study shows that renewable energies are an environmentally friendly solution to the rising demand for drinking water in Marsa Alam. By switching the energy and water system to renewable energies, the town can reduce its dependence on fossil fuels and stabilise the cost of water treatment in the future. This sustainable approach to water treatment may also boost the image of this tourist resort at the Red Sea.

Massimo Moser is a research assistant in the Department of Systems Analysis and Technology Assessment at the DLR Institute of Engineering Thermodynamics in Stuttgart.

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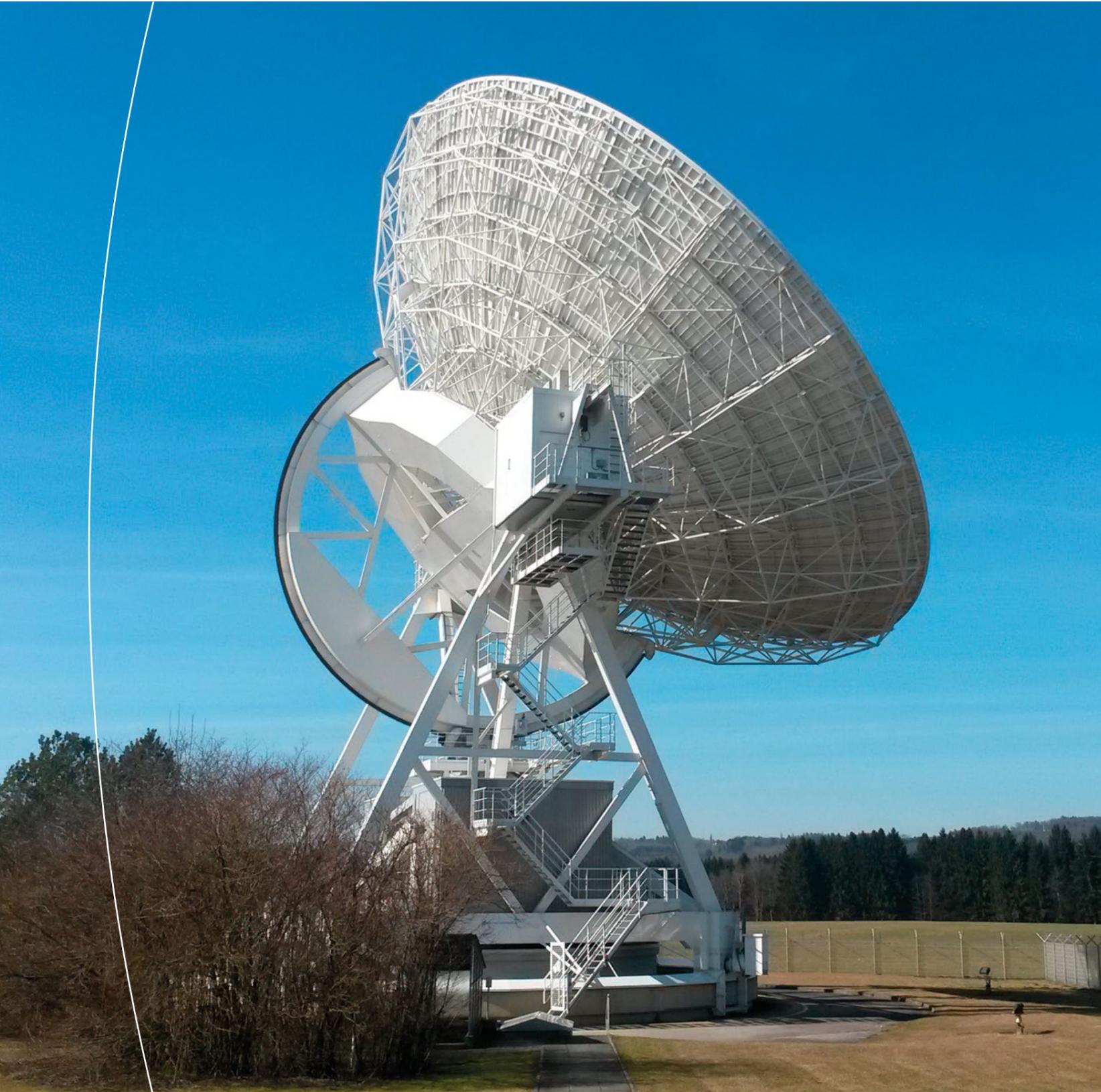
PROS AND CONS

REVERSE OSMOSIS (RO)

- Electricity consumption: four to five kilowatt-hours per cubic metre of water
- Water quality: drinking water quality, but still too salty for agriculture
- Boron content of water: depending on the location, boron cannot be adequately removed, so may not be suitable for agriculture
- Requires well-trained personnel
- Feedwater must be treated with precisely measured chemicals; otherwise, the energy consumption increases and the membranes are damaged
- Lower capital costs
- Lower seawater consumption than thermal processes, but very high salt concentration in the waste water, which, typically, is fed back into the sea

MULTIPLE-EFFECT DISTILLATION (MED)

- Electricity consumption: 1.5 kilowatt-hours per cubic metre
- Thermal energy consumption: approx. 60 kilowatt-hours per cubic metre
- Water quality: low-salt drinking water, may also be suitable as process water and for agriculture
- Robust process: less sophisticated pre-treatment of seawater needed, water may contain more salt and be more contaminated
- Higher capital costs than RO
- Higher seawater consumption than RO



FROM EARLY COMMUNICATIONS SATELLITES TO SWARM INTELLIGENCE

By Bernadette Jung and Susanne Haas

In the early years of space exploration, Germany planned to launch its own research satellite – AZUR. From 1964 onwards, a group led by Philipp Hartl worked intensively on this large-scale project. In 1966, this led to the foundation of the Institute of Satellite Electronics, the predecessor of today's Institute of Communications and Navigation. Fifty years later, the technologies are very different, but the drive to conceive better communications and navigation capabilities and develop new technologies remains unchanged.

Since its foundation in 1966, the Institute has been involved in groundbreaking developments. One highlight was Symphonie, the first European communications satellite, launched in 1974. The Institute played a major role in developing the satellite. In 1974, radio signals were the only means of transmitting information between satellites and ground. Today, the Institute works on methods that use optical signals instead. Initially, voice and images were transmitted by analogue means. For decades, scientists at the Institute in Oberpfaffenhofen contributed to the development and introduction of digital communications – from the first trials using coded modulation to the design of the future aeronautical digital communications systems.

DLR also played a leading role in the area of satellite navigation. One of the very first European GPS receivers was built at DLR in 1982. Today, the Institute of Communications and Navigation designs the world's most robust receivers. Early work in ionospheric research dates back even further – more than one century ago, scientists and engineers at the present-day DLR Neustrelitz site were already working in this field. The first algorithms to forecast the electron density in the ionosphere were demonstrated at this site not long ago.

For Christoph Günther, who has been in charge of the Institute for more than a decade, being a pioneer in new technologies is both an aim and a claim. He wants to explore new territory and push the boundaries of what is possible. His motivation is to obtain results that are both highly relevant and have never before been achieved.

Satellite systems remain at the heart of numerous research activities. However, the Institute's 170 employees also devote their time to topics in the fields of aerospace, transport and security. Their work covers a broad spectrum – from answering fundamental questions to demonstrating

technologies. The projects are geared towards five missions, which are outlined below. One of the Institute's particular strengths is the combination of theory and experiment in its work. Theory supplies the foundations for algorithms and defines what is feasible in terms of data rates or position accuracy, for example. The purpose of prototypes is to demonstrate the practicability of the new approaches and to identify and overcome hurdles to their implementation. Furthermore, the experiments are an opportunity to develop models and thereby continuously improve the theory. The Institute places particular emphasis on transferring the results into industrial applications. It is involved in the development of standards, and cooperates with businesses and supports spin-offs.

Mission 1 – Global networking

Networking has dramatically increased in our daily lives. Many systems are dependent on Internet access and most people would not want to be without a broadband connection. Satellite systems are the most cost-effective means of establishing communications networks in sparsely populated areas and the only means at sea and in the air. There are two options – constellations of several hundred to several thousand satellites at an altitude of around 1000 kilometres, or a handful of extremely powerful geostationary satellites at an altitude of approximately 36,000 kilometres. Low-flying satellites enable short transmission times between ground terminals; however, the mechanism for their disposal after approximately five years in operation is not yet determined. Geostationary satellites require capacities in the range of terabits per second. For these satellites, the Internet connection presents the greatest challenge – and it is precisely that challenge that the Institute intends to tackle using optical communications, as the available bandwidths with this form of communication are 1000 times greater than that which can be achieved using radio signals. However, both clouds and the fluctuating refractive index of the atmosphere impede transmission. The careful positioning of ground stations makes it possible to switch to an alternative station in cloudy conditions. New approaches are being pursued at the Institute to overcome other forms of atmospheric interference. The first transmission tests began in the first half of 2016. If they are successful, transmission rates comparable to those of fibre optic networks will, for the first time, be possible for space applications.



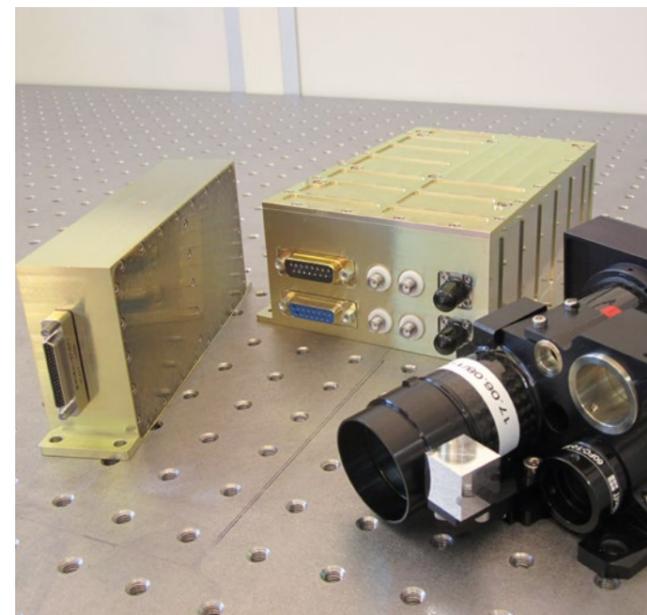
Researchers from the Satellite Networks Department in front of the optical ground station on the roof of the Institute building in Oberpfaffenhofen. The Transportable Optical Ground station, TOGS, is visible on the left.

Conventional radio transmission remains the method of choice for communication between users on Earth and satellites due to potential cloud cover in the skies. The Institute has also undertaken pioneering work in this area, developing new low-loss methods to enable the uncoordinated access to radio channels. It also developed the world's most effective error protection codes. On the experimental side, it has demonstrated 'network coding' via satellite for the first time, potentially halving the required bandwidth and satellite power. Several hundred million euro can be saved for every communication satellite not required.

Following the powerful submarine earthquake in 2004 and various other natural disasters, global warning systems became an important and very specialised aspect of global communication. With Alert4All, researchers at the DLR Institute of Communications and Navigation succeeded in designing, implementing and demonstrating the functional capability of such a system. Alert4All is able to inform every individual via a multitude of channels: satellite-controlled sirens, terrestrial and satellite-based television, satellite navigation receivers, building security systems, the Internet, as well as through mobile radio using apps on a smartphone or tablet.

Mission 2 – Communications solutions for science, exploration, and reconnaissance

Every photographer wants a camera with higher resolution. The same is true of scientists who use cameras to observe Earth or distant planets. High-quality images are also of great value in disaster management or peacekeeping missions. However, in these situations, the cameras are installed on aircraft and satellites. Consequently, transmission systems that are capable of sending the largest possible amounts of data in a short time are required. Optical transmission offers extraordinary capabilities, enabling higher transmission rates while requiring smaller equipment. In 2008, the Institute demonstrated the first optical connection between an aircraft and the ground. In 2013, it was followed by the first demonstration on a German Air Force Tornado aircraft. These developments are being implemented industrially by the DLR spin-off ViaLight Communications GmbH.



Components of the OSIRIS system – using the miniaturised laser transmission terminal, data from the BIROS satellite will be sent to the ground by laser for the first time in 2016.



First journey with an anti-collision system for trains. The public demonstration of the Railway Collision Avoidance System, RCAS, conducted in a real train on a test track at the Bayerische Oberlandbahn in 2010 was successful. Since then, the system, which was designed at DLR, has been implemented by industry.

The DLR BIROS satellite is scheduled for launch at the end of May 2016. It is equipped with a terminal weighing just 1.65 kilograms that is capable of transmitting one gigabit per second from near-Earth orbit. Further developments of the associated technology are also suitable for connecting communication satellites from 'mega constellations' to the Internet.

Mission 3 – Safe and efficient air, sea and land transport

Aircraft and ships lack visual orientation in foggy and cloudy conditions. This is why, in the 20th century, radio navigation systems and radar were developed. GPS was the first globally available system that could be used almost everywhere, for almost any purpose. With the increasing number of satellites and systems, it will be possible to overcome more and more of the remaining limitations. This is one of the aims that the Institute has set itself. It would then be possible to reliably land aircraft or berth ships with marginal support. To achieve this, all the natural causes of error must be investigated and eliminated. In addition, it is becoming increasingly important to suppress deliberate interference caused by humans. For this purpose, the Institute is developing the most robust receivers in the world. The article 'Antennas with character' discusses these developments.

Robust and reliable satellite navigation will enable completely new procedures for aviation and shipping that will greatly improve efficiency while offering at least the same level of safety. However, transport users must be in accord with this. As the radio systems in aviation and shipping are largely speech-based and analogue, new and robust digital communications systems are required. For aviation, the Institute has successfully designed a system that does not require new frequencies (this is introduced in the interview with Michael Schnell entitled 'Revolutionising aeronautical communications'). The International Civil

Aviation Organization started a standardisation procedure for this technology. The fact that this system's communication signals can also be used for navigation makes it even more interesting. This allows for a backup system that can be used in the event of disruption of satellite navigation systems. Inertial sensors, radars, and sonar (on ships) are used for this too.

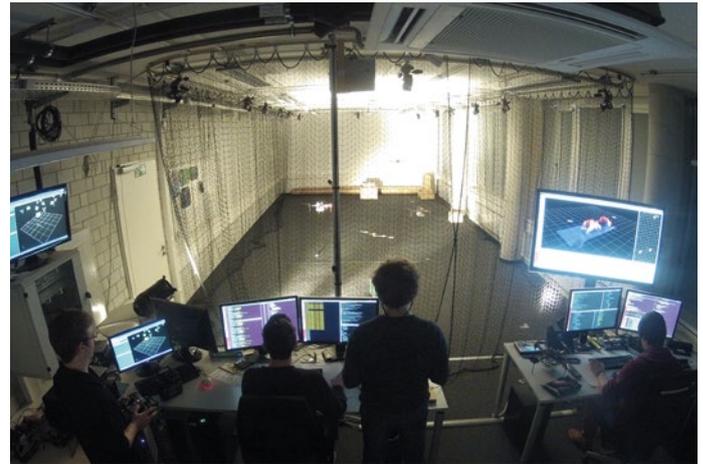
In aviation, collision avoidance systems are already being used with success to prevent collisions. Researchers from the Institute of Communications and Navigation are seeking ways of coordinating anti-collision systems at an even earlier stage and intend to extend them to other modes of transport. Of particular note is the 'Railway Collision Avoidance System', which was designed at the Institute and is now being developed by the start-up company 'Intelligence on Wheels GmbH'. The system will warn of impending train collisions on branch lines and in shunting situations.

Mission 4 – Navigation systems

Galileo will soon be introducing its first services, and the DLR Space Applications Company (Gesellschaft für Raumfahrtanwendungen mbH; GfR) is playing a pivotal role. The Institute of Communications and Navigation is supporting the deployment of the system by measuring signals – a task for which it is using the 30-metre antenna at DLR's Weilheim site. Precise knowledge of the signal distortions is particularly important for safety-critical navigation, as the techniques use measurements on the aircraft and on the ground, and distortions typically affect these receivers differently. Investigating the influence of the ionosphere on the signals and, in particular, predicting the ionisation state play an important role for many services; this capability is currently undergoing further development on behalf of ESA, so that warnings can be issued and reliable forecasts made, even during solar storms. Moreover,



This autonomous multicopter is part of a swarm. Each swarm member autonomously maps its surroundings using ultrasonic sensors. During testing, ground profiles are simulated with a tarpaulin. The individual measurements are communicated to other swarm members so that an overall picture of the environment is created.



The researchers in the 'Swarm Exploration' group verify their algorithms in the 'Holodeck', a special laboratory at the Institute.

characterising the ionisation state was crucial to the approval of GPS-based aircraft landing procedures (Ground-Based Augmentation System; GBAS) in Germany.

Developments for the next generation of the Galileo system are a new focus of the Institute's work on navigation systems. These developments address a new timing system, new signals, automatic calibration on the satellite and on the ground, and communication with the satellite and the user. Algorithms that further increase the availability of high precision and safety are a central aspect of this.

Mission 5 – Autonomous navigation and exploration

GPS and the Galileo system are not available everywhere. Position information is also of great interest inside buildings and subway systems. For this purpose, DLR researchers developed the Simultaneous Localisation and Mapping (SLAM) method, which enables localisation in buildings using low-cost sensors. If a person is wearing one of these sensors when walking around a building, it records data such as accelerations and turn rates, magnetic fields and radio signals. What makes it unique is that the sensor itself does not have the capability to visually record the environment. However, the data obtained can be used to estimate

the route taken and produce a map that is accurate to within a few tens of centimetres. A team of researchers working on this topic moved to Google in 2014.

A high degree of autonomy is important not only on Earth, but also for exploring distant planets. This is where another element comes into play: the capability of deciding on the next step. At present, this decision is predominantly controlled remotely from Earth. This is a slow process, which is susceptible to communications outages. Hence, the Institute of Communications and Navigation is developing systems that use swarm intelligence, like that displayed by ants. Each element works for itself, but in concert with its neighbours. If a system breaks down, the other elements continue. With this, the Institute has found an extremely efficient way of determining an elevation profile using a swarm of quadcopters.

The DLR Institute of Communications and Navigation will continue to investigate and develop pioneering technologies of benefit to society.

Susanne Haas is responsible for, among other things, public relations at the DLR Institute of Communications and Navigation.

Bernadette Jung is the communications officer at the DLR site in Oberpfaffenhofen.



Large antennas maintain communications links between the ground and satellites. For the Galileo system, precise knowledge of the signal distortions is required. For this purpose, the Institute of Communications and Navigation analysed the signals. In this image, the 30-metre antenna at DLR Weilheim.

ANTENNAS WITH CHARACTER

GALANT – a robust receiver for satellite navigation

By Achim Dreher and Achim Hornbostel

Signals from GPS and Galileo are highly susceptible to interference because the received signal power is generally extremely small – about one tenth of a femtowatt; a number possessing 15 zeros after the decimal point! However, availability and reliability are critical for many applications. In aviation, maritime transport and autonomous driving, people and control systems must be able to rely fully on the estimated position and attitude. The GALANT receiver, developed by the DLR Institute of Communications and Navigation, is a system that meets the highest standards.

The development began about 10 years ago, in view of the construction of the European navigation satellite system Galileo – hence the name GALANT, which is the acronym of ‘Galileo antenna’. Today, the system covers several frequency bands and is suitable for both Galileo and GPS signals. The basic idea is that the antenna characteristics are adaptively shaped in such a way that they spatially fade out interfering signals while improving the reception of the desired signals. This ensures an even more extensive use of satellite navigation for safety-critical applications in the future.

Fake signals exposed

Commercial navigation devices are based on receivers that work with a single antenna element. For safety-critical applications, this type of receiver has limitations. The advantage of a receiver with multiple antenna elements is that the reception characteristics of the array can be adaptively shaped using digital beam forming. The received signals from all antenna elements can be specifically combined and processed using a microprocessor so that the antenna pattern gets the desired characteristics, individually for each satellite. In this way, GALANT is able to adapt to different receiving situations. In addition, the direction of the incoming satellite signals can be determined through the application of suitable algorithms. By comparing the estimated direction with the known position of the satellite, the system detects deceptive satellite signals, such as those generated by spoofers or by the retransmission of received signals with a repeater (meaconing).

The DLR Institute of Communications and Navigation in Oberpfaffenhofen is continuously extending GALANT and adding new functions. One objective is the integration of the array into the surface of aircraft, vehicles and ships. A compact design is also essential to allow future applications in the automotive sector. Further projects to reduce the size of the antenna are currently underway in collaboration with partners.

Successful deployment in the field

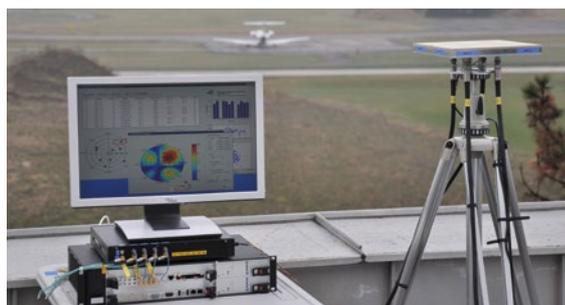
The capabilities of the antenna system have been demonstrated on multiple occasions. Experiments in the German Galileo Test and Development Environment (GATE) near Berchtesgaden have demonstrated the successful use of the GALANT technology for interference suppression. In particular, an interference situation that disabled a GPS-based landing system at Newark Airport (New Jersey, USA) was reproduced – the GALANT receiver reliably and precisely determined the location, whereas commercial receivers used for comparison either did not supply any positional data at all or experienced major errors. The GALANT system can also reliably detect interference caused by a repeater – for example, used for maintenance in aircraft hangars. Further test campaigns at sea, in the air and on the road were carried out. The medium-term goal for this technology is to cover a wide range of safety-critical services that guide aircraft when landing, assist ships with docking and keep vehicles on the road. The technology is also suitable for use in ground reference stations of the Galileo and EGNOS systems themselves.

Achim Dreher is Head of the Antenna Group at the DLR Institute of Communications and Navigation.

Achim Hornbostel heads the Algorithms and User Terminals Group.



