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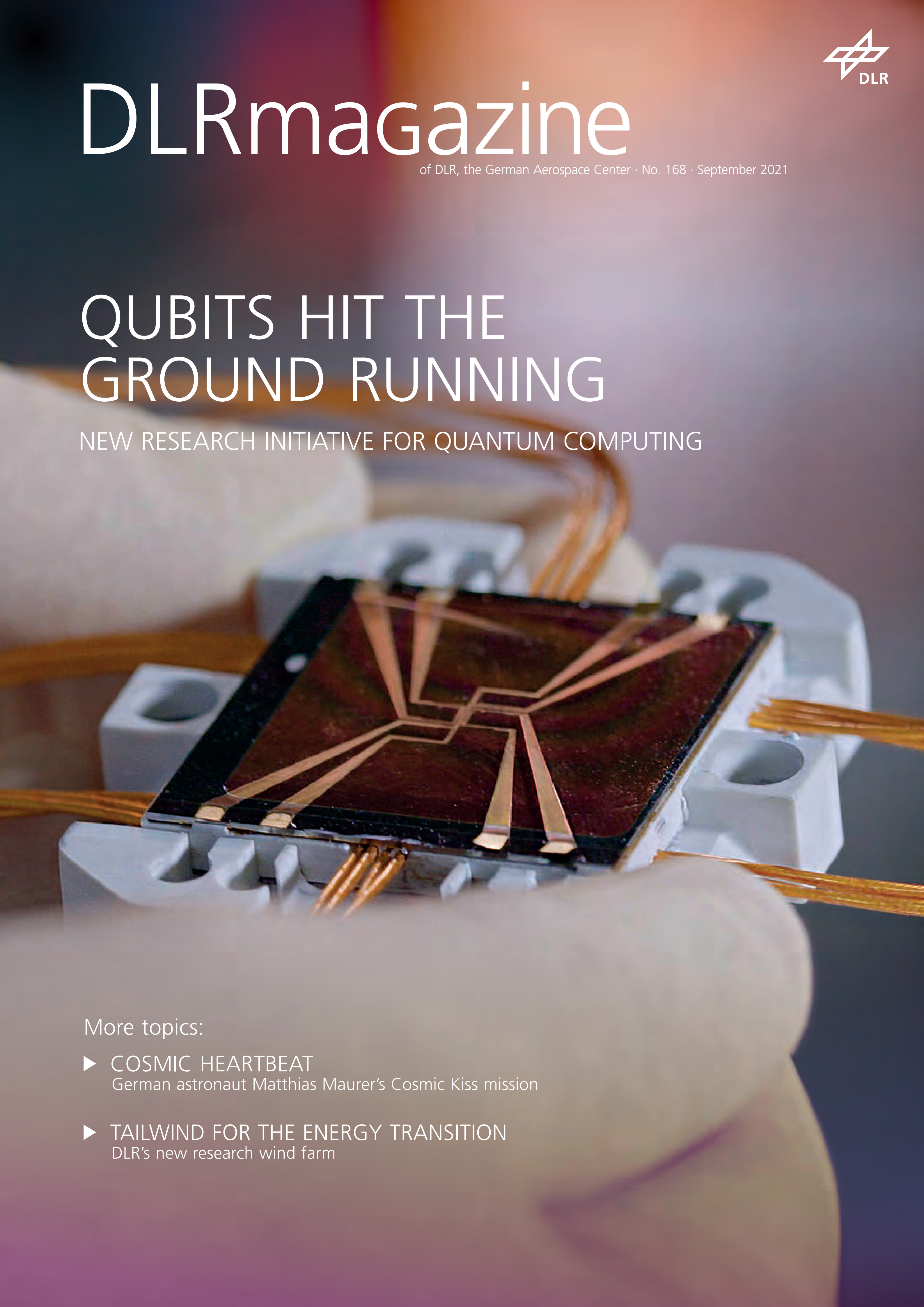

QUBITS HIT THE GROUND RUNNING

NEW RESEARCH INITIATIVE FOR QUANTUM COMPUTING

More topics:

- **COSMIC HEARTBEAT**
  German astronaut Matthias Maurer's Cosmic Kiss mission