Individual antenna elements combined in an array make navigation more reliable



Tests showed that interfering signals could be suppressed using GALANT technology

REVOLUTIONISING AERONAUTICAL COMMUNICATIONS

DLR Magazine speaks with Michael Schnell



About Michael Schnell

Michael Schnell has worked at the DLR Institute of Communications and Navigation in Oberpfaffenhofen since 1990. He heads the Aeronautical Communications Research Group and is Theme Coordinator for Aeronautics at the Institute. The main research topics of his group are the modernisation of communications and surveillance technology in civil aviation, and the integration of unmanned aerial vehicles (drones) into civil air space. He also advises the German air navigation service provider Deutsche Flugsicherung (DFS) on various committees at EUROCONTROL and at the ICAO. He is the designated chairman of the ICAO Working Group on LDACS Standardisation. From 2003 to 2014 he was also a lecturer at the Karlsruhe Institute of Technology (KIT). He is the author/co-author of over 100 publications, including 20 magazine articles.

Air traffic is constantly increasing. Air traffic controllers are its backbone. For them – and for air transportation as a whole – efficient and secure communication is vital. Susanne Haas spoke with Michael Schnell, Head of the Aeronautical Communications Research Group at the DLR Institute of Communications and Navigation, about the future aeronautical communications system for air transportation.

How do air traffic controllers currently control and guide air traffic?

■ The controllers are in constant radio contact with the pilots. In addition, they receive information about the real-time positions of aircraft in the airspace for which they are responsible. The positions of the aircraft are determined both passively – using radar – and actively, via automated queries sent to the aircraft. Thus, the air traffic controllers have a complete picture of the situation that enables them to guide air traffic. Any conflicts are identified early on and any changes to flight paths are made in a timely manner. At present, controllers exchange information – changes in direction, altitude and so on – with pilots mainly via analogue radio telephony, which works similarly to a walkie-talkie.

Why is this no longer adequate?

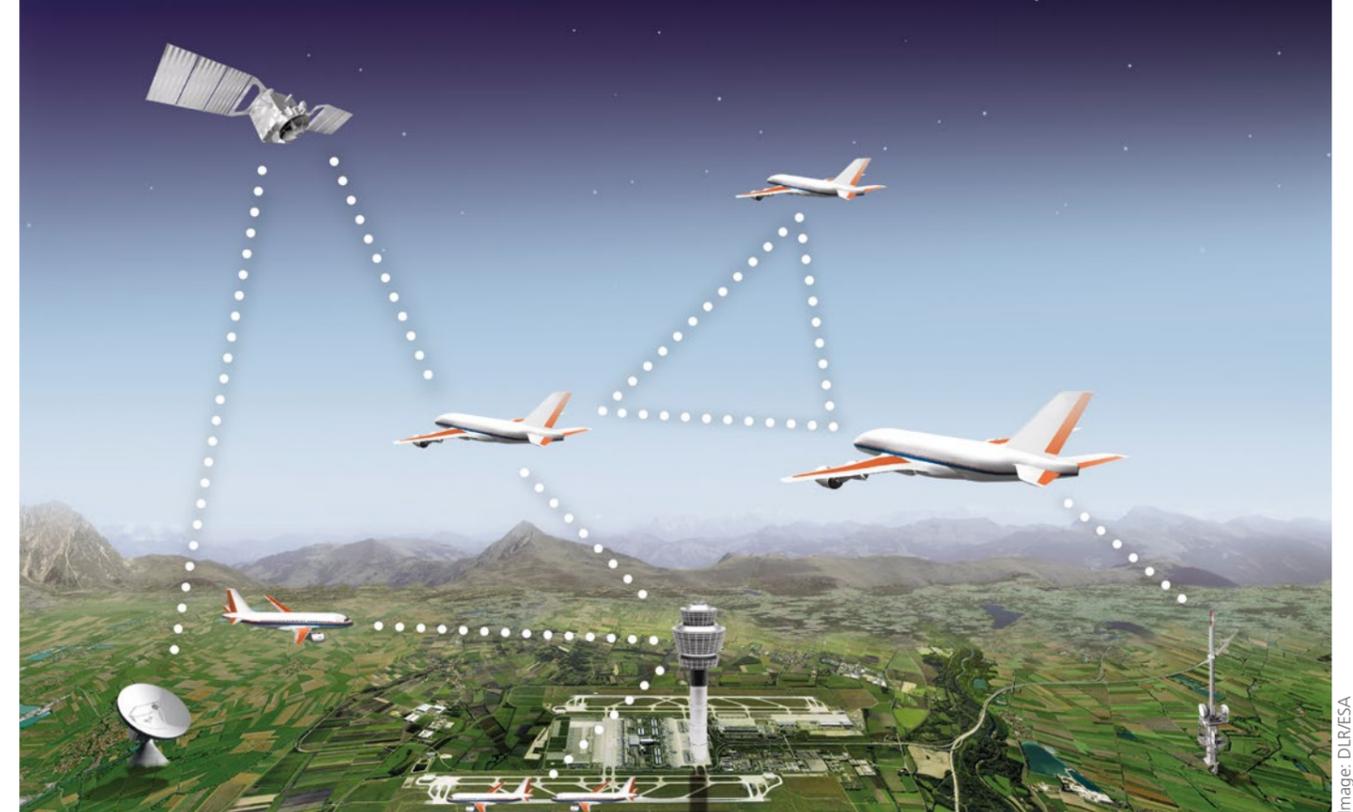
■ The analogue technology upon which present-day radio telephony is based was introduced in the late 1930s; it is safe and robust, but outdated and complicated to use. The pilots have to sign on and off verbally and tune to different radio frequencies manually. In addition, because of its inefficiency, analogue radio telephony requires large parts of the available frequency spectrum and so ties up frequency resources. Those resources are, however, limited and sought-after; just look at recent spectrum auctions for mobile radio licences. But as the number of flight movements continues to rise, so will the demand for communication. To meet that demand, new communications technologies that make much more efficient use of the available frequencies than does the analogue radio telephony technology in use today are needed. The LDACS digital communications system guarantees the necessary spectrum efficiency. A further reason for introducing LDACS has to do with the modernisation of the entire air traffic management system currently underway. For increasing air traffic to be safely accommodated in future, new control and management procedures are being developed and introduced. These are significantly more efficient but also more complex than the previous ones, so they require the support of fast and secure digital data transmission. In the future, for example, aircraft will fly according to four-dimensional trajectories – for example, according to predefined time-stamped flight paths. Owing to their complexity, these trajectories can no longer be communicated by the air traffic controllers via voice using analogue radio telephony – digital data transmission is required.

What changes will LDACS bring about? What will the improvements be?

■ LDACS will enable greater quantities of information to be exchanged between pilots and air traffic controllers more quickly and efficiently. What is more, LDACS supports the introduction of new procedures in air traffic management. LDACS is thus a key technology when it comes to integrating an aircraft into the information network for future air traffic management.

How does the new communications system work?

■ In principle, it works similarly to mobile telephony, where the LDACS ground station would correspond to the base station and the radio device in the aircraft to the smartphone. The LDACS radio technology is based on modern communications technology, such as the one used for mobile telephony and WLAN transmission. But this technology had to be specially adapted to the requirements of aeronautical communications and the characteristics of the frequency band used. The L-band is already used by several radio services in aviation, particularly radar-based navigation services. Because of this, the LDACS signals had to be designed to not interfere with the existing L-band radio services or be affected by them.



Networked communications infrastructure with LDACS as the key component, supported by satellite communications: the aircraft is fully integrated into the information network for air traffic management.

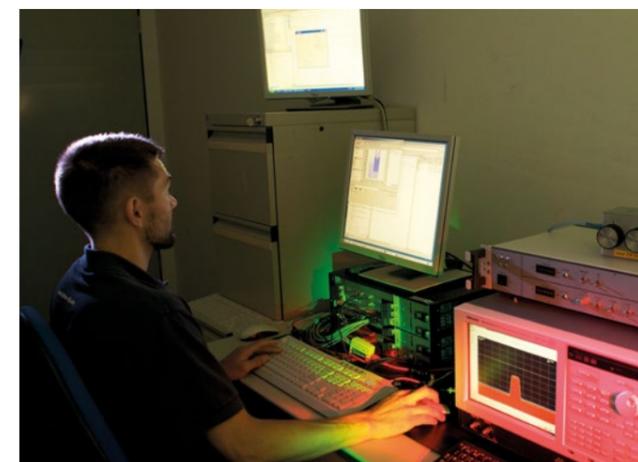
What role does DLR play in the development of LDACS?

■ DLR has played a leading role since the work began in 2007. In the beginning, the development of LDACS was driven forward together with two Austrian partners, Frequentis AG and the University of Salzburg and, since 2012, with the company Rohde & Schwarz as well. The DLR scientists carried out the first theoretical considerations on LDACS, designed large parts of the LDACS system, and verified the system design in subsequent computer simulations. The LDACS technology developed was implemented in hardware by DLR, and the world's first LDACS demonstrator was built, allowing the technology to be tested under laboratory conditions. Flight tests with a prototype created by Rohde & Schwarz are currently in the planning stage. We also actively support the standardisation and implementation of LDACS on all relevant bodies – primarily EUROCONTROL (European Organisation for the Safety of Air Navigation), EUROCAE (European Organisation for Civil Aviation Equipment), which deals specifically with the standardisation of aviation electronics and ICAO (International Civil Aviation Organization).

The scientific results we have obtained have been published in various international conference papers and journals.

What are the next steps? When will LDACS be introduced?

■ The ICAO Communications Panel decided to establish a working group on LDACS standardisation, which will start its work in 2016. Because of our expertise, DLR is nominated to chair this working group. A draft standard should be available in 2018. The target is to have a final standard by 2020. After that, industry, aircraft manufacturers and airlines will be required to embrace and implement the standard. Modern, efficient communication for civil aviation air traffic management – with all of the advantages it has to offer – could be a reality from as early as 2020. LDACS will undoubtedly remain in use for a number of decades because the radio technology upon which it is based is very flexible and scalable, and can easily be adapted to future requirements.



Implementing the LDACS design in a demonstrator for testing and measuring the characteristics of the LDACS system in a realistic environment

LDACS – AERONAUTICAL COMMUNICATIONS OF THE FUTURE

LDACS (L-band Digital Aeronautical Communications System) is the future of communication between air traffic controllers and pilots. It is a digital transmission system for air traffic control and management. Similar to mobile telephony, it enables both speech communication in CD quality and rapid data exchange. The L-band aeronautical communications system integrates the aircraft into the information network for air traffic management.

ON THE SAME WAVELENGTH AS LIGHT

Christian Fuchs – passion for free-space optical communications

By Elisabeth Schreier

Christian Fuchs is well aware that, to the layperson, free-space optical communications is a closed book. With a smile, the researcher acknowledges that, although friends and acquaintances are indeed very interested in his work, most of the issues do not have a connection with their everyday lives. But data transmission by laser will soon play an important role in our daily life – of that, he is confident. The 34-year-old communications engineer has been researching the development of this technology at DLR for almost 10 years.

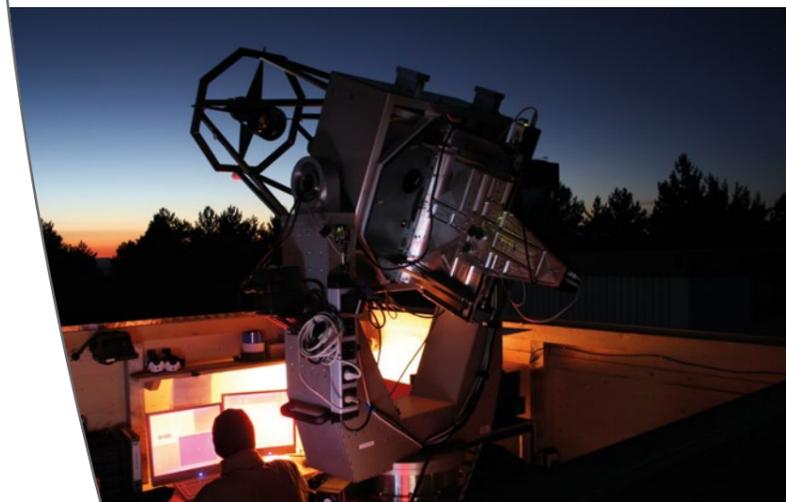
Since his first year, Fuchs has dedicated heart and soul to DLR. It all began when he was seeking a project for his Master's thesis. Various internship and university projects left him in no doubt – research is his passion and would be his future career path. "I truly wanted to work in space engineering," he says, remembering the time during which he was seeking out a career path. "It is more or less by chance that I am now working on free-space optical communications. But I have not regretted it for a moment." This passion for a subject that sounds rather complicated at first, arose when he was working on his Master's thesis in 2005/2006 – and it remained. Immediately upon completion of his thesis, he was offered a job at the DLR Institute of Communications and Navigation.

Fuchs has been the Leader of the Optical Communications Systems Group at the DLR Institute of Communications and Navigation since 2011. Together with his 10-person team, he is working on significantly increasing transmission rates between aircraft, satellites and the ground. "The benefits of laser communication lie in the concentration of the light beam, much as with a laser pointer. Because of this, a larger proportion of the power reaches the receiver than with radio communication," he explains. Laser communication enables the transmission of large amounts of data from high-resolution optical, infrared and radar satellites to the ground. Compared with the hitherto conventional process of sending and receiving radio signals, this light-based form of transmission is far more efficient – it allows for data rates of one gigabit per second or more. Data rates of more than one terabit per second are being envisaged for larger satellites.

Worldwide use

Through his projects, Fuchs has the opportunity to collaborate with colleagues at other institutions and organisations. For him, the OSIRIS project is particularly exciting; his team has developed an experimental laser communication system optimised for small satellites. The current generation has been integrated into the BIROS satellite – designed by the DLR Institute of Optical Sensor Systems – and will be put through its paces after its launch in 2016. The system will provide a data rate of one gigabit per second using a satellite terminal that weighs just 1.65 kilograms. "This is one order of magnitude higher than has been achieved with anything that has flown," he says.

Fuchs' group is also responsible for receiving the data. The scientists have built two receiving stations: the optical ground station in Oberpfaffenhofen, which is permanently installed on the roof of the Institute and the Transportable Optical Ground Station (TOGS), which can be used worldwide.



Christian Fuchs prepares the optical ground station before a campaign in southern Spain

However, there are a few things to bear in mind when using laser technology to transmit data – weather and atmospheric effects can complicate data reception. To ensure that trials such as OSIRIS are not adversely affected, Fuchs and his team have optimised the ground stations and measuring instruments. When communicating with BIROS, everything has to work. "It will be incredibly exciting to see how, after months of work, the first live data from BIROS is received at our terminal, and to see if all the systems and applications function as planned. The experiments carried out in advance during the first tests with a NASA system, which is currently installed on the ISS, have been promising. With the planned experiments, we will obtain data on the transmission behaviour of the atmosphere at an essential frequency. This will be vital to the design of future systems and the



standardisation of the technology. It is a great feeling to contribute to the success of such a wide-ranging project," says Fuchs, with pride.

The researcher's projects are not just amongst the stars. To achieve faster results and gain valuable experience, many of his experiments use aircraft. After initial successes with a propeller-driven DLR research aircraft, the transfer to a German Air Force Tornado as part of a special development was carried out in conjunction with the spin-off Vialight, who commissioned work from Cassidian (now Airbus). For project DODfast (Demonstration of an Optical Data link fast), a Micro Laser Terminal was integrated onto a platform on the Tornado. In addition to dealing with strong vibrations on board the aircraft, optimising the TOGS mobile receiving station was a challenge. It was necessary to track the aircraft at very high speed and with extreme accuracy to keep the received laser light focused on a small photodiode. This required optimisation of the systems and software, which was performed by the team during numerous ground tests prior to the main tests being



Last adjustments for satellite downlink at the ground station

conducted near Oberpfaffenhofen. Fuchs greatly appreciates getting away from his desk and working in the field with exciting flying objects.

Highly versatile

When it comes to the use of optical space communications, Fuchs can reel off a list of possibilities. For instance, his department supports the VABENE++ project, intended to use tools, such as aerial images, to help workers deployed on disaster relief missions restore a functioning transport system. The images captured on overflights can be easily and quickly transmitted using laser technology. Laser communication is of particular importance to global Internet access, for which the connection between satellites and the Internet is established using lasers. Ground stations at various locations ensure that cloud-free conditions are sufficiently likely for at least one connection. The number of ground stations required is far fewer than for radio systems. The latter require these stations to provide capacity. "In radio communication, we measure available bandwidth in gigahertz, but in laser communication it is measured in terahertz. That's 1000 times more!" says Fuchs enthusiastically.

Christian Fuchs is a driving force behind ensuring that DLR plays a key role in global research into optical space communications. Because of this, he is determined to, over the next 10 years, promote the international visibility of his Institute, establish new contacts, and realise exciting projects with various partners. However, he does not want to give up being a researcher: "Of course one never stops growing into the role of project manager and dealing increasingly with coordination tasks, but in the future I would also like a mix of research and management. I don't want to lose the freedom to do some of my own technical work."

Of the projects planned in 2016, the launch of BIROS is the most exciting for Fuchs. As soon as it has reached orbit, valuable remote sensing data will be sent to the ground by laser. If this works, it would be a tremendous triumph for the scientist and his team. And Christian Fuchs, with his great passion for, and delight in his job and his subject, will have thoroughly earned such success.



IT TAKES TWO TO TANGO

Field campaign in Heligoland investigates the transfer of large amounts of data at sea

By Manuela Braun

Sea spray rises over the pier and foams over the dark stone. The 'Hermann Marwede' is still safe and protected at the pier. But behind the quays, it is a different story – waves are towering three metres high all around Heligoland. The wind is reaching speeds of more than 50 kilometres per hour, or force 7 on the Beaufort scale; in other words, 'near gale'. Some gusts are even reaching wind force 8, battering the water, other boats and the colourful wooden houses that line Heligoland's harbour. "It's not pretty," says Thomas Müller unimpressed, as he looks out, sitting on the captain's chair on the ship's bridge. "Oh well," he continues, as he shrugs his shoulders. There have been times when the rescue vessel has had to battle its way through eight-metre-tall waves.

The man from the German Maritime Search and Rescue Service has clearly experienced worse. Researchers from the DLR Institute of Communications and Navigation, on the other hand, have not. That said, this is exactly what they had been hoping for, and they would not want it any other way. "We want to find out what impact such circumstances have on signal propagation," says Project Manager Ronald Raulefs, explaining the aim of their investigation. He was, however, in his office at the DLR Institute of Communications and Navigation in Oberpfaffenhofen at the time. Everything was in its place, on terra firma, nothing flying around in all directions, and his laptop did not need to be fixed down to the desk. Soon, however, everyone would feel every movement caused by the sea. The 'Hermann Marwede' has a draught of 2.8 metres and, despite its 46-metre length, does not have a large displacement. When someone is in distress at sea, this ship has to be able to arrive at the scene quickly – it cannot plough through the waves.

Radio communication between rescue vessel and icebreaker

While the 'Hermann Marwede' was still in dock, DLR researchers attached the additional antennas needed for their experiment; they continuously transmitted a signal during the experimental voyages and determined the exact location of the vessel using GPS. One day before going out on the high seas, Thomas Jost, Paul Unterhuber, Wei Wang, Michael Walter and Siwei Zhang installed and secured the equipment on the ship. Of course, the equipment cannot go flying across the bridge in the event of high waves! The rescue vessel is now a swaying, floating broadcasting station at sea. The receiving station is also on its way to the North Sea: the 'Neuwerk', a ship operated by the Cuxhaven Waterways and Shipping Administration, is the counterpart of the 'Hermann Marwede' for this mission. Normally, the 80-metre vessel can be found in the North Sea performing coast guard duties and acting as an emergency tug, or in the Baltic Sea as an icebreaker. This time, however, captain Dietmar Seidel will be steering his ship through the waves in the name of science.

Before the 'tango' begins at sea:
Thomas Müller steers the rescue boat
'Hermann Marwede' through the
harbour of Heligoland. In the
background, the Coast Guard's
'Neuwerk' is still at the pier.

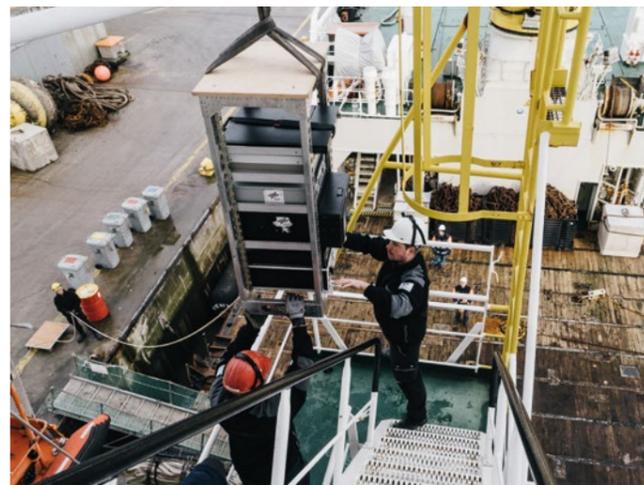




The team of the 'Hermann Marwede' discusses the different formations for its work with the 'Neuwerk' during the measurement campaign

The DLR researchers have considered many possible scenarios for their investigations this Wednesday. But both boats should, whenever possible, travel parallel to one another, cross over in front of each other, and also send and receive signals despite the great distance between them. To date, no one has ever investigated how hulls, rough seas or even turbine rotors in wind farms affect broadband signal propagation. Radio, the conventional communication method between boats, only transmits one thing – voice. The transfer of more data is not possible in the maritime industry at the moment, unless costly means of communication, such as satellites, are used.

New knowledge about transmission channels acquired under realistic conditions at sea could enable boats like the 'Hermann Marwede' and the 'Neuwerk' to, in future, send medical instructions via video even before medical personal have arrived at the scene. Ships could even send traffic information to each other in the form of radar images. This field campaign conducted by the DLR Institute of Communications and Navigation will contribute to a project being run by the DLR Maritime Safety Research Department, which aims to develop a model that shows how signals change when external influences are at play during transmission. The industry would then be able to adapt transmitting and receiving systems accordingly at a later date.



An unusual terrain for DLR's measurement technology: it is lifted to the bridge of the 'Neuwerk' with a crane.

From trough to trough

On board the 'Hermann Marwede', Thomas Müller is browsing through the researchers' specifications. He traces the routes they would like to take with his finger and discusses these with Third Officer Norbert Sarnow. "We would be better off following a north-south direction so that we don't roll too much," the captain of the 'Neuwerk' can be heard from the control panel's black telephone handset. The first formation to be sailed by both boats has been decided – the 'Hermann Marwede' will sail in the quiet waters between Heligoland and its offshore island, and the 'Neuwerk' will sail around the island. In so doing, the island will shadow the radio signal. "Then, we will perform the first routine," Captain Dietmar Seidel says over the radio.

This, however, would not be the reason why the DLR researchers got an upset stomach. It was the second manoeuvre, when the 'Hermann Marwede' left the quieter waters and sailed around the cliffs. Lange Anna, a 48-metre tall rock in the northwest of Heligoland, and a symbol of the island, quickly disappeared from everyone's sight. "Everyone back inside the bridge now," calls Ulrich Wenzel, the paramedic. The rescue vessel bounces through the waves like a stubborn bull, dropping into the troughs and then shooting back up towards the sky. It goes without saying that the only people on board who look completely at ease in this situation are the members of the rescue crew, who have had plenty of experiences like this.

The wipers are fighting in vain against the masses of water. The 'Neuwerk' is just a small, blurry dot on the horizon. We receive a message over the phone – the rough ride is not only getting to the scientists, but



The 'Hermann Marwede' is a mobile broadcasting station battling the rough seas

also to one of the new members of the crew. DLR's measuring equipment, on the other hand, is operating correctly on both ships. A frequency of five gigahertz is being used to send data. Later, back in the comfort of the laboratory, the first look at the measurements shows that everything worked out the way the scientists had planned, and there is sufficient data for several doctoral theses.

Round two in the North Sea

Shortly before 13:00, the first run is complete. The 'Neuwerk' sails into harbour so that the researchers can climb up the ship's mast to a height of 26 metres and change one of the antennas. Rather than using one antenna, the second run aims to capture more signal reflections from various directions by using an array of 32 antenna elements.



Germany's bright lighthouse is the site for the signal transmission between ship and shore. High above Heligoland, the DLR scientists install their antennas.

The 'Hermann Marwede' is on standby in quieter waters between the islands. A welcomed break from the rise and fall of the waves offers a necessary recovery period so that everyone can prepare for the shaky environment at sea once again. Then the programme starts – this time involving a turbulent journey off of Heligoland with the 'Neuwerk', which is pushing its way through the waves just 50 metres away.

As darkness begins to fall, the ships enter the quiet harbour. Next to the 'Neuwerk', which is like a floating multi-storey building among the quays, the 'Hermann Marwede' looks rather small. As if the high-speed winds were not enough, it starts to rain. Battery-operated lamps are used to light up the small carts that the researchers will use to transport their receivers from the quay to the lighthouse on the rocky island. In addition to measuring ship-to-ship communication, ship-to-shore communication must also be measured to determine how it is influenced and changed by environmental factors. A metal basket filled with measuring equipment is slowly lowered from the top of the ship on a crane. If nothing else, it saves having to transport it from deck to deck via narrow staircases. The next day, things look different from the 35-metre high lighthouse.

Measuring under the beacon

There are 160 steps to the top of the tower, and eight storeys to climb before you reach the platform beneath Germany's brightest lighthouse. Bread, meat and cheese await the team on the windowsills of the top storey. The food, which was provided on board the day before, yet left untouched due to the rough seas, is now being served to the field campaign team on land. Someone even remembered to bring coffee with them to the lighthouse. The team will work from the lighthouse all day, during which time the 'Hermann Marwede' will transmit as it sails the chosen routes. "That was the awkward part," says Michael Walter, looking somewhat unimpressed as he taps against the metal frame in which the receiver, recorder and screen have been installed.

One floor up, the wind is whistling over the exterior platform of the lighthouse. Christian Gentner and Markus Ulmschneider are measuring the exact location of the DLR antenna. Once the scientists know exactly where the transmitter and receiver are, the transmission channel between the two can be analysed precisely. Back in the harbour, the 'Hermann Marwede' is still at the pier. Those who proved themselves to be seaworthy the day before, or who think they can withstand several more hours out at sea, make their way there to climb on board. Today's trip will be a journey to a wind farm located some 25 kilometres away.

The researchers want to find out how some components of the transmitted signals will be reflected off the rotor blades, and how they then get scattered around the ship.

Off to the wind farm

The decision to embark on the journey was made in the morning by Thomas Müller, the Captain of the 'Hermann Marwede'. "We'll see what the weather is like," he had said the night before, sat in the mess of the 'Hermann Marwede'. Higher waves and stronger winds had been forecast. "If the wind is too strong, we are not going anywhere." The waves are predicted to reach heights of 3.5 metres in the morning and go down to three metres by the afternoon – but it is still not raining. However, the Captain of the 'Hermann Marwede' decided that everything was all right, so the field campaign gets a thumbs-up.

Wei Wang gives the OK over the phone to Ronald Raulefs, who is on board the 'Hermann Marwede'. "We are here and ready to go." The antennas are firmly attached to the grid located on the exterior deck of Heligoland's lighthouse, the atomic clocks in the transmitter and receiver have been synchronised exactly with one another, and the North Sea is playing its part, providing the necessary waves for the investigation. The first readings appear on the screen of the receiver, standing out from the vast amount of noise. The 'Hermann Marwede' transmits, and the lighthouse receives. Measurements will be performed well into the afternoon and will be finished after the return trip to the wind farm has been completed.

Data for the laboratory

The prospect of obtaining more measurements the next day is not looking good – storms are expected and the 'Hermann Marwede' has to remain on standby in the harbour in case of an emergency. The equipment in the lighthouse must, however, be dismantled, and carried back down all eight flights of stairs. It is not until Saturday that the scientists will receive data at sea level from the harbour, when the rescue vessel sails to the horizon from Heligoland. Raulefs is, nevertheless, more than satisfied. The team will return to the Institute in Oberpfaffenhofen with a vast amount of data. "And in the meantime, spending a full day on land is truly great."



The orientation and position of the antenna must be accurately determined so that the data acquired can be analysed in the home laboratory

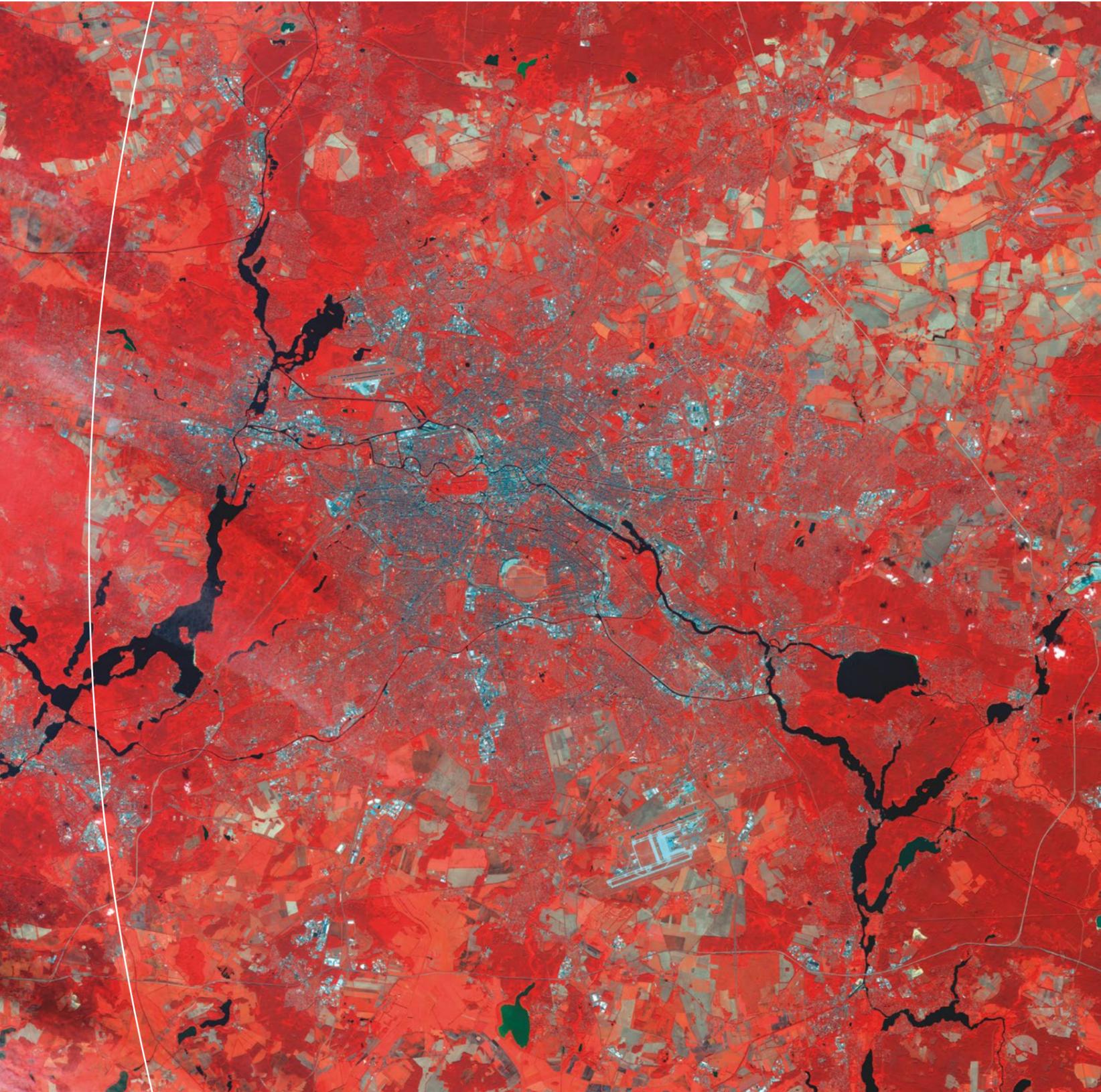
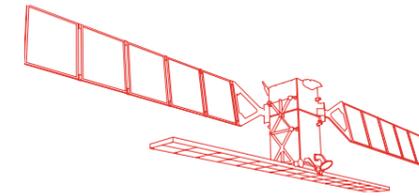


Image of the greater Berlin area acquired by Sentinel-2 on 12 September 2015, as a false colour composite. The representation of the infrared wave-lengths shown in red brings the differences in vegetation into sharp relief.

Image: Copernicus Sentinel data (2015)/ESA.

COPERNICUS EARTH OBSERVATION 4.0



Earth in focus – the Sentinel programme heralds a new chapter

By Gunter Schreier

25 April 2015, 11:56 local time: The Roof of the World – the Himalayas – rising up from the Indian tectonic plate, which dips beneath the Eurasian plate here, is in the throes of one of the most powerful earthquakes in decades. The epicentre of the quake lies 80 kilometres northwest of the Nepalese capital of Kathmandu. International aid organisations are preparing to rescue trapped victims and help the injured; DLR is also assisting. Collapsed buildings, destroyed monuments and inaccessible valleys are quickly mapped with the aid of the latest satellite images. The specialists for this work at DLR are working in the Center for Satellite-Based Crisis Information (ZKI) at the Earth Observation Centre (EOC) in Oberpfaffenhofen. On this occasion, ZKI also has access to very high-resolution aerial images of the Nepalese capital that were taken during a DLR flight campaign in January 2014.

The data acquired by DLR reveals not only the widespread destruction, but also its cause. Scientists and engineers at the EOC calculate the displacement created by the earthquake and show how vast stretches of the land were displaced several metres within a matter of seconds. To do this, they compare radar signals of the region captured by satellites before and after the earthquake. When continuous observation methods are used, these interferometric methods enable the measurement of movements down to centimetres – or even millimetres. In this case, however, the data has not been acquired by the well-proven German TanDEM-X satellite duo, but by the European Sentinel-1A radar satellite, which was only put into orbit just about one year ago, in April 2014.

Sentinel-1A is the first of an entire fleet of satellites being launched under the European Copernicus programme – it marks a milestone in European Earth observation. National or European missions of limited duration have now been superseded by an ongoing European strategy geared towards continuity, based on available long-term funding. In addition to the data from the Sentinel satellites, this strategy encompasses various national Earth observation missions and ground-based measurements. For the first time, a reliable, long-term database will be created that can be used in future by researchers, civil administrations and industry for planning purposes.

Extended user group

Until now, planning and disaster control authorities could not be sure whether the foundations for their work – specific types of satellite data and Earth observation missions – would still be available over the coming years or decades. Copernicus changes all that; the model is based on European weather satellites that, in 1983, with the establishment of the European Organisation



The foothills of the Upper Bavarian Alps, with Munich on the left hand edge of the image. Acquired by Sentinel-2 on 13 August 2015

Image: Copernicus Sentinel data (2015)/ESA

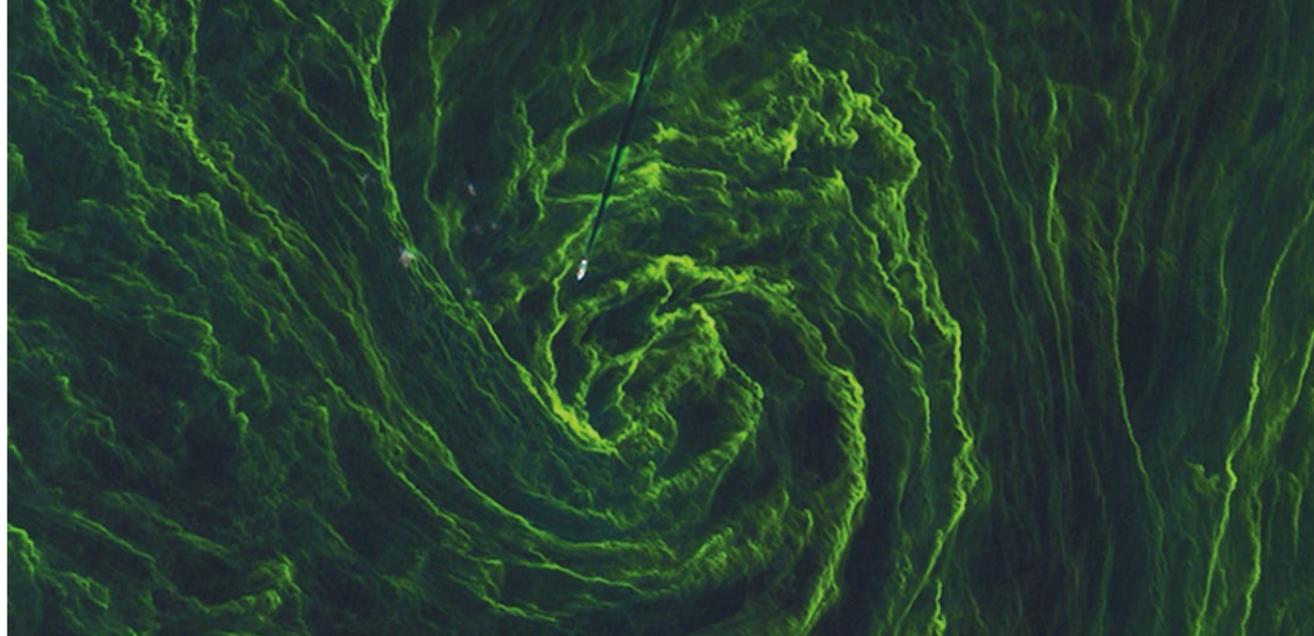


Image: Copernicus Sentinel data (2015)/ESA.

Algae storm in the Baltic Sea in a Sentinel-2 image acquired on 4 September 2015. A ship is passing through the eye of the storm and can be seen as a small white dot.

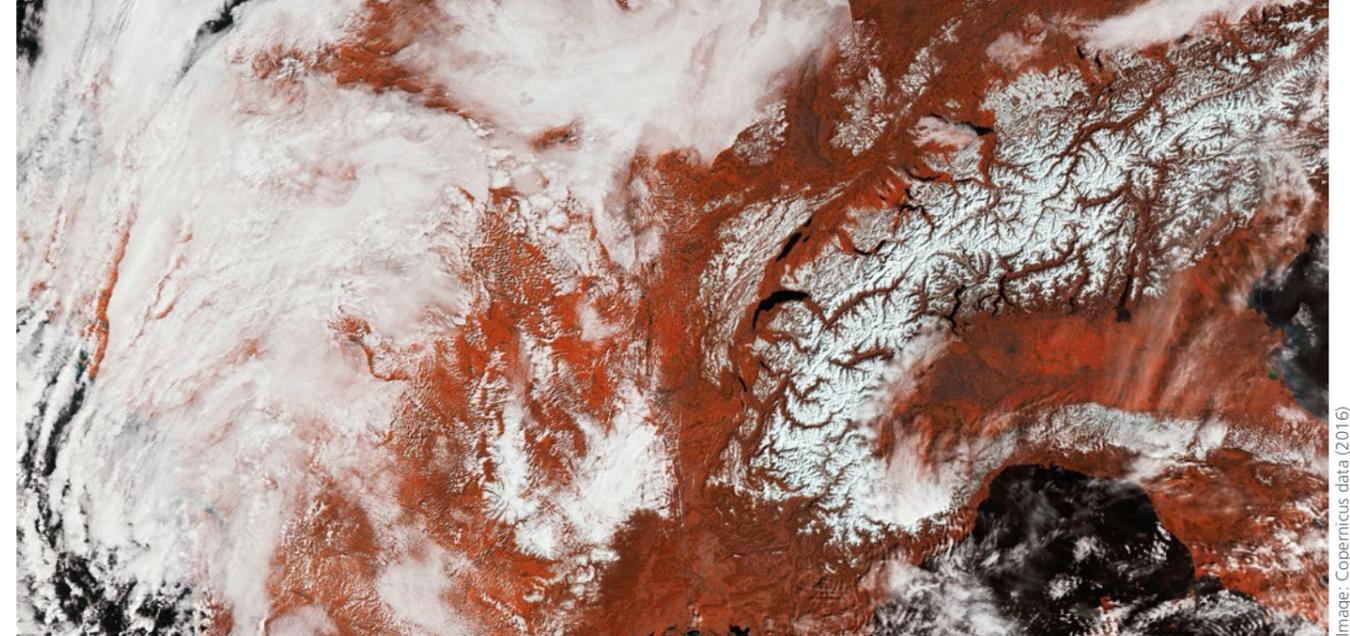


Image: Copernicus data (2016)

Part of Europe from the Alps in the lower right to the North Sea in the upper left was captured by Sentinel-3A's Ocean and Land Colour Instrument on 10 March 2016. The image utilises only three of the instrument's 21 spectral channels – giving a false colour impression with land in red.

GUARDIANS IN THE SKIES

There are six Sentinel missions in the Copernicus programme. Two Sentinel satellites for each mission will be in orbit at any one time.

Sentinel-1 – C-band synthetic aperture radar (SAR) for observing the oceans, polar regions and land surfaces under all cloud conditions – day and night; first launch 3 April 2014.

Sentinel-2 – optical instrument suite with 13 spectral channels having a maximum resolution of 10 metres and a 290-kilometre field of view, performing continuous mapping of Earth's land surfaces; first launch 23 June 2015

Sentinel-3 – several instruments for observing land and oceans, main instrument with 21 spectral bands and a resolution of 300 metres, coverage of the whole Earth with two satellites in less than two days; first launch 16 February 2016.

Sentinel-4 – payload on the third generation geostationary Meteosat satellites (MTG) for observing trace gases in the atmosphere; launch planned from 2018.

Sentinel-5 – atmospheric monitoring payload on polar orbiting second generation MetOP satellites; launch: planned from 2019.

The **Sentinel-5 Precursor** will bridge the gap in observation until then; launch planned for 2016.

Sentinel-6 – radar altimeter for measuring the oceans; launch planned from 2019.

for the Exploitation of Meteorological Satellites (EUMETSAT), were transferred to a sustained European programme. However, it is not just meteorologists who need information from satellites. In addition to disaster management, other authorities and services are keen to make greater use of up-to-date satellite data in areas such as agriculture and forestry, urban planning, protection of the environment and nature conservation, a multitude of planning tasks, and safe shipping. The continuous data stream supplied by Copernicus will vastly increase the variety of users. For the first time, commercial providers of geo-information services will be able to use this reliable and free data source to develop new information services. Scientists will, of course, benefit from access to long-term data series. In future, it will be possible to use the data from the Sentinel satellites to survey vegetation and land cover over decades, and obtain important geoscientific parameters and indicators. These will be invaluable, not only for global change research, but also to make decisions on how to deal with those changes and manage increasingly scarce resources.

After the European satellite navigation system Galileo, Copernicus is the largest programme in the space strategy adopted by the European Commission in 2004. The European Space Agency (ESA) and, to some extent, EUMETSAT are also involved in developing and operating the satellites and terrestrial infrastructure in the Copernicus programme. Parts of the terrestrial infrastructure will be operated by institutions in the member states on behalf of ESA. One of those is the EOC at DLR Oberpfaffenhofen.

Copernicus is also continuing the longstanding data series that, until 2012, was supplied by the ESA Envisat (Environmental Satellite) Earth observation mission and – prior to that – by ERS-1 and ERS-2 (European Remote Sensing Satellite). With its radar, optical systems and atmospheric sensors, the Envisat platform already possessed precursors to the present-day Copernicus instruments. But rather than placing all the sensors on a large research satellite, Copernicus comprises six dedicated missions, known as Sentinels – two Sentinels in a series will be in operation at any one time.

Current services

To promote the use of the new satellite data in routine planning, political and economic affairs in Europe, six core services have been introduced initially. Consortia tasked by the Commission use the constant stream of Sentinel data to create, among other things, maps of current land use, overviews of nature conservation areas, and up-to-the-minute forecasts on air pollution. With its scientific expertise, the EOC is a sought-after partner for these Copernicus services. The findings of the services will be made freely and publicly available via the Internet in Europe and worldwide by organisations such as the European Environment Agency (EEA) in Copenhagen.

Time is a critical factor for some of the applications. The European Maritime Safety Agency in Lisbon, for example, uses Sentinel-1 data to detect oil slicks and identify the perpetrators on the coasts of Europe. The Coast Guard needs the information just moments after it is acquired so that it can respond quickly with appropriate measures. The central receiving and processing facilities that are part of the Copernicus ground segment are not always able to provide the information as quickly as needed. Therefore, some ESA member states receive the Sentinel data directly via their own ground stations – or globally via the new geostationary European Data Relay Satellites (EDRS) – and process it in near real-time to produce the required information.

DLR's EOC also receives and processes Sentinel data in real time at the DLR site in Neustrelitz in Mecklenburg-Vorpommern. As well as being an important source of information for DLR's Maritime Safety research centres in Bremen and Neustrelitz, the Sentinel-1 data is also available to partners in academia and industry.

Free and Open

The Sentinels provide an overall picture of Earth in just a few days, with a maximum geometric resolution of down to 10 metres. Whilst ideal for many global monitoring activities, this resolution is still too low for tasks such as mapping cities or refugee camps for humanitarian purposes.

For this kind of tasks, the Copernicus programme obtains data from commercial satellite missions that are able to provide a higher resolution for smaller areas. These are usually operated by companies, or in a public private partnership with national space agencies, two examples being the DLR TerraSAR-X and TanDEM-X satellites, operated in partnership with Airbus.

Unlike these mostly commercial 'Copernicus contributing missions', the data and products from the Sentinel satellites are free and openly available to all users. This 'Free and Open' data policy was a hard-won political victory but, ultimately, pressure from the scientific community, the need to differentiate Sentinel data from commercial missions and the positive experiences with a similar policy in the United States won. There, it was not just scientific demand for global data that dramatically increased – following the availability of the data acquired by Landsat, a host of commercial geo-information companies and service providers turned to this free data source and opened up new markets. Because of this the 'Free and Open' data policy is also seen as a practical path to follow in the Copernicus programme.

'Free and Open' means that, in principle, all Sentinel data is available worldwide to scientists and commercial providers via online portals. The challenge lies in ensuring that Copernicus users can access the data fast enough and process the huge volumes of data. Google and Amazon do both – they are already saving freely accessible Sentinel data via the ESA portals and making it available to their users worldwide, along with huge computing power. It remains to be seen how this engagement by the Internet giants will develop. In Europe, there is some ground to be made up in this regard – in terms of both powerful data networks and large, global Internet companies with virtually limitless storage and computing capacity.

Following the launch of the first Sentinel satellite in April 2014, those responsible for the Copernicus programme in Brussels became aware that simply generating satellite data and giving priority to services in the European Union when supplying that data is not enough; it is also essential to facilitate access to the data and make it technically



Image: Copernicus Sentinel data (2015)/ESA

Beautiful detail of the Jungersen Glacier, flowing into the Nordenskiöld Fjord. The satellite image (Sentinel-2) shows the movement of the glacier.

attractive to all users. At the end of the day, the Copernicus data can only be used effectively for new applications when combined with a huge computing and storage capacity (such as cloud computing). Some initial national and commercial solutions for this 'Big Data' in Earth observation are already in place, including in Germany. At the same time, the European Commission has begun harmonising these national efforts to meet the information and data engineering challenges presented by Copernicus at a European level.

New era

Copernicus heralds the dawn of a new era in Earth observation. DLR's EOC was quick to realise this. From the outset – and like other European facilities – it applied for activities in what is known as the Payload Data Ground Segment of Copernicus. This is the technical term for all the functions involved in the reception, processing, archiving and distribution of Sentinel data. As a Processing and Archiving Center (PAC), the German Remote Sensing Data Center (DFD) at the EOC was already working for ESA's ERS-1, ERS-2 and Envisat missions. As part of Copernicus, the DFD now performs these tasks for Sentinel-1, Sentinel 3/Land and Sentinel-5 Precursor. All the data from these Copernicus missions is handled through DLR in Oberpfaffenhofen, where it is saved for many years for subsequent long-term evaluation, and is transmitted from Oberpfaffenhofen to the Copernicus Services and the Internet distribution nodes.

At the same time, the 'German Copernicus Center' initiative was launched at EOC to ensure that this wealth of data is accessible to DLR scientists and for national applications. Backed by partners from industry, EOC has devised a proposal for the use of the Copernicus data, centred on the idea of combining the huge volumes of data and

their processing in one location, thereby avoiding the time and cost-intensive process of data transfer. Securing the long-term availability of the valuable data is pivotal to this. 'Big Data' at DLR and cooperation with partners are the answer to the challenges faced in Earth observation. EOC's internal cloud, GeoFarm, serves as a test platform for such a scenario. In preparation for such use scenarios, cooperation with commercial partners in data and CPU-intensive processes is already being tested as part of the OPUS project, which is supported by the Bavarian State Ministry for Economic Affairs.

All Sentinel data – current and historical – will in future be available at this Copernicus Center, along with the requisite computing capacity. The German Satellite Data Archive (D-SDA) at the DFD will handle the long-term archiving of, and access to, all Sentinel data. This relieves users of the need to first download terabytes of data to their computers; instead, they will be able to run their algorithms on the computers of the future centre and use them together with the data. At the end of the process, the user obtains the results. These are sent to the user and can be shared with other users on the platform. As logical as this approach may seem, and despite all the discussions about cloud computing, there are still many technical challenges to overcome and legal issues to be clarified. DLR's EOC is working on these challenges and developing new methods to deal with 'Big Data' in Earth observation – intelligent algorithms, efficient processors and the rapid processing of Copernicus data for the environment and security. In short – Earth Observation 4.0.

Gunter Schreier holds a degree in Geophysics and, as the Deputy Director of the German Remote Sensing Data Center at the DLR site in Oberpfaffenhofen, coordinates business development matters, in particular for Copernicus.

Image: ESA/P. Carril



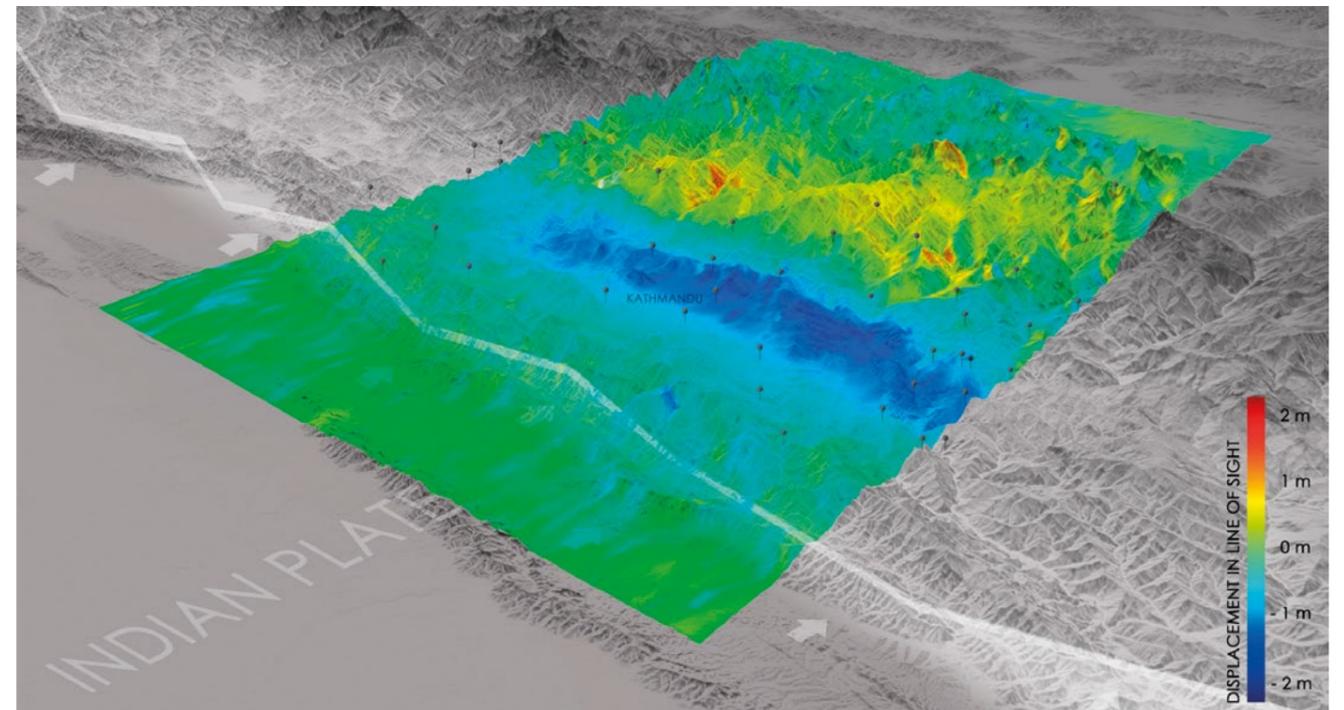
Sentinel-1

Image: ESA/ATG medialab



Sentinel-2

Following the earthquake in Nepal on 25 April 2015, this Sentinel-1 composite of two data takes shows the changes. The deformations created are colour-coded. Close to the tectonic boundary, the ground shifted upwards (blue area) and the associated subsidence can be seen further north (areas in red/yellow) – a countermovement that often occurs during subduction zone earthquakes.



COPERNICUS CORE SERVICES

Land monitoring

Information and data on the land surface – from local to global level – providing a basis for thematic maps and forecasting, and planning future developments affecting the environment and land use.

Monitoring the marine environment

Data and products on the protection of the oceans, sea routes and coastal regions, and, for example, a component of weather and climate forecasts.

Disaster and crisis management

The Copernicus Emergency Management Service (EMS) provides general and planning information for dispatching aid workers and providing them with local support.

Monitoring the atmosphere

Provision of data on the global distribution of atmospheric trace substances, in particular on the distribution of trace gases and aerosols (particulate matter).

Monitoring climate change

Still in the planning phase – products and information for monitoring climate change.

Security

Still in the planning phase – products and information for safeguarding civil security.

WHEN RAINFALL THREATENS

System created by the DLR Earth Observation Center warns of potential hazards

By Peter Fischer

Monday, 28 July 2014 – the ‘Quintia’ storm system is shifting westwards, from the north of France towards Germany. This has serious implications for a number of regions in North Rhine-Westphalia, particularly for the residents of Münster and Greven. The torrential rain begins at 13:00 and continues for several hours, reaching historical proportions. Rainfall of up to 292 litres per square metre is measured in the space of seven hours. By way of comparison, the annual average expected rainfall for Münster is a little more than 750 litres per square metre. The impact on the city is devastating – more than 14,000 homes sustain damage, mainly due to flooded basements. The total damage is estimated at around 80 million euro. On this day in July, public life grinds to a halt in some places – roads are flooded, a number of people are injured and two lose their lives in accidents.

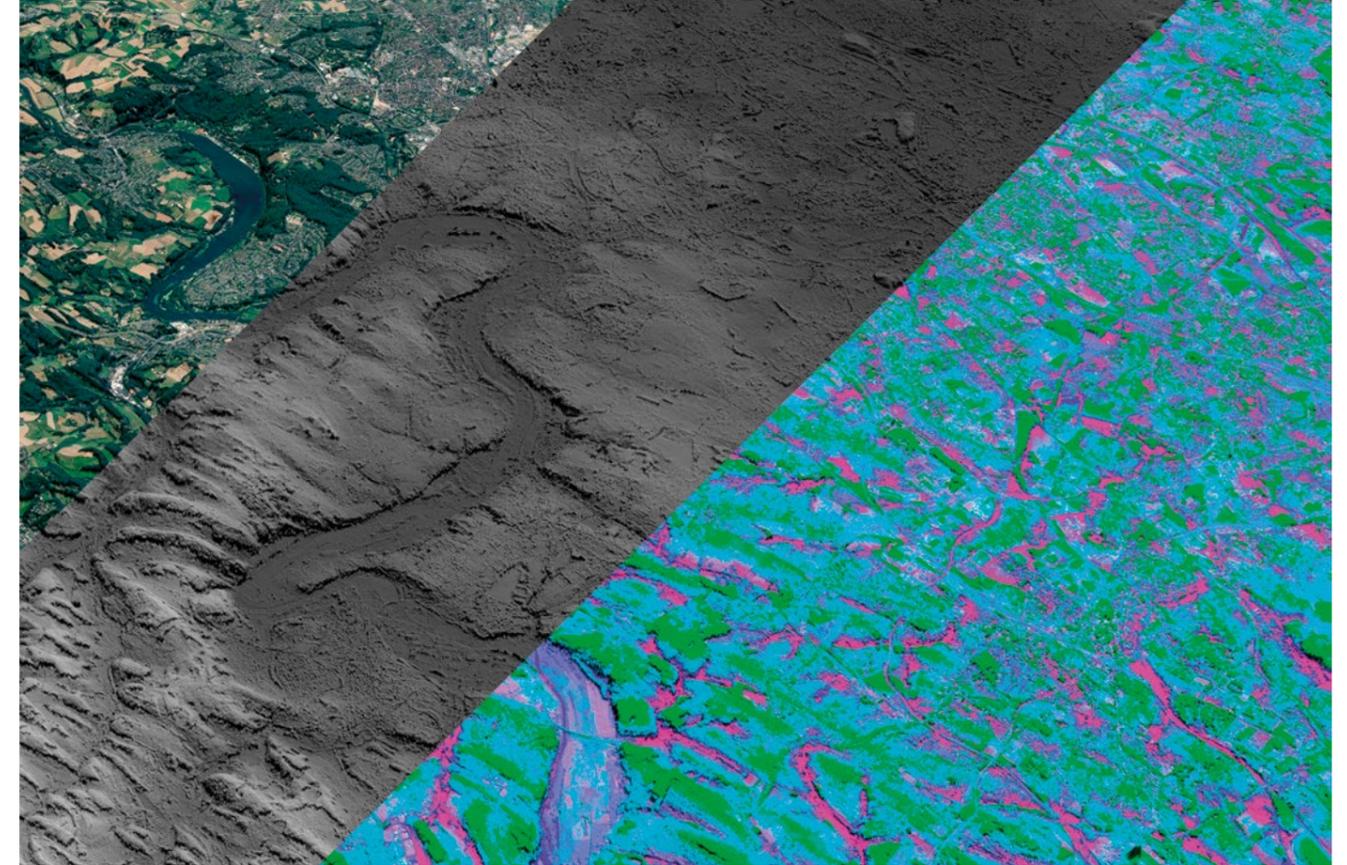
Events like this are tragic proof of the need for action – because they are set to become a more frequent occurrence. Time series analyses show a trend towards more rainfall in the last four decades, particularly in the autumn and winter months. However, it is not just more rain that is to be expected; there will also be an increase in extreme rainfall events. Reliable information of potential local hazards will therefore prove invaluable.

The existing systems used by German insurance companies accurately inform about the threat presented by flooding. A key element of this zoning is proximity to rivers. However, the assumption that, the greater the distance to the nearest river, the safer one is may prove to be complacent, as heavy rainfall has the potential to cause sudden and severe flooding away from rivers.



Image: Provinzial

Heavy rain can also cause flooding away from watercourses. Terrain models that make lower lying areas recognisable can indicate the location of vulnerable regions.



Superposition of images of a river – from left to right, a true colour satellite image, a terrain model and a hazard map (vulnerable zones are shown in pink and purple, safe areas in green).

This ever-increasing threat situation and the associated, difficult-to-estimate risk has been troubling the German insurance company Westfälische Provinzial Versicherung – an innovation partner of DLR – for a number of years. DLR Technology Marketing identified the right departmental matches at DLR and brought together representatives from the areas of science and industry. A collaborative project was launched in October 2013. The objective was to determine the potential threat caused by heavy rain – down to the level of individual buildings.

Unlike the tools currently available, the DLR system does not use hydrological databases, which are inadequate for predicting the risk of heavy rain. Instead, terrain models are statistically analysed and classified. The underlying idea is quite simple – as water always flows downhill, lower regions are potentially at greater risk than elevated areas. Even the need for meteorological data, such as precipitation measurements, can be eliminated. The precision of the model calculations has been demonstrated by comparing them with historical loss data recorded by Westfälische Provinzial Versicherung over a 10-year period.

Halfway through the project, the issue unfortunately became topical among the general public – Münster, the home of Westfälische Provinzial Versicherung, was hit by the heavy rainfall event described above. Although no generalisations can be made on the basis of such isolated events, it should nonetheless be possible to, at least approximately, depict the actual situation using the demonstrator that has been developed. Indeed, DLR’s hazard map and the damage reported locally corresponded.

The simulation tool combines expertise in the area of 3D modelling and geo-statistics at the two institutes of the DLR Earth Observation Center (EOC) – the Remote Sensing Technology Institute and the German Remote Sensing Data Center. High-resolution terrain models – created using a procedure also developed at the EOC to use data from images captured by the Indian Cartosat-P5 satellites – were used for the demonstration. The risks can easily be modelled using any available terrain model. The EOC scientists tested their predictions against

terrain models derived from radar data. As part of the TanDEM-X mission, the EOC is currently preparing a global terrain model with the highest resolution ever achieved, and which is ideal for such an application. With the aid of the new procedure and various elevation datasets, risk modelling is possible on various scales, from high-precision, local analyses through to global predictions.

The project, undertaken at the EOC, was completed in October 2015. Various organisations have expressed an interest in the results of the study. Heavy rain zoning is likely to be used in a similar form by insurers throughout Germany from the end of 2016 onwards.

The new risk analysis method is not only important for the insurance industry; the findings could also prove valuable in the planning and execution of construction and infrastructure projects, and might also be used by the public and private sector. In the real estate industry, properties could be revalued based on their risk exposure. Individual homeowners could also benefit from the findings – if, for instance, the information on risk zones were freely available on the Internet, people could, if necessary, take appropriate flood protection measures.

The hazard forecasting system developed at DLR also has the potential to be used for modelling risks of other natural events and weather phenomena, such as those associated with storms or severe ground frost. Geoinformation can be used to clarify a multitude of issues relating to civil security. In future, Westfälische Provinzial Versicherung AG plans to work closely with DLR researchers to optimise additional risk modelling processes.

Peter Fischer is a researcher at the Department of Photogrammetry and Image Analysis at the DLR Remote Sensing Technology Institute at DLR in Oberpfaffenhofen.

A WAY AROUND THE VOLCANIC ASH CLOUD

Volcanic ash simulations show ways out of the crisis

By Angela Schmitt

In the cockpit, the pilots cross the last items off their checklist. No thunderstorms have been forecast for today – but a volcanic ash cloud from Iceland is making its way across the sky. Will the flight have to be postponed or cancelled on short notice? Can the ash cloud be circled, or is it expanding in the opposite direction? Will the destination airport be ash-free upon arrival? Will the air traffic controllers give clearance for landing at all?

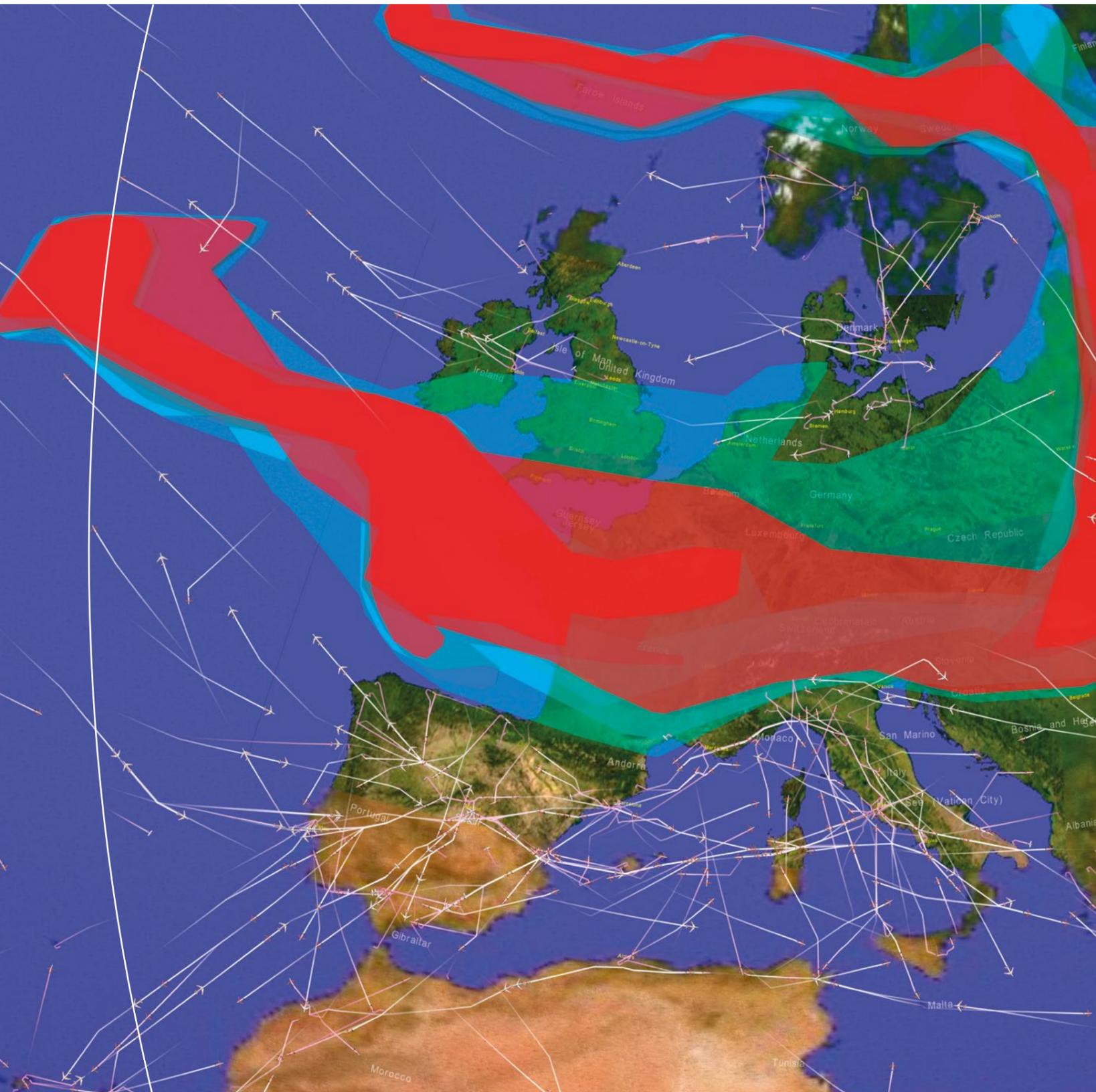
The DLR project 'Volcanic ash impact on the Air Transport System' (VolcATS) examines the issue of volcanic ash, its effects on air traffic and possible solutions to these problems. The ash spewed into the air during a volcanic eruption heavily restricts the surrounding air space that is usable for air traffic. The free air space must then be used efficiently to minimise the negative impacts on both the airlines and the passengers. DLR researchers in Braunschweig have used different simulations to identify the reasons for flight cancellations or delays due to volcanic ash and have developed action strategies for better handling problems encountered as a result of ash clouds. The aim is to carry out as many flights as possible and to assist in making the best decision possible about whether or not flights should be conducted.

Flying in the event of a volcanic eruption

The general rule is that flying through clouds of visible ash is prohibited. After a volcanic eruption, a central agency gathers all data relevant to air traffic. This information is processed for the pilots, the airlines and the responsible air traffic services so that all parties involved can make a well-founded decision. If flying is considered to be possible, the pilot will still have the final say: this is the person who is most aware of the local situation and ultimately decides whether the flight will or will not take place. For this crisis programme to work, efficient communication between all players involved is of utmost importance.

The crisis scenario simulated by the researchers is based on the recorded ash cloud caused by the eruption of the Icelandic Eyjafjallajökull volcano in April 2010. Based on this data, two different scenarios were created – one simulates the worst case in which great quantities of ash are spread widely, and the other shows the more optimistic case in which the ash cloud is predicted to only be present at lower altitudes and over smaller areas.

To play out these scenarios, the Braunschweig researchers extended the area covered by the Airport and Control Center Simulator ACCES. All of the flights scheduled on the day in which flying was heavily restricted due to the ash cloud were fed into the realistically replicated control centre. They computed the flight paths of the originally scheduled flights, and were thus able to examine whether the strategies developed in the meantime would really have resulted in more flights occurring on that day. Approximately 5000 flights took place on the day observed – had air traffic been 'normal', there would have been 22,000 flights. A newly developed module – the Trajectory Optimiser – searches for efficient trajectories to circumnavigate the ash clouds. In the control centre, a central projection screen shows the graphically processed trajectories.



Simulation of air traffic over Europe in the event of predicted volcanic ash clouds (red and light blue zones; DLR Software: FATS)

The Trajectory Optimiser determines the shortest or fastest ash-free routes; these may differ depending on wind conditions. Based on an airline's policy, it may then decide which trajectory is to be flown. Subsequently, the experts analyse whether the decisions made would have had positive or negative effects on the total number of possible flights.

Two different airspace structures were examined in the VolcATS project; first, the currently used structure in which the airspace is divided into smaller areas, known as sectors. There are two air traffic controllers for each sector, who guide the aircraft safely and efficiently through their sector. The associated problem is that alternative flight routes can result in too many aircraft travelling through the same sectors in the vicinity of ash clouds, thus overloading these areas. Therefore, a cross-sectoral structure was also analysed in the simulated ash scenario. In this variant, what comes into play is not the individual sectors, but rather one single air traffic controller guiding specific flights – from take-off through to landing. The evaluation of this procedure determines whether or not the sectors are overloaded – if so, detours through other sectors are necessary, which may lead to delays.

Different strategies to the test

A scenario: the ash cloud forecast is announced in the planning stage. The experts determine that a scheduled flight can no longer take place. Computing an ash-free trajectory is possible, but it conflicts with another flight. The crisis committee of the control centre simulator enables the affected airlines to discuss their plans and decide on the specific flights, keeping the lines of communication short. The ultimate decision is then fed into the airline information system via a specially developed program. The updated flight schedule is then accepted by the air traffic management and updated in the overall situation overview.

One result of the simulated crisis – the progress achieved in the forecast of ash clouds in recent years leaves more room for planning. Information on the spreading of ash clouds is updated every six hours – similar to weather information. This means that an up-to-date information package is available every six hours. The information package includes the status of the last six hours: the actual status (T+0), and forecasts in six-hour steps for the next 18 hours (T+6, T+12 and T+18). The six-hour forecasts show the range of motion of the ash particles. The bigger the ash clouds, the less airspace remains available for air traffic.

THE VOLCATS PROJECT

In VolcATS (Volcanic ash impact on the Air Transport System), six DLR institutes investigate the impact of volcanic ash on air traffic. The project will last until September 2016. The simulated volcanic ash data was made available by the DLR Institute of Atmospheric Physics. The Institute of Flight Guidance analyses strategies to minimise the impacts on air traffic.

The improved ash forecasts make it possible to limit no-fly areas with greater precision. This increases the number of areas cleared for air traffic, and more flights can be carried out.

In addition, the extended simulation environment showed that the main cause of cancelled flights is the ash load at the airports. The ash spewed into the air by the volcano naturally decreases over time – like a pyramid, it covers a larger area on the ground and decreases with increasing altitude. Even with six-hour forecasts, the large area on the ground remains blocked for the entire period of time. Only about 20 percent of cancelled flights are due to problems with ash clouds in flight. The scientists are, therefore, testing different options in the simulations to further decrease the number of flight cancellations caused by the impairment of airports. One research question, for example, is: can the number of cancellations at the airport be reduced if the departure time is postponed several hours?

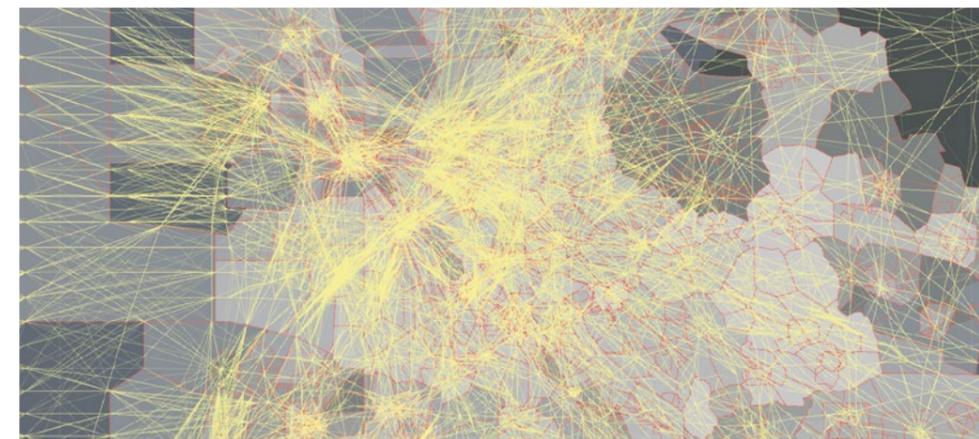
The simulations of both ash forecast scenarios showed that 30 to 70 percent of the normal traffic volume is affected by the ash clouds. Even in the worst ash-volume case, approximately 1900 more flights could take place with the improved forecast alone. An additional 1500 flights are possible by planning alternative routes – a result that offers hope that extreme situations – such as that caused by the Eyjafjallajökull eruption six years ago – do not repeat themselves.

Angela Schmitt is a research assistant at the Institute of Flight Guidance and FL project manager for VolcATS.



The same day – above with ash, and below without ash. Avoidance air traffic (yellow) and existing sector structure (red) together reveal congested sectors. Flying is also possible over the predicted ash zones.

Software: AirTop, air traffic based on EUROCONTROL DDR data (below).



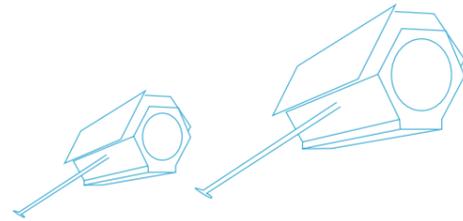
Joint decision: coordination of emergent and planned flights between airlines. In the 'Crisis Centre', the planned air traffic is negotiated and adapted to the situation one last time.



Simulation of ash crisis in the control room simulator ACCESS at DLR Braunschweig. On the big screen, the overall situation is always visible.



TANDEM SATELLITE MISSION ON COURSE FOR SUCCESS



3D map of the Earth is nearing completion

By Manfred Zink and Alberto Moreira

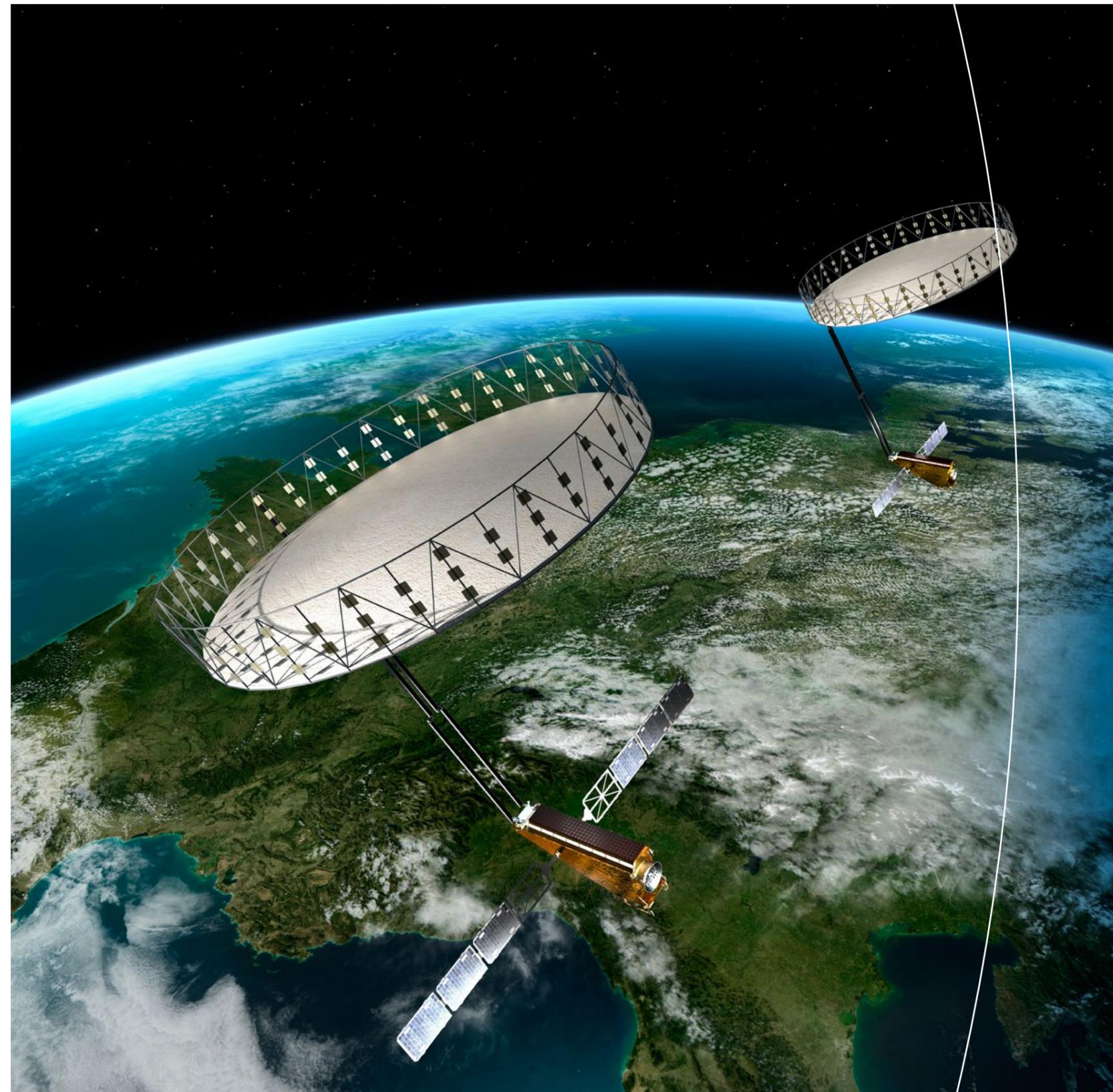
Six years after its launch, the TanDEM-X radar satellite mission will achieve its primary mission objective. A digital elevation model of the Earth with unprecedented accuracy is now more than 90 percent complete and available for use by the international scientific community.

This mission has broken new ground in many areas. The close formation flight of the twin satellites TerraSAR-X and TanDEM-X – at a minimum separation of 120 metres – has now become routine, just like the many different manoeuvres involved in continuously adjusting the formation to fulfil the requirements on the imaging geometry. The same applies to the radar operations using two satellites in the so-called bistatic mode, which initially presented a major challenge but was essential to ensure a high degree of precision in the elevation models. DLR is a global pioneer in this advanced technology – both in terms of the operation of the radar system and the degree of precision required for its calibration. TanDEM-X has set outstanding benchmarks in this respect. The process of determining the distance between the two satellites with millimetre accuracy is one example.

The satellites have acquired images of all the Earth's land surfaces at least twice – up to four times for mountainous terrain – and, by the beginning of 2015, had collected more than 400 terabytes of data for the global elevation model and transmitted it to Earth via a network of receiving stations. Since 2014, sophisticated processing chains involving efficient, high-precision algorithms have been producing the final elevation models. During this process, the data volume has grown to more than 2.5 petabytes, pushing the IT systems involved to the limits of their capacity.

Final elevation models are now available for more than 90 percent of the Earth's land surface, and the quality of the data exceeds all expectations. While the relative height error is consistently within the specification of two metres for flat areas and four metres for steeper terrain, the absolute height error is one order of magnitude lower than the requirement. Instead of the stipulated 10 metres, the data available thus far has an absolute error of a little over one metre – a result of the excellent calibration of the system.

In addition to elevation precision, the completeness of coverage is another important quality attribute, as there can be gaps due to shadowing in mountainous regions or insufficiently strong radar backscatter in desert areas. In sandy deserts in particular, the radar signals penetrate the ground, where they are almost totally absorbed and very little energy is reflected.



Graphical representation of the Tandem-L mission concept – two satellites flying in formation, each with a 15-metre-diameter deployable reflector.

To counteract the low backscattering, the areas concerned were repeatedly imaged at a steeper incidence angle – a measure that significantly reduced the gaps in the elevation models in the Sahara and on the Arabian Peninsula. In mountainous regions, capturing a third or fourth image from the opposite viewing direction closed most of the gaps. The expectation is that overall, the 97 percent completeness requirement will easily be met.

800 scientists around the world want to use the data

This dataset is now available to the international scientific community through an established process. Principal Investigators can submit project proposals. If a proposal receives a positive assessment and is approved, the research group is given access to the data.

Examples of data usage range from precise georeferencing (map projection onto a geodetic reference system), infrastructure planning (urban development and road construction), glaciology (for example, observing the reduction of ice mass due to glacier melt), hydrology (water runoff models and flood forecasting), volcanology (estimating lava volumes after eruptions), agriculture (biomass estimates derived from the height of vegetation) and forestry (determining tree height), through to oceanography (measurements of ocean currents).

More than 800 scientists from around the world have already registered on the DLR portal to make scientific use of TanDEM-X data and are gradually receiving high-resolution data for evaluation and the demonstration of new application fields.

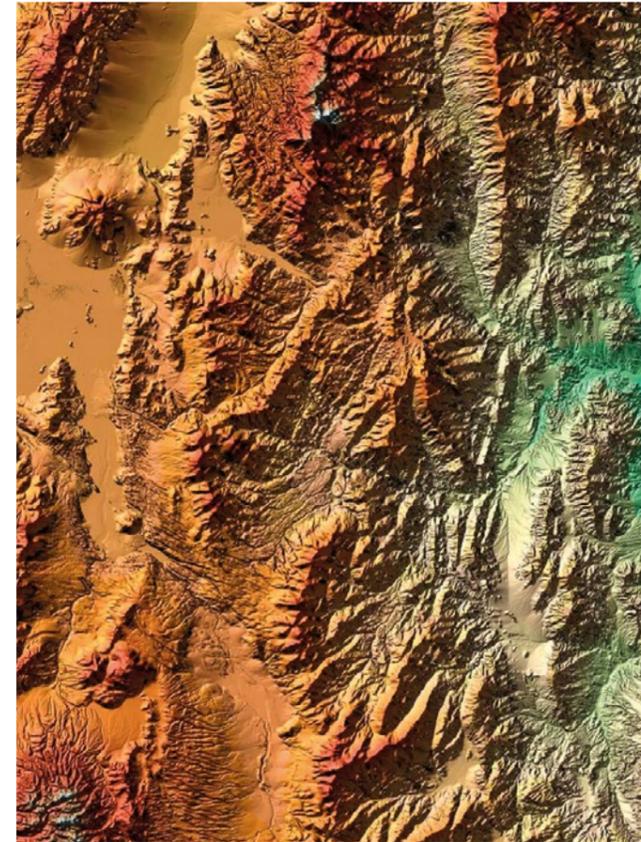
Until the end of 2014, image acquisition planning focused on the global elevation model, and scientific experiments could only be considered within those plans. During the subsequent scientific mission phase, the priorities were changed and the distance between the two satellites adjusted according to scientific needs. For example, agricultural land was observed throughout the entire growing season at a separation of up to four kilometres. Prior to this, a whole range of separations – referred to as baselines – were used to enable, for instance, tomographic investigations of snow and ice in polar regions. During all these phases, the

experimental fully polarimetric mode of the radar system was also used. The conclusion of the scientific phase at the end of 2015 did not herald the end of the mission. Both satellites are fully functional and have sufficient propellant for their hydrazine thrusters to enable up to five more years of operation. The cold gas propulsion system on TanDEM-X that has been used until now to fine-tune the spacecraft's orbit during close formation flight, will run out of gas in a few months. However, alternative solutions that do not require cold gas have been developed. The focus of the mission will then be the generation of even more precise elevation models, with a spatial resolution of just six metres for limited regions. More scientific experiments are also planned.

Paving the way for the Tandem-L radar mission

The TanDEM-X mission is a milestone in radar remote sensing – two radar satellites flying in formation as a bistatic SAR interferometer are a world premiere. But TanDEM-X is also a forerunner of future radar missions. Since 2012, as part of the Helmholtz Alliance 'Remote Sensing and Earth System Dynamics' programme, 132 scientists from eight Helmholtz centres, as well as 18 partner and associated research facilities, have been working intensively on the development of new applications and geo-information products for the next generation of radar satellites. The focus of the research is on Tandem-L, a proposal for a satellite mission to perform global observation of dynamic processes on the Earth's surface with unprecedented quality and resolution. Approval of the Tandem-L implementation is expected at the beginning of 2017.

Based on novel technologies, innovative imaging techniques and the resulting extensive recording capacity, Tandem-L will provide vital information to help solve important scientific and societal issues relating to the bio-, geo-, cryo- and hydrosphere. Tandem-L will make it possible to simultaneously observe seven essential climate variables with one single satellite mission for the first time. It will thus play a crucial role in gaining a better understanding of the Earth's systems and their dynamics, and confirm Germany's position as an international leader in the field of radar remote sensing.



The complex shape of the Andes in the Argentinian province of Catamarca, revealed in a digital elevation model.

Tandem-L has a series of key mission objectives. The global measurement of forest biomass and how it changes over time will enable a better understanding of the carbon cycle. In addition, systematic observation of deformations in the Earth's surface in the millimetre range will be conducted for earthquake research and risk analysis. Tandem-L will also quantify glacier movements and melting processes in the polar regions, allow for monitoring of dynamics in permafrost regions, conduct extensive observations of ocean currents and measure small-scale variations in soil moisture.

In times of intense scientific and public debate regarding the extent and impact of climate change, Tandem-L will supply essential and hitherto unavailable data for improved scientific projections that will form a basis for proposed socio-political courses of action. Beyond the primary mission objectives, the dataset recorded by Tandem-L will open up a huge potential for the development of new scientific, commercial and government applications. One example is the preparation for and monitoring of international climate and environmental conventions such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation). Using radar tomography, necessary information such as tree height, forest biomass and their changes (due to factors such as deforestation, forest fire or degradation, but also reforestation), and the vertical forest profile can be derived.

The Tandem-L mission concept uses two L-band (23.6 centimetre wavelength) radar satellites. By using synthetic aperture radar techniques, high-resolution images of the Earth's surface can be acquired regardless

THE FUTURE TANDEM-L MISSION

An up-to-date image of the Earth's entire land mass will be available every eight days.

The imaging capacity will be more than 10 times better than that of any previous SAR satellite.

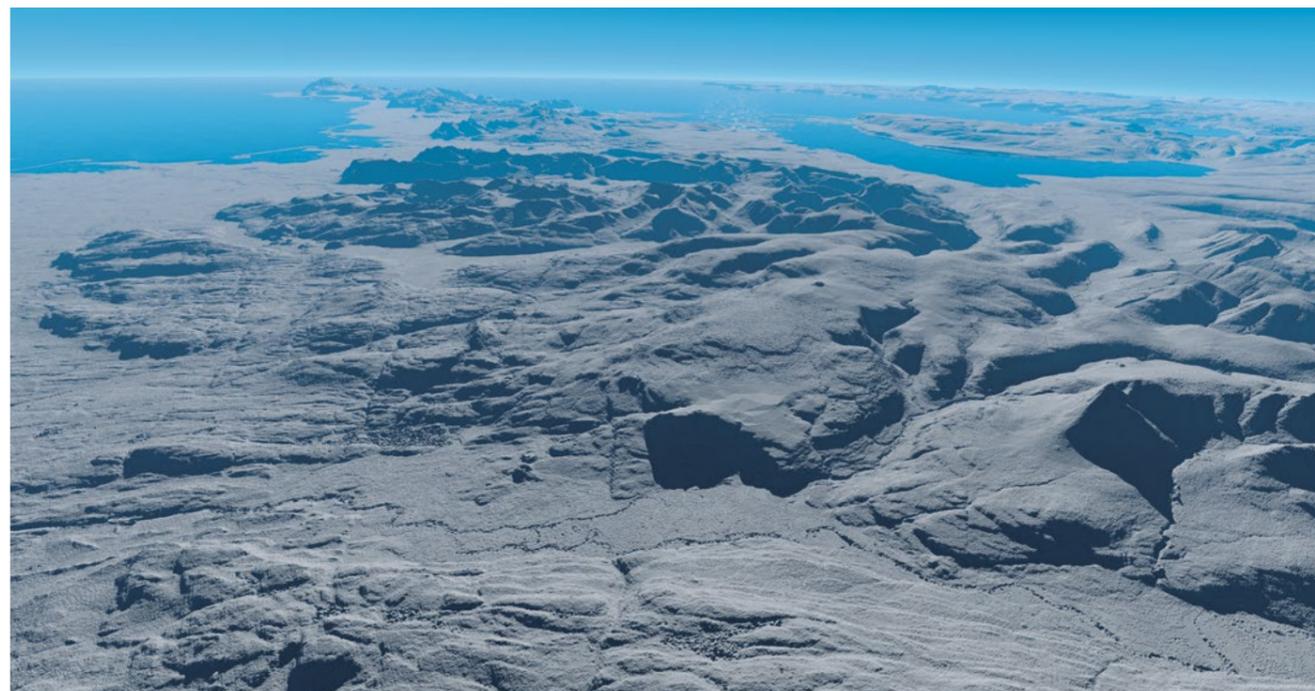
For the first time ever, Tandem-L will use polarimetric SAR interferometry and tomography, developed in Germany, to survey the vertical structure of vegetation and ice around the world.

Eight centres belonging to the Helmholtz Association of German research centres, as well as 18 partner and associated facilities, are involved in a Helmholtz alliance to prepare for the comprehensive and systematic use of data from Tandem-L.

Tandem-L will make it possible to simultaneously measure seven essential climate variables with one single satellite mission.

Tandem-L will be the world's first mission for the systematic, high-resolution observation of dynamic processes in the bio-, geo-, cryo- and hydrospheres.

More than 100 research institutes have already expressed a keen interest in using the Tandem-L data, and are members of the Tandem-L scientific team.



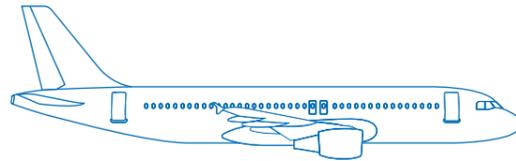
This image, acquired by TanDEM-X, shows the Icelandic Snæfellsnes peninsula in the centre and, on the right, the Breidhafjörður with the Vestfirðir peninsula in the northwest of Iceland.

of weather conditions and the availability of daylight – making it the ideal solution for continuously monitoring dynamic processes on the Earth's surface. One of the particular challenges faced by the Tandem-L mission is satisfying the requirements of the potential users – high bandwidth, short revisit intervals, high resolution and fully polarimetric operation. To achieve this, DLR researchers have developed an innovative technology that combines a digital antenna with a large, deployable reflector. Combining the advantages of digital beam forming with the high sensitivity provided by the large aperture of a deployable reflector is a technological revolution. Tandem-L will offer 10 times the capability of conventional radar satellites. Under the current plan, the Tandem-L satellites could be launched in 2022. The revolutionary techniques and technologies that will be used in Tandem-L will form the basis for future generations of satellite SAR systems. The Tandem-L mission thus opens the door to a global remote sensing system for the continuous observation of the Earth's surface akin to the system already used for weather forecasting, which relies on a network of geostationary satellites.

Manfred Zink works at the DLR Microwaves and Radar Institute.

Alberto Moreira is the Director of the Institute.

AERODYNAMIC 'HAT-TRICK'



By Yvonne Buchwald and Ralf Rudnik

What can a flight test reveal that a wind tunnel experiment cannot? What can a simulation achieve once experimental techniques have reached their limits? Most importantly – how can these methods be used together and an authoritative database be created using the combined data?

For aerodynamicists, this much is clear; plenty of reliable information is available if one is looking at the 'normal' conditions for which today's passenger aircraft are designed – high-speed cruising flight. However, when an aircraft approaches the boundaries of its flight envelope – for example if it is flying very slowly – it is much harder for researchers to obtain reliable information. This was the major challenge faced by the DLR-led joint HINVA (High lift INflight VALidation) project. HINVA involved more detailed research into one of the most important aerodynamic limits – the maximum lift or, to be more precise, the maximum lift coefficient of an aircraft. This is particularly important during landing. To stay airborne during its landing approach – at a speed of less than 250 kilometres per hour – an aircraft needs additional lifting surface. This is created by extending a complex system of mechanical flaps from the wings, which increases the wing area and wing camber, producing more lift.

There are, however, other factors – additional weight, additional energy consumption, the required length of runway and noise pollution during the approach – and the way in which these conflicting factors can be better reconciled in future. But before any of this can be achieved, researchers need a better understanding of the complex aerodynamic processes involved in low-speed flight – they need more reliable data. But what method should they employ? Should they rely on a computer simulation in which only a somewhat simplified flow dynamics situation using 'rigid' aircraft geometry is calculated? Are the values measured in a wind tunnel accurate, despite being affected by the model mounting and tunnel walls? Does a flight test alone yield reliable results, because the aircraft is exhibiting 'real' behaviour, meaning that it might also be deformed by aerodynamic forces? Or is the opposite true – is the computer simulation preferable because of the unpredictable external influences at play during a flight test?

The researchers chose a different, parallel approach in the HINVA project – they combined all three methods. For the first time in a single project, they conducted identical measurements or calculations with a complete aircraft configuration in a computer laboratory, in a wind tunnel and in the air. Simulation and experiment went hand in hand; measured and calculated data from wind tunnel and flight tests as well as simulations could be directly compared. This resulted in a shared database that the project partners can use in future research projects.



Image: WTD61

The A320 ATRA is the biggest aircraft in DLR's research fleet. Pilots in the HINVA project used it to test the limits of extremely slow flight.

Wind tunnel test, actual flight and numerical model working as one

It is a cold winter's day in early 2014. Niko Bier and his colleagues are in the control centre at the European Transonic Wind Tunnel (ETW). Inside the tunnel's large steel shell, it is bitterly cold – minus 160 degrees Celsius – and the pressure is very high – 3.5 bar. To achieve this, up to 250 kilograms of nitrogen are injected into the 50-metre long test section every second. From a safe distance, on their monitors, the researchers first observe their aircraft model being lowered into the test section. The huge compressor in the Cologne wind tunnel is then switched on. The flow measurements can now begin.

Bier and his colleagues represent one third of the research triumvirate of wind tunnel test, actual flight and numerical model. The wind tunnel experts exchange brief words and instructions. They are all transfixed by the sequences of numbers and the images coming out of the computers during the measurements. Inside the tunnel the nitrogen is roaring as it moves through the tube at approximately 150 kilometres per hour. Now, it is just a matter of time. They are all well prepared; they have been working meticulously for a long time on the half model of the A320 ATRA, which they are now testing under realistic conditions in the wind tunnel. "Not only have we reproduced the flow dynamics of a flight test, we have also used the same instrumentation and even enabled deformation of the model in a way similar to the actual aircraft," explains the engineer from the DLR Institute of Aerodynamics and Flow Technology. "In the beginning, we were not sure of whether it would actually work," he adds, but he says he and his colleagues were able to get the model in the tunnel to behave exactly like the original aircraft during a complex, slow landing approach. "Our wind tunnel measurements are quite a good match for the results obtained during the test flights."

To confirm this, they will place their model in the wind tunnel a few more times and take measurements under different conditions. This is where Bier's key colleagues – the pilot and the numerical analyst – have a part to play. They supply him with data from the air and from the computer laboratory. Only by working together can they make optimum decisions on the design of the wind tunnel model – how it should be manufactured, how it should be mounted, which instruments to install, and the points at which measurements should be made.

These decisions also involved DLR test pilot Hans-Jürgen Berns making stall flights. The first flight tests with the Airbus A320 ATRA, DLR's largest research aircraft, took place in Toulouse in 2012. Berns made a number of flights during the five years of the project. He recalls: "It really was not always easy. We had to fly this complex manoeuvre – sometimes in winter, in the dark and in cloudy conditions." During a flight test in early 2015, clouds were necessary to enhance the visibility

of a laser beam that the researchers directed from the cabin onto one of the wings to take optical measurements of the airflow. In order to do this, a new measurement method called PIV (Particle Image Velocimetry) was used; this is one of the many experimental tools of the HINVA project, which had previously been used in the wind tunnel.

For Berns, this was not the only challenge, as he had to supply as much accurate measurement data as possible from the flight tests for the colleagues working with the computer and in the wind tunnel. In March 2015, he took off one last time with the DLR ATRA. In these last four flight tests, he took the aircraft, with its elaborate measurement technology, to the very limits of its flying capability – no less than 30 times. Berns flew as slowly as possible to obtain the best measurement data on high lift. To do this, he steadily lifted the nose of the aircraft higher and higher, constantly increasing the angle of attack. When the angle for the slowest possible level flight was exceeded, the airflow over the wings became disrupted and the aircraft began to drop, requiring the pilot to take corrective action. These stall manoeuvres required Bern to have an extreme sensitivity to the aerodynamic limits of such a large aircraft. Despite this: "It all went very well; the weather, the collaboration among colleagues and the good measurement results that we obtained."

The third person in the team played his part seemingly unnoticed – almost always present and constantly refining the software. Simulations were conducted before the first flight test, after the last one and in between, as well as before the first wind tunnel test and during additional measurements. David Rohlmann, of the Institute of Aerodynamics and Flow Technology, worked with millions of unknowns in millions of operations, fed in data and visualised results. Was it a challenge? "Yes," he says, "because in this case we put in such huge effort. We always considered the entire, highly complex geometry of the A320 ATRA, and all its small details. We simplified very little – less than usual – and always remained faithful to the original aircraft. Although this meant lengthy simulation processes, it was extremely accurate." With more than 65 million grid points, the elaborate networks of calculations generated on the computer yielded a high spatial resolution for the airflow around the aircraft. Each of the calculation runs was performed on 190 processors of a supercomputer, and the flow dynamics of several aircraft configurations were calculated simultaneously. Moreover, the aerospace engineer repeatedly changed the angle of the aircraft in his numerical simulations, in order to gather as much aerodynamic data as possible – using between 3000 and 4000 computing hours in the process.

If anything was not quite right, Rohlmann noticed it straight away. By combining his portfolio of algorithms with the measurement data from the first flight test, he was able to check whether – and under what

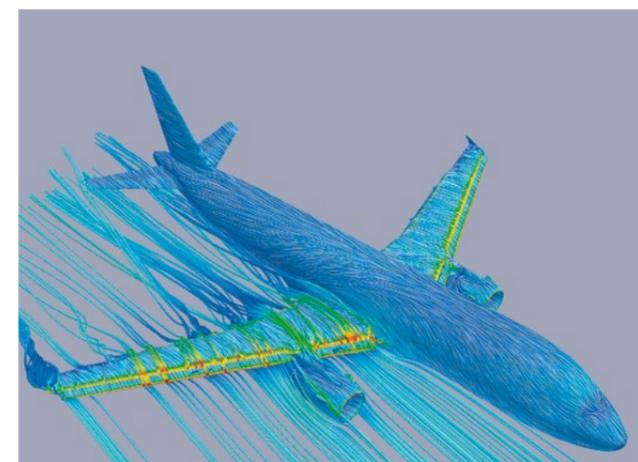
"IN THE BEGINNING, WE WERE NOT SURE OF WHETHER IT WOULD ACTUALLY WORK"



The HINVA model in the ETW in Cologne



Laser measurements over the wing during preparations for a night-time flight test



Computer simulation of the flow pattern on and above the surface of the aircraft configuration

conditions – the results acquired during the flight were consistent with his simulations. The constant exchange and comparison of results made apparent early on whether, for instance, the measuring instruments had been attached at the right places on the aircraft or whether adjustments had to be made.

The researchers were aiming for the smallest possible divergence in the results – less than two percent. This is important because an inaccuracy of just one percent in the design of a new flap system can determine whether a large passenger aircraft can carry an additional weight, equivalent to around 20 passengers. But the HINVA researcher's three-pronged approach paid off, leaving the wind tunnel experts, numerical analyst and pilot with the certainty that they had achieved the right combination and made a big contribution to the aim of the project – the development of high-lift systems that are even better adapted to slow flight – and thereby reduce weight, fuel consumption, speed and noise pollution around airports.

Yvonne Buchwald works at the DLR Institute of Aerodynamics and Flow Technology providing public relations support to the researchers.

Ralf Rudnik is the Head of the Transport Aircraft Department at the DLR Institute of Aerodynamics and Flow Technology in Braunschweig and led the HINVA joint project.



During a measurement flight – airflow captured in a laser beam.

THE HINVA PROJECT

The 'High lift INflight VALidation' joint project was funded by the German Federal Ministry for Economic Affairs and Energy, and led by DLR. In addition to DLR, the project involved partners Airbus and ETW, as well as research work by the Technical University of Berlin, the Technical University of Braunschweig and the University of Stuttgart. The project ran from 2010 to 2015.

A short HINVA glossary

ATRA
... the Airbus A320-232 'D-ATRA' is the largest member of the DLR research aircraft fleet and, in the HINVA project, was used as a common configuration basis for numerical simulations and flight and wind tunnel tests.

ETW
... stands for 'European Transonic Wind Tunnel'. The world's leading cryogenic wind tunnel (and the only one of its kind in Europe) in Cologne enables measurements to be performed under realistic conditions. This requires low temperatures (down to minus 163 degrees Celsius) and high pressure (up to 4.5 bar). Speeds of up to a Mach number of 1.35 can be achieved.

Maximum lift coefficient Cl_{max}
... in a similar way to the drag coefficient, the lift coefficient describes the aerodynamic properties of an object for lift generation. Along with wing surface area, air density or altitude, and speed, it determines the achievable lift. The maximum lift coefficient corresponds to the state in which the aircraft will just sustain level flight. For a given aircraft weight, it defines the slowest flight speed. When combined with a safety factor, it also determines the approach speed.

Numerical simulation (Computational Fluid Dynamics)
... is an umbrella term for computer simulations that, with the increasing availability of supercomputers in recent decades, have become an established tool in research and technology. The computer simulations, which are often less expensive, faster and have a lower risk than experiments, are also a valuable tool in aviation, as in the 'virtual laboratory' of a computer, many processes can be simulated and analysed before the first experiments.

PIV
... stands for Particle Image Velocimetry. This is an optical method of measuring velocity fields. Researchers at the DLR Institute of Aerodynamics and Flow Technology have refined laser measurement technology. Micrometre-sized particles are scattered into the flow field to be investigated and a laser is simultaneously directed onto the field. The movements of the particles (in the HINVA flight tests, the researchers used fog droplets that were flowing past the aircraft) are recorded by cameras. Using specially developed software, the entire flow field can then be depicted in three dimensions and analysed.

TAU
... is the name of a computer program developed by the DLR Institute of Aerodynamics and Flow Technology, which is now used worldwide. The Computational Fluid Dynamics solver 'TAU' was used in the HINVA project to perform the flow simulations on the biggest supercomputer in use in Europe for aeronautical research, the C²A²S²E II (Center for Computer Applications in AeroSpace Science and Engineering) simulation facility at DLR in Braunschweig.



SOS – UNMANNED RESCUE ON THE WAY



Heavy and persistent rainfall has caused massive flooding of the Elbe Lateral Canal and the Tankumsee, a lake near Gifhorn in Lower Saxony, Germany. Roads are completely covered by water and, in some places people have become isolated. Parts of the traffic infrastructure are damaged and this is hindering the deployment of the emergency services. Similar situations have already occurred in other parts of Germany. This, however, is a simulated crisis scenario that is part of a large-scale demonstration project. In the meantime, DLR's D-CODE research aircraft is taking off from Braunschweig-Wolfsburg Airport on a reconnaissance mission. The aim is to acquire up-to-date aerial images to determine the situation in the crisis area and provide essential information for planning relief operations. On board the research aircraft is just one safety pilot. The aircraft flies almost automatically, controlled and monitored from the ground – an important first step towards the use of unmanned aircraft (Remotely Piloted Aircraft Systems; RPAS) for crisis management.

New disaster relief system demonstrates its effectiveness – the DRIVER project

By Dagi Geister

Floods, severe storms, heat waves, forest fires, earthquakes and technological disasters often lead to crisis situations in the affected areas. To be better prepared for such events at a transnational level and to organise the necessary assistance more effectively, the European Union is supporting the 'Driving Innovation in Crisis Management for European Resilience' (DRIVER) project as part of the 7th Framework Programme. The project began in May 2014 and involves a total of 36 European project partners from 15 countries. This makes DRIVER one of the world's largest publicly funded demonstration projects in the field of crisis management.

Fastest possible position detection

In the EU DRIVER project, with the participation of DLR, various technologies for crisis management in the event of a disaster are being combined and applied as part of a Europe-wide, joint demonstration. Real-time aerial images make a significant contribution to assessing the situation in a disaster region, enabling a more effective planning of relief services. This is where DLR's contribution is important. For DRIVER, the D-CODE research aircraft, a Dornier 228-101, has been equipped with an experimental system to demonstrate the features of unmanned flights. On board the aircraft are camera systems provided by DLR's Earth Observation Center (EOC) in Oberpfaffenhofen.

Using the 3K Camera System on board D-CODE, and depending on the flight altitude, it is possible to record an 80-kilometre-square area in approximately two minutes, produce georeferenced areal images and transmit the results to a ground station via a data link. As soon as the image data has been transmitted to the ground, further analysis of the situation can be conducted and maps can be created at the EOC's Center for Satellite Based Crisis Information (ZKI). Crisis information (such as road navigability) can then be derived from the aerial images,



DRIVER crisis scenarios – flooding and pandemics.



Mediterranean tsunami with additional risks



Heat wave with cascading effects (for example, forest fires)

and special maps produced to generate a realistic visualisation. In the test scenario, these showed the possible spread of the flooding of the Elbe Lateral Canal and the Tankumsee.

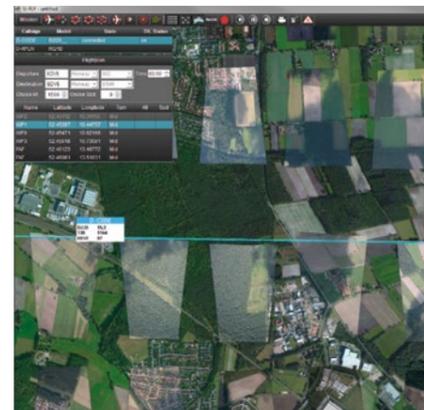
In parallel to the work being undertaken by ZKI on DRIVER, the DLR Institute of Transportation Systems in Berlin used the latest aerial images provided in near real-time by the RPAS flight demonstrator together with the survey data from the EOC, to produce an up-to-date picture of the traffic situation in the affected region. The rescue teams can better coordinate the logistics of disaster relief measures if they have data regarding the current and predicted situation, as well as information on travel routes and times. Moreover, various scenarios for the arrival of additional rescue teams can be simulated and evaluated.

Unmanned aircraft for crisis management

RPAS are becoming increasingly important in civil protection and crisis management. The advantage of unmanned aircraft is that they can be used even in dangerous or hard-to-access areas, as well as enable observation of the affected regions – or regions under threat – over an extended period of time. For the flight trials of RPAS in controlled airspace, the D-CODE research aircraft was modified to allow flight control commands to be received from the ground and processed. The aircraft's flight and mission were planned by the ground station for unmanned aircraft, U-FLY, at the Institute of Flight Guidance in Braunschweig. U-FLY is able to create various four-dimensional flight paths in advance for simulations and flight experiments and check a variety of aspects, most notably safety (such as altitudes, obstacles



Mission planning and remote operation of the D-CODE aircraft with the U-FLY ground station for unmanned aircraft



Aerial image data of the Tankumsee region



Sensor data is used to identify the locations of the test subjects in the water



Crisis centre at DLR



The test subjects are rescued from the Tankumsee



and restricted areas) and mission objectives (for example, identifying objects as quickly as possible, acquiring comprehensive aerial image data), for different unmanned aircraft types.

The first test flight to demonstrate unmanned flights in crisis management as part of the DRIVER project took place in September 2015. The people involved at DLR, along with pilots, rescue workers and test subjects, met at DLR's crisis centre in Braunschweig for the flight. The scenario was one of widespread flooding that trapped people within the flood area and damaged parts of the traffic infrastructure. The aim was to evaluate novel systems that could be used to support the rescue teams with planning and coordinating their deployment.

The flight test began by examining the current extent of the crisis situation from the air. To this end, an RPAS pilot produced a mission plan at the U-FLY ground control station, which provided for the most extensive aerial images possible. In a second step, the flight path was rerouted from the ground to find the most affected areas in terms of impact on people and observe the main traffic routes from the air. Based on the aerial images acquired, the traffic situation could then be analysed and available emergency routes revealed. In parallel to this, an image analysis system was evaluated for crisis management that can be used to detect people in an emergency situation on the aerial images. Test subjects had been sent to the Tankumsee for this purpose. Some of them swam in the water by themselves, while others were grouped together in boats.

The RPAS demonstrator flew search patterns over the test area and supplied images from which the necessary information was extracted for targeted response measures. If it was suspected that people were in distress, the U-FLY ground station altered the aircraft's flight path to rapidly confirm the 'initial suspicion'. In this way, in a real crisis situation, it will be possible to provide rescue teams with more specific information, direct help to the right places and transport aid supplies – such as water, medicines or food – to the crisis zone. In a possible future scenario, these technologies could be used to enable an unmanned aircraft to perform other tasks in addition to independently observing the crisis zone, such as delivering urgently needed relief supplies directly to the optimum locations.

Two further flight trials will be conducted in the next three years as part of large-scale experimentation campaigns within the DRIVER project. These will investigate different disaster scenarios, such as floods in The Netherlands and tsunamis in the Mediterranean region. The overall system created in the DRIVER project will then be put to the test during realistic aid exercise – with the involvement of rescue and aid workers, including the German Federal Agency for Technical Relief (THW) and representatives of the Red Cross from Austria, the United Kingdom and Denmark. The project will conclude in the autumn of 2018 with a Europe-wide demonstration of the system.

Dagi Geister is a researcher at the DLR Institute of Flight Guidance and DLR's Project Manager for DRIVER.

RPAS RESEARCH AT DLR BRAUNSCHWEIG

The Institute of Flight Guidance has spent a number of years researching concepts and technologies that will enable the integration of unmanned aircraft into controlled air space. One of the main focuses of the research is optimised mission planning by means of which missions by one or multiple RPAS – either individually or flying in formation – with differing tasks (for example, surveillance, transport of aid supplies) and requirements (for example, time-critical deployments) can be planned and carried out. The safety of the RPAS operations is always paramount. In addition to conflict detection and avoidance procedures, research is also conducted into possible strategies and technologies for failure and outage situations. These are regularly tested and evaluated with the involvement of the users, initially in a simulation environment and then in flight tests using the D-CODE research aircraft.

QUIETER ON THE RAILS

Using disturbances to reduce rail noise in populated areas

By Vera Koopmann and Tilo Schumann

Rail transport is regarded as the most environmentally friendly motor-powered mode of transportation. In terms of fuel emissions, it has the edge over cars and aircraft – not so in terms of noise emissions. Noise causes sleep disturbances, can lead to cardiovascular diseases and increases the risk of suffering a heart attack. In particular, freight transport – often handled at night – causes tremendous nuisance to residents in the vicinity of railways. The Ibo:LES concept offers a solution to this problem – anticipatory driving. The name of the project is an acronym of the German for ‘Integrated operational optimisation: noise, energy, stability’. The technique can be deployed well in advance – even if the reason for deceleration is still kilometres away, the train will travel more slowly in areas where residents are exposed to severe railway noise.

BACKGROUND

One in five German citizens lives in the proximity of a railway, and the volume of freight transport is steadily growing. Together with Deutsche Bahn AG, the German Federal Government has resolved to halve the noise from railway traffic by 2020. This will entail switching freight wagons to ‘whispering brakes’ and implementing noise control measures for badly affected stretches. But the huge costs involved undermine the competitiveness of railways compared with road transport, which in turn prevents a rapid move to noise-reduction technologies. Freight transport customers will be very reluctant to pay higher transport costs in return for reduced noise emissions. Since the scrapping of the ‘rail bonus’ that, in the past, allowed a noise limit five decibels higher than that for road traffic, the freight transport sector has had to become more proactive in the drive to reduce noise emissions.

There is a great deal of tension between residents’ need of protection against noise pollution, the rate at which the wagons can be modified, and the profitability and operational viability of rail freight transport. To solve these conflicts, DLR is drawing on its interdisciplinary competencies – scientists at the Institute of Transportation Systems, the Institute of Aerodynamics and Flow Technology, the Institute of Aerospace Medicine, and the Institute of Atmospheric Physics are working on new noise reduction concepts as part of the Transport Development and Environment (Verkehrsentwicklung und Umwelt; VEU) project.

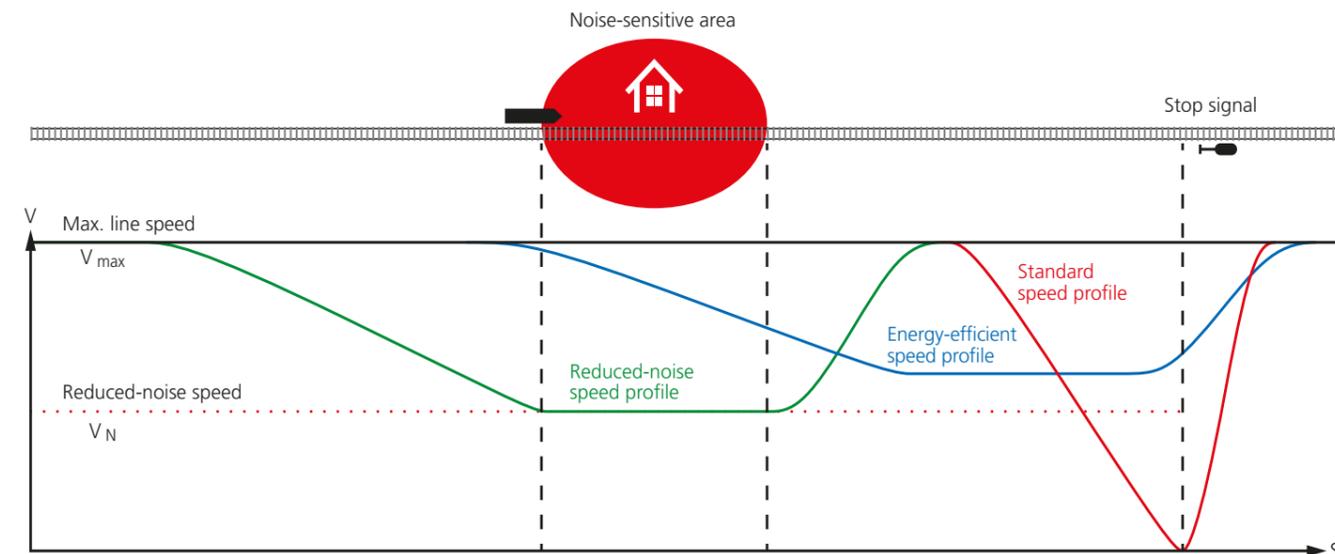
The researchers see great potential in the acoustic design of new wagons. Individual noise components can be selectively manipulated in a ‘Sound Machine’, to make a sound seem more pleasant while the volume remains unchanged. This technique allows the comparison of various noise sources – such as braking systems, rails, or bogies – at the perceived volume, and the findings are incorporated into technological developments.

Other options for reducing railway noise include more stable operations and a more efficient driving style in the event of a holdup – driver assistance systems provide the train conductor with speed recommendations to avoid the need to brake at signals by reducing the speed in advance. This makes the journey more energy efficient, thus minimising the traction power required.

But in terms of lowering noise emissions, the main solutions being discussed are the prohibition of railway circulation at certain hours and speed reductions. These would – at least – be fast and economical to implement. However, this approach again ignores the medium- to long-term consequences for the railway system – rail freight would become far less appealing than other modes of transportation. Costs of transport would rise and coordinated logistics chains would be broken. Slower rail freight traffic would also affect passenger transport, leading to longer journey times or even route cancellations. These are the findings of a study carried out by the Institute of Transportation Systems in 2013.

A speed reduction for freight trains is also dividing opinion among Germany’s politicians. The affected regions are demanding immediate operating restrictions. The Federal Ministry of Transport, however, does not want to impose speed restrictions in 2016. The EU Commission also considers the competitiveness of rail freight to be more important than noise control. A similar debate occurred in the world of aviation. More than 10 years ago, transport policy concepts to reduce noise were called for, as a technical noise reduction at the source – from development to market launch and penetration – would take too long. In response to this, DLR developed a lower-noise, flight-approach management system. The system comprises quieter approach procedures and alterations to flight routes. The aim was to make the best possible use of air and runway capacity while ensuring maximum safety and minimum environmental impact.

A speed reduction for freight trains is also dividing opinion among Germany’s politicians. The affected regions are demanding immediate operating restrictions. The Federal Ministry of Transport, however, does not want to impose speed restrictions in 2016. The EU Commission also considers the competitiveness of rail freight to be more important than noise control. A similar debate occurred in the world of aviation. More than 10 years ago, transport policy concepts to reduce noise were called for, as a technical noise reduction at the source – from development to market launch and penetration – would take too long. In response to this, DLR developed a lower-noise, flight-approach management system. The system comprises quieter approach procedures and alterations to flight routes. The aim was to make the best possible use of air and runway capacity while ensuring maximum safety and minimum environmental impact.



The Ibo:LES approach involves a highly anticipatory driving style to shift deceleration to noise-sensitive areas

The idea behind the concept is as simple as it is effective – a technical system ‘tells’ the freight train when to reduce its speed so that it does not have to wait behind another train that is blocking the line. This measure is more energy efficient, as the freight train is instructed to slowly reduce its speed rather than grinding to a halt. But the truly clever part is that the freight train does not reduce its speed in front of the red signal; it does so in the most logical place from a noise-reduction perspective – the surrounding inhabited areas. The noise is thus reduced for the residents, the train travels in an energy-efficient manner, and the stability of railway operations is ensured as long waiting times are eradicated. Unlike general speed reductions, the system only intervenes when it is able to do so without any negative impact on capacity and stability.

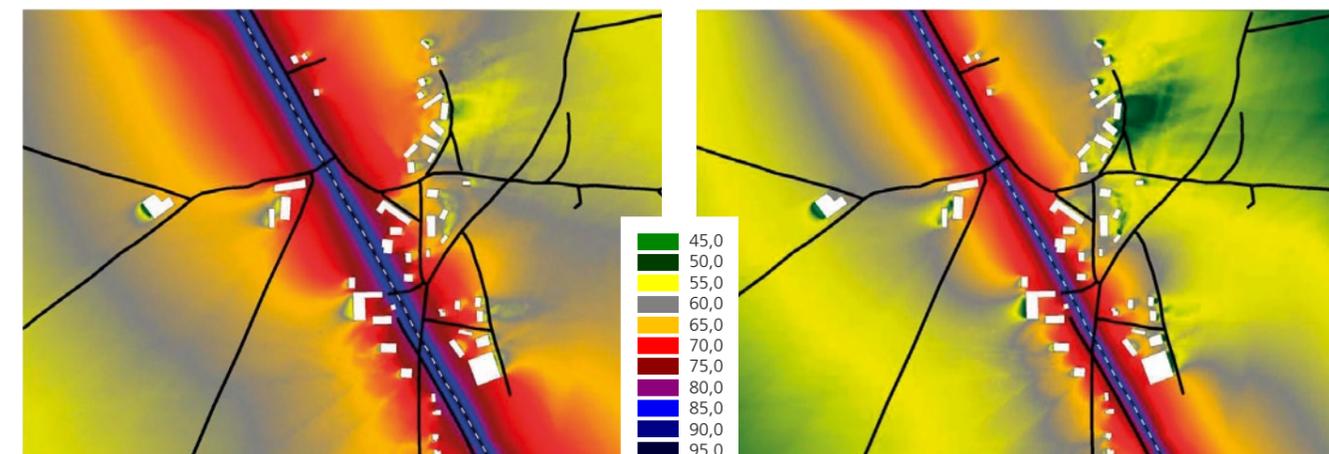
Moreover, the speed profile is calculated so that, by the time the train reaches the signal, it has returned to the full speed of the line. This has a number of advantages: the reduced speed in inhabited areas prevents noise pollution for the residents; the train avoids stopping at the signal and the anticipatory driving style reduces fuel consumption; the train clears its current stretch of track as quickly as possible, which in turn has a positive impact on operational stability.

The results of the feasibility study carried out by the DLR scientists are outstanding. In general, if two trains travel one after the other on the same line, one of the trains would have to stop at some point. By adopting the Ibo:LES driving method, the stop by the second train can be avoided, fuel consumption can be reduced by approximately 15 percent, and the noise level in the surrounding residential area reduced by three decibels. Furthermore, there is a significant reduction in the peak sound propagation level.

Further research is now being conducted to establish the potential of this approach for a longer rail line with a full day of operation and some disturbances. The next step is the automated calculation of the dynamic speed profiles to, for example, incorporate driver-assistance systems.

Vera Koopmann is responsible for Public Relations at the DLR Institute of Transportation Systems.

Tilo Schumann develops solutions for railway noise as part of the DLR Transport Development and Environment project.



Peak level in standard driving behaviour – the freight train travels through a locality with a scheduled maximum speed of 100 kilometres per hour; the noise level in the residential area near the railway line is correspondingly high.

Peak level when Ibo:LES is used – the freight train (50 kilometres per hour) is selectively instructed to reduce speed within the inhabited area, significantly reducing noise levels.

318 METRES FOR EXCLUSIVE AERODYNAMIC TESTS

DNW, the German-Dutch Wind Tunnels, is Europe's leading organisation for wind tunnel tests. The masterpiece it has in the Netherlands is considered one of the world's best research facilities – in it, even a runway can be simulated.

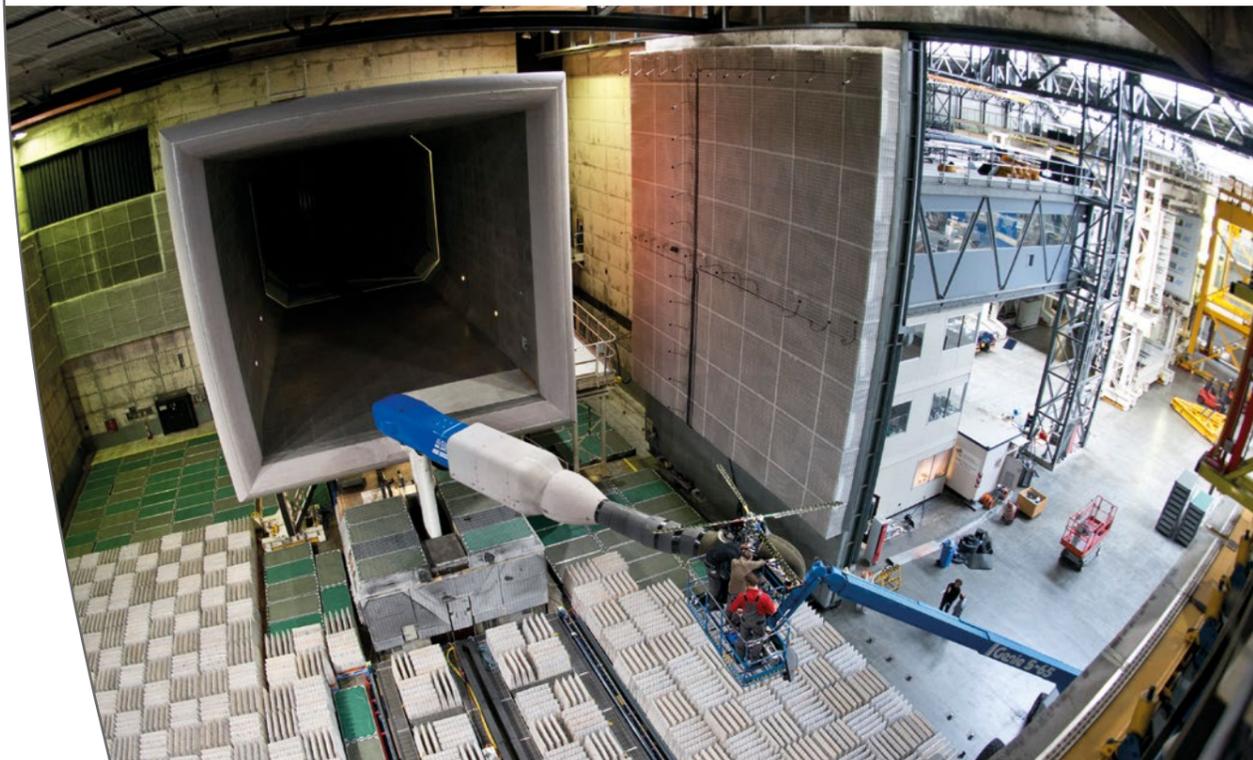
Part 5 of the series 'The Wind Machines'

By Jens Wucherpfennig

DNW was founded by the German and Dutch national aerospace research institutions – DLR and NLR respectively. In 1975, the two organisations decided to embark on a joint project to construct an immense new wind tunnel. A subsidiary was established under Dutch law to operate it. This was the birth of DNW-LLF (Large Low-Speed Facility). Over the years, a number of other large wind tunnels were added under the DNW umbrella.

The DNW-LLF was completed at Marknesse in the Netherlands in 1980. The first tests on an Airbus model took place one year later. "All models of the Airbus fleet have been examined here," says Georg Eitelberg, Managing Director of DNW, "and we are proud of that." The LLF is a strategic element of the European aeronautics research infrastructure.

The LLF also enjoys a good reputation at the international level. Models from all the world's major aircraft manufacturers have been studied here; they include Embraer from Brazil, COMAC from China, Dassault from France, and even Boeing from the United States. The latter is particularly surprising, because test facilities are not usually shared on account of the competition between Airbus and Boeing. Nevertheless, the US has even had tests performed in the European wind tunnel for the most expensive and most extensive military aircraft programme in the world – the F-35 Joint Strike Fighter. In the coming decades, this mass-produced, stealthy, multi-purpose aircraft will be the backbone of the US Air Force and several NATO allies.



Size is relative – although most objects are only wind tunnel tested in the form of a model, they can still be so large that, as with this helicopter, access can only be achieved at seven metres up by means of a crane. Compared to the huge dimensions of the wind tunnel, however, the model appears tiny.

Image: DNW



In 2014, the propeller of the Advanced Propulsion Integration Aerodynamics and Noise (APIAN) model was tested in the DNW-LLF.

According to Eitelberg, what persuaded the United States was the particular strengths of LLF, namely the control and measurement technology as well as the special benefit of being able to study the take-off and landing of aircraft – something that is not available elsewhere. This is particularly important in the case of the F-35, because a vertical take-off variant, which imposes special aerodynamic requirements, is planned. For these tests, a 1.5-metre model with the engine running was tested in the wind tunnel – "the smallest model we have ever tested," says Eitelberg. Military projects like the F-35 are the exception; civilian projects account for the vast majority of tests conducted in the LLF.

Despite the enormous dimensions of the LLF, almost no aircraft of original size are tested at the facility. The largest dimensional range is 9.5 metres wide by 9.5 metres high and 20 metres in length. This requires a wind tunnel that is 318 metres long. A larger test section would increase the costs astronomically because of the vast size of the corresponding wind tunnel.

Although the largest object studied in the wind tunnel in the Netherlands was a full-size Airbus 320 wing, research is usually confined to aircraft models on a reduced scale. In principle, it would be possible to test small civilian aircraft at their original size in the LLF. However, it makes little sense to investigate an aircraft that is already in use. Moreover, such aircraft would have to be equipped with sophisticated measurement technology in order to test them, which of course would bring about prohibitive expenses. According to Eitelberg, a full-scale model would be more expensive than the aircraft, and therefore would not be an option. This is due to the fact that wind tunnel models are not just scaled-down copies of the original, but custom-built versions adapted to the research at hand and generally equipped with sensors and instrumentation.

A test run in the LLF is expensive. A week's fee starts at about 250,000 euro. It is clear that with such sums being involved, the operator, DNW, must acquire its customers from the aeronautics industry. But there are also European research programmes that enable research institutions to conduct studies in cooperation with industry in the LLF.

In addition to aeronautics research – which accounts for most tests in the LLF – test runs for other fields, such as energy and transport, are also carried out. "Many truck manufacturers have their vehicles tested here," says Eitelberg. Car manufacturers have their own wind tunnels, where they conduct tests with scale models: "But we are the only facility where a full-sized articulated lorry can be tested," says Eitelberg. Wind turbine manufacturers also use the test facility – they even test wind turbines whilst they are rotating.

Throughout its 35-year existence, the LLF has been constantly modernised, and the ways of studying aerodynamic processes have been continuously improved. It is now one of the quietest wind tunnels in the world – an important consideration when the research conducted involves the causes of noise generated by aircraft. Another strength of the LLF is engine simulation. "And thirdly, we have the best runway simulation in the world," says Eitelberg. With these advantages, the DNW Director is convinced that the LLF will continue to play an important role in aeronautics research.



Even the most expensive defence project in the world, the US F-35 Joint Strike Fighter, was tested at the LLF in Marknesse – a sign of the valuable characteristics of the wind tunnel.

Image: DNW

A day in the wind tunnel

08:30 The day starts with a briefing in the LLF control room. The wind tunnel control room is filled to the brim because a large team is involved. Up to 20 DNW employees are working on the preparation phase of the new experiment; 10 colleagues from DLR are present as well. English is the working language. There is coffee, but no cosy chatter – the wind tunnel is booked for nine days, each of which costs almost 75,000 euro – more than 2.5 euro per second of testing time. And a sharp watch is kept on the time. “If something does not work on our side, the clock continues to run – and so do the costs,” explains Bartels. “Therefore, we try to resolve the problems in the evening, outside of testing time. Yesterday, we worked until 23:00.” The clock only stops if there is a problem with the wind tunnel itself, and in this case the troubleshooting time is not charged.

Everybody agrees that this test run will be a special one. Helicopter tests in the LLF are rare, and for the first time a new high-speed camera system has been installed on the ceiling to make stereo optical recordings of the rotor using four cameras.

The first hover test will take place today.

09:10 Before the actual test begins, it is necessary to check that the rotor does not exhibit any imbalance. In a real helicopter, any imbalance would be very uncomfortable for the passengers, which is why every rotor must first be balanced – just like car tyres. The helicopter model used for the wind tunnel experiments is more complex than a real helicopter: the rotor, which will be exposed to immense stresses because of the large centrifugal forces, is equipped with cables and pressure sensors.

09:36 The preliminary tests are going well. The rotor does not exhibit any imbalance.

09:40 Suddenly there is concern. An actuator controlling one of the two META swashplates is no longer functioning, and thus, neither is the rotor control system. The rotor is stopped and a crane quickly lifts a member of staff to the model, suspended at a height of 6.7 metres. A quick check is carried out to see whether the actuator needs to be replaced. Exchanging it will be difficult because it is installed deep within the model. Up to now, the tests had been going exceptionally well – the day before, the model was operated for 7.5 hours non-stop, an unusually long time.

10:30 Relief – the actuator is working again, replacement is not necessary.

10:53 The preliminary tests are completed. Now, the previously open test section is closed off by a gate.

11:30 The actual test begins – initially without wind. The aim is to examine the behaviour of the rotor while hovering. This produces comparatively little noise.

Most data is obtained in real time by DLR staff seated in various measurement containers. It is very different from the past, when everything was recorded on magnetic tapes and later laboriously read out.

12:02 The airflow through the tunnel is switched on. The model is ‘flown’ at more than 100 kilometres per hour. This corresponds to the typical situation of a helicopter approaching a landing site, at the transition point between cruising and touchdown. This is precisely the flight condition where helicopters are at their noisiest.

At this point, a microphone traverse moves from its starting position, travelling along a dedicated rail system. It stops every half-metre and measures the noise emitted by the rotor over an area of six by six metres.

12:29 The first series of tests is complete. It is time for a lunch break.

12:35 The gate opens with a hissing sound and slides to one side on its air cushions. For some employees, there will be no lunch break. They will adjust the test instrumentation and check the model.

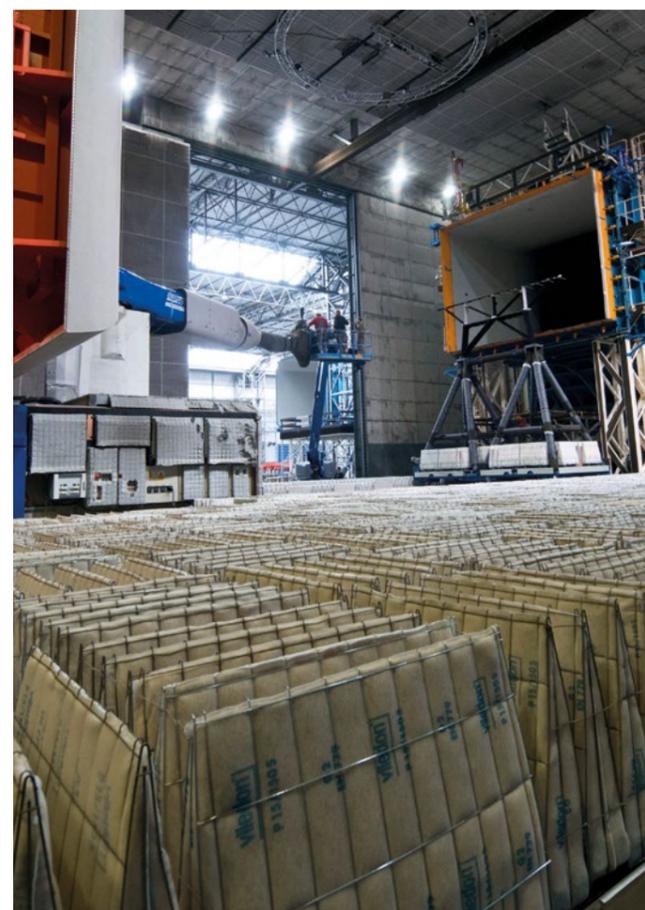
13:47 The gate closes again. Shortly afterwards, the rotor is restarted. The next set of tests is about to begin – this time with active rotor control.

14:05 The microphone traverse system moves back into position. Then the airflow is started up again, and this time it hits the rotor that is set for a six-degree descent. It is particularly loud in this configuration. The traverse system, with its measuring devices, remains in each position for a few seconds, takes a reading, and then continues in small increments to the next measuring point.

14:26 The microphone traverse system moves to its starting position, and the scanning process is repeated. Step by step, a complete noise footprint is produced. In between, the DLR researchers have changed the control input of the rotor blades, which are being actively controlled by META.

The incoming measurements look good. Berend van der Wall examines the immediate outcome of the microphone measurements. It is clear that active control of the rotor blades reduces the noise. “The noise can be reduced by up to six decibels – that is an important result,” he says. Then he points to a line on a screen: “One signal is flat-lining here, probably due to a broken cable.” In contrast with the actuator, this is not a problem as there are several hundred sensors. “Later, I will tell an engineer to check the cables leading to the yellow blade,” he says.

16:15 The series of tests planned for the day is complete – the rotor is turned off and the gate opens again. For most DLR employees, there is still work to do – they must evaluate the data, review the process and prepare for yet another day of measurements.



Not the bridge of the Starship Enterprise – but comparable; the control room at DNW.



The ‘clients’ of the wind tunnel – in this case, DLR researchers – sit in various rooms and containers filled with measuring equipment.



Inspection at nearly seven metres; researchers who have to fix a problem during wind tunnel test time not only have to find a solution quickly, but also need to have a head for heights.



Does the actuator need to be replaced? If so, it will be difficult, as it is housed deep within the model. Fortunately, it is possible to get it functioning again.

WHAT MAKES THE RUNWAY SIMULATION SO SPECIAL?

When an aircraft approaches the ground during landing, its aerodynamic characteristics start to change because air can no longer pass freely under it as it descends. There is usually more lift, depending on the exact aerodynamic characteristics of the aircraft and the engine settings during landing. To obtain realistic results, the wind tunnel must simulate the runway; this is achieved by installing a rapidly moving belt at the bottom of the LLF. It moves at the same speed as the air stream that flows over the model, which in reality does not move at all. In the LLF this can be done at speeds of up to 80 metres per second.

THE PRICE OF EXCLUSIVE SERVICES

Universities and small research institutes are unable to afford studies in the LLF at rates that start at 250,000 euro per week. They have to seek European funding to be able to use wind tunnels.

In addition, large wind tunnels are operated in particular cycles. Only a limited number of projects fall within the scope of aeronautical research programmes. When the stage at which a wind tunnel is needed for such a programme begins, the tunnel needs to be available around the clock and sometimes only for that particular purpose. At times when no tests are scheduled, however, there are still costs for maintaining the technology and infrastructure. It remains a challenge for management to determine who will assume responsibility for the costs.

THE QUEST FOR A QUIETER AND SMOOTHER HELICOPTER RIDE

As part of the joint research project ‘Advanced Swashplate Concepts’, the DLR Institute of Flight Systems is testing the multiple swashplate system (META) in the LLF to help advance active rotor control. Under certain operating conditions, the rotors are the main source of noise caused by the helicopter. The collision between a tip vortex shed by one blade and a following blade can generate a lot of noise – especially during approach. The purpose of the wind tunnel experiment is to find out whether the vibratory parts of the blade loads and the resulting noise can be reduced by advanced active blade pitch control. In current conventional helicopters – featuring one main rotor and one tail rotor – the rotor is generally controlled by means of a single swashplate. For rotors with four or more blades, individual blade control is not possible with just one swashplate. In the DLR test, the rotor blades are connected alternately to the two META swashplates configured concentrically around one another. This technique allows individual blade control without the need for active components in the rotating system. In addition to various other sensors (microphones, strain gauges, accelerometers, etc.), four high-speed cameras are used during testing to record the elastic deformations of the blades. This way, conclusions can be drawn about the loads working on each of the blades in every kind of situation. With META, the researchers hope to achieve a significant reduction of the noise and vibrations occurring in helicopters. The manager of the FTK-META-WK project is Rainer Bartels from DLR Braunschweig.



Space for space – the Ries Crater Museum in Nördlingen makes apparent to visitors the cosmic relationships that caused Earth to repeatedly experience asteroid impacts with disastrous consequences. Created 15 million years ago, the Nördlinger Ries is one of the best-preserved remnants of a large impact event on Earth.

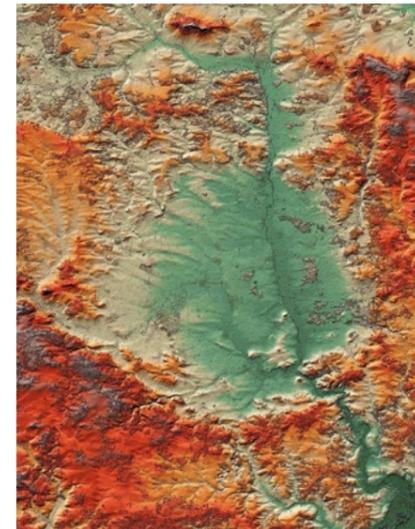
Image: RiesCraterMuseum

Amazing, worth knowing or just beautiful? In the best case, all three are true. The 'At the Museum' section of the DLR Magazine is dedicated to a small, but excellent, museum in the Swabian town of Nördlingen. Fifteen million years ago a meteorite struck exactly here, and now the museum informs visitors about the surrounding nature and presents an impressive display of the remaining relics. The exhibition is complemented by a series of DLR satellite images of impact sites.

CSI – COSMIC SCENE INVESTIGATION

At the Ries Crater Museum in Nördlingen

By Ulrich Köhler



Unmissable from space; for an 'Earthling', not so easy to recognise – a depression surrounded by a 150-metre-high crater rim, created by the Ries impact event. This TanDEM-X image is part of the DLR 'Impact Traces' exhibition.

Nature is full of things that surpass our imagination – they are too big, too small, too far away, too fast, or just plain invisible. The duty of science is to provide knowledge – but this also includes making its findings tangible. We have a theoretical understanding of the devastating forces at play when an asteroid collides with Earth. But how can we visualise a boulder measuring kilometres and weighing three billion tons, burrowing into the ground at a speed of a hundred thousand kilometres per hour? A small but wonderful museum does just that: the Ries Crater Museum in Nördlingen in Swabia in Germany – right on the border between Württemberg and Bavaria, in the Nördlinger Ries crater, which is the relic of just such a cosmic catastrophe.

With a diameter of 25 kilometres and surrounded by a 150-metre tall rim, the Ries is a prominent, circular depression in the Franconian-Swabian Jura, a chain of slightly tilted table mountains of outstanding beauty. Geologists have long recognised it as a crater – but surely, from a volcano. In 1904, on the pages of the Schwäbischer Albverein, nature lover Ernst Werner wrote that: "In its 'strangeness' it resembled more the 'curious circular mountains on the Moon, invoking the thought that these, as well as the Ries basin, owe their genesis to the same cause'."

When in the 1960s it became widely accepted that lunar craters were not formed by volcanoes, but by the impact with cosmic debris, the Ries finally started to tell its story. It was two United States scientists, Edward Chao and Eugene Shoemaker (who, admittedly, had German ancestry) that deciphered the mystery. The square where the beautifully renovated 'Holzhofstadel' building from 1503 forms such a harmonious ensemble with the other historic buildings is, in fact, named after Shoemaker. Chao and Shoemaker found tiny quartz crystals that could only have been created under the most extreme pressure – just like during an asteroid impact.

So what exactly happened here? The animals that inhabited the area 15 million years ago would have surely panicked when a piercing whistling sound filled the air, growing into an infernal roar – before a shockwave swept away everything in its path. The impact itself would have lasted only a few tenths of a second. As the kilometre-wide rock penetrated thousands of metres into the ground, the pressure rose to millions of atmospheres and the temperature reached 30,000 degrees Celsius in a fraction of a second. The asteroid and the surrounding rock vaporised, and the bedrock melted into huge chunks that were catapulted up to 10 kilometres into the air before falling back to Earth over an area extending hundreds of kilometres. The pressure spread deeply through the rock, violently shattering even the toughest granite.

Image: RiesCraterMuseum



The museum is housed in a more than 500-year-old renovated building, which was part of the medieval town of Nördlingen.

Less than an hour later, the crater was born – a cosmic scar that today is one of the most outstanding landscapes found in southern Germany. Nördlingen's famous landmark, the tower of the Church of Saint George (known as the 'Daniel'), which can be seen from miles around, is also a product of this event. It was constructed with the Swabian rock unique to the Ries – suevite. Its melted layers of gneiss actually resemble the Flädle, a specialty of the region made of sliced pancakes. Visitors can experience all that they see and learn in the museum for themselves in nature. In addition, the visitors can go to the National Ries Geopark, where they can see the main geological outcrops.



Groups of visitors can take a guided tour of the museum. The museum is run by scientists.

Image: RieskraterMuseum



"Asteroids with orbits that intersect Earth's come from the sky." Approximately 12,000 such objects are known; fortunately, none are currently on a collision course with Earth.

Image: RieskraterMuseum



The best, or finest, product of the Ries disaster – moldavites – formed from silicate rock that was melted and then resolidified amorphously without crystal structure.

Image: RieskraterMuseum



Exclusive and very old – rocks from the Apollo 16 landing site, shattered by a mega-impact on the Moon 3.8 billion years ago.

Image: RieskraterMuseum

RIES CRATER MUSEUM NÖRDLINGEN

Eugene-Shoemaker-Platz 1
86720 Nördlingen
www.rieskrater-museum.de

The excellent educational museum guide is packed with the latest scientific information and is well worth reading. The DLR exhibition 'Impact Traces – Earth's impact craters in radar images by the TanDEM-X mission' will be on display until the end of the year.

Geopark Ries:
www.geopark-ries.de

Few locations on Earth demonstrate such a huge natural catastrophe as the Ries. The Ries Crater Museum itself is a one-of-a-kind educational niche. Since it opened its doors in May 1990, it has welcomed over one million visitors. Funded by the town of Nördlingen and run by the Staatliche Naturwissenschaftlichen Sammlungen Bayerns (Natural Sciences Collections of Bavaria), it is special because scientists are involved in the management of the museum. The museum regards itself as an educational institution and is very closely involved in the latest impact research being conducted at the Berlin Museum of Natural History, various universities and, of course, DLR.

The museum is also affiliated with the Zentrum für Rieskrater- und Impaktforschung in Nördlingen (Centre for Ries Crater and Impact Research; ZERIN), a small research institute. Leading scientists from around the world continuously gather at the museum and the medieval town, with its fully preserved city wall, which often host conferences. Due to its similarity to the moonscape, the Ries was visited by astronauts from Apollo missions 14 and 17 in 1970, where they carried out field studies and exercises. And so, the collection exhibits a genuine Moon rock – shattered and fragmented by an impact on Earth's companion, and retrieved from the Apollo 16 landing site.

The museum explains the origins of the destructive projectiles found in the Solar System (and why they exist in the first place). The displays vividly illustrate the chain of events that led to the creation of the Ries crater, and explain its 'anatomy'. In addition, the crater's impact on the landscape is shown. For millions of years, the crater contained a lake that formed deposits of sediment responsible for the fertile agricultural

soil in present-day Ries. Comparisons are drawn with other meteor craters on Earth and, of course, with other bodies of the Solar System in which they exist in far greater numbers because they are not worn away as quickly by erosion. The cosmic context is omnipresent and palpable.

Six rooms covering a total of 900 square metres of exhibition space await the visitors. The displays perfectly balance scientifically compelling content and the need for information that is as clear as possible. They convey the essentials – in words and images – to anyone completely unfamiliar with the subject matter, as well as a more in-depth explanation for a better understanding.

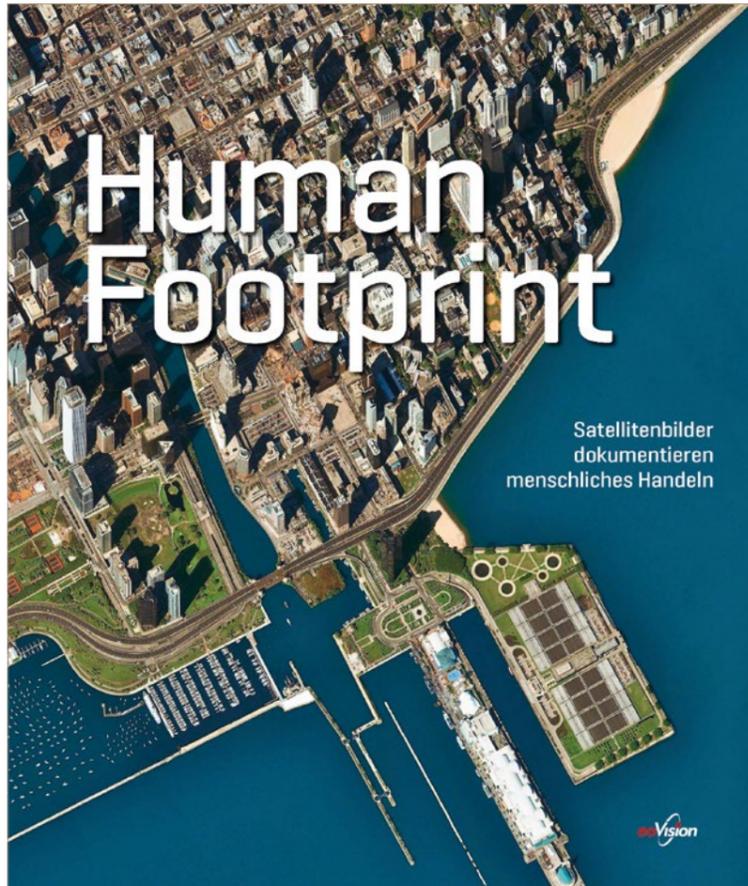
Also impressive is the extensive meteorite collection, which illustrates the great diversity of these rocks that – rarely but surely – fall to Earth from our cosmic neighbourhood. Stony meteorites, stony-iron meteorites, iron meteorites – they are key to our understanding of the chaotic emergence of the Solar System. Visitors to the museum are doubtless relieved to learn that events as devastating as the Ries impact are rare in Earth's history, occurring only once every few million years.

The most beautiful exhibit from an aesthetic point of view was also created by this catastrophe: moldavite, an emerald green gemstone with a gorgeous play of colours. It was catapulted from the crater in the form of fused silicate rock at 25 times the speed of sound. It quickly cooled during flight, and so no crystals formed before it fell back to the ground in the region of Moldova. It is rumoured that there are also some Ries diamonds ...



One of the strengths of the museum is how vividly it shows young and old the elusive relationship between the cosmic dimensions of distance, speed, energy, mass, pressure and temperature, and their effect on Earth.

Image: RieskraterMuseum



WHEN PICTURES SAY MORE THAN WORDS

Spider webs, sweet pastries and fried eggs – a bizarre assortment of images! There is plenty more that astounds within **Human Footprint** – an impressively large book of 127 two-page spreads of satellite images published by Austrian publisher eoVision Media. The images, acquired from a distance of between 460 and 680 kilometres from Earth, are based on data from IKONOS, WorldView-2, QuickBird, and GeoEye1 satellites.

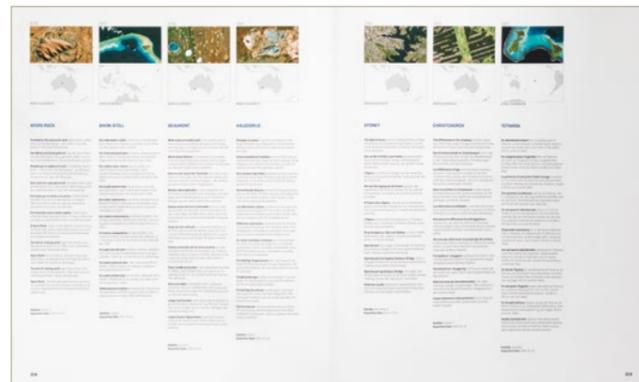
This book is in a league of its own. Beyond its expensive look and feel, the quality and consistency of the images and text never cease to impress. For the most part, the book lets the stunning images speak for themselves; the pages are devoted entirely to the expansive and richly detailed photos of cities, harbours, rivers, coasts, forests, fields, deserts, and ice. But clearly and conveniently laid out explanations can be found at the end of the book.

From continent to continent, the images depict astounding scenes: bizarre ice fragments, their angular features seeming to leap out of the pages; cities with baffling labyrinthine layouts and fields so geometric they seem to have been drawn by hand. Elaborately looped channels trace circular patterns around irrigation systems, while stunning images of islands and coasts are wondrously captivating.

Yet the marvellous abruptly gives way to intense discomfort. Vast copper and diamond mines and uranium mining areas have the appearance of open wounds; fields encroach on rain forests; and mangrove swamps are displaced by shrimp farms. These are the images of Earth that the human hand has knowingly altered. Seldom do images of real landscapes so vividly illustrate the damage that human activity has done to nature. The term 'human footprint' seems almost blasphemous.

In this book, commentary is superfluous. There is no need for words to drive home humankind's responsibility for planet Earth, an obligation that resonates throughout the images. It is the last 22 pages of the book that explain, with extreme brevity and in decidedly matter-of-fact terms, what each image shows – in no less than 10 languages. The text for each image is supplemented by a small map in subtle grey, indicating the region from where the image originates. In the main body of the volume, however, one finds only images – and the message is all the more potent for that.

Cordula Tegen



REACH FOR THE STARS

Science educators, proactive parents, amateur space enthusiasts (of all ages) rejoice! There is a guilt-free addition to your child/student's iPad that even you will want to make some time for. **Reach for the Stars: Touch, Look, Listen, Learn**, a free e-book download for iPad, is a wonderful introduction to the science and wonder of stars, designed with students of different learning abilities in mind. Alongside engaging and accessible text, this easy-to-navigate e-book includes different multimedia features that enhance the learning experience for all.



As an e-book, audio narration is standard. What really brings the information to life are the stunning photos from the Hubble Space Telescope that are also supported by audio-enabled captions and tap-to-reveal features, which makes exploring images of nebulae, for example, both informative and fun. Fun Fact Q&As help readers track what they have learned along the way. But perhaps the greatest feature is the use of sonification – non-verbal sound to communicate information – that both visually- and non-visually impaired students will love. Adding sound to image, speech and text creates a truly immersive experience; for example, in the graphic describing the life cycle of different types of stars, the sound intensifies with the size/longer lifespan of the star, adding another dimension to drive the information home.

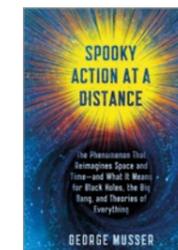
Reach for the Stars also includes video interviews with astronomers, who explain their work as well as offer advice on pursuing a career in astronomy. Brief, concise, and engaging, the videos are also closed captioned and work well to humanise astronomy, a field most kids may think is too complex to pursue.

The introductory scope and depth of scientific information includes the basic science of stars, the tools astronomers use to explore them, a more in-depth look at the star-packed Tarantula nebula, and advice on careers in astronomy, making this e-book a good start for students with a growing interest in the cosmos. Developed by a team featuring a renowned astronomer (Sabbi), a science educator (Lopez), and a visually impaired computer scientist (Summers), Reach for the Stars helps cast the net of science outreach wider, to include a generation of students with different learning abilities.

Laylan Saadaldin

SPOOKY ACTION AT A DISTANCE

In physics, locality is the idea that things are only influenced by forces that are local or close by. In **Spooky action at a distance**, George Musser sets out to explore the opposite: nonlocality, or the idea that two particles are in contact with one another, even when separated by large distances. Although experimental evidence has, for a long time, suggested that this could be true, accepting nonlocality was thought of as explaining physics with magic. Hence Albert Einstein's name for it: 'spooky action at a distance.'



This book introduces the reader to the possible role that nonlocality plays in black holes and cosmic background radiation, among other things. Musser tells us about scientists' struggle with nonlocality and how it is continuously challenging their understanding of how the Universe works.

Spooky Action at a Distance is a must-read. This rather complex book will take you on a journey through space and time and will definitely raise a few questions.

Karin Ranero Celius

RECOMMENDED LINKS

HIGGS HUNTERS

www.higgshunters.org

Developed by Zooniverse, a collection of online citizen projects on different scientific topics, Higgs Hunters allows volunteers to mine through tons of Large Hadron Collider (LHC) data to unravel the biggest mystery of particle physics: the Higgs boson. The site shows volunteers how to spot an OCV (which the LHC computers are not designed to look for) and then provides them with real and simulated data to hunt for them. Besides helping to analyse large volumes of available data, participants will also help teach computers how to spot exotic particle events.

SPACE AND MAJOR DISASTERS

www.disasterscharter.org

Initiated by the European and French space agencies, and joined by other (space and ground) agencies as charter members, the International Charter Space and Major Disasters provides rapid satellite data during natural and manmade disasters to assist rescue authorities. The Charter makes this possible via a collaboration between owners and operators of Earth observation missions.

LIGO LABS DETECTS GRAVITATIONAL WAVES

bit.ly/1PoSEzw

2015 marks a milestone in human history: the detection of gravitational waves or ripples in the fabric of spacetime predicted by Albert Einstein in his general theory of relativity. Thought to be nearly impossible to detect because the size of the event is so small, the Laser Interferometer Gravitational Waves Observatory (LIGO) is the product of exploiting the relatively simple idea behind gravitational waves.

THE CYCLONE CENTER

www.cyclonecenter.org

The Cyclone Center allows volunteers to interpret satellite images of tropical cyclones to extract critical data on storm intensity. Users are presented with a satellite image and asked a series of questions following the Dvorak method for detecting wind strength. This new information is gathered in a database that will help climatologists better estimate future storm intensity.

FOLLOW SOFIA

www.sofia.usra.edu

The NASA/DLR Stratospheric Observatory for Infrared Astronomy (SOFIA) aims to study various astronomical objects and phenomena while developing new scientific instrumentation for infrared astronomy. SOFIA is the largest airborne infrared observatory, with a reflecting telescope mounted on a Boeing 747SP aircraft.

About DLR

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

DLR has approximately 8000 employees at 16 locations in Germany: Cologne (Headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Göttingen, Hamburg, Jülich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Stade, Stuttgart, Trauen and Weilheim. DLR also has offices in Brussels, Paris, Tokyo and Washington DC.

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Cover image

The 30-metre antenna at DLR Weilheim. Researchers at the DLR Institute of Communications and Navigation have received and analysed navigation signals using the antenna.



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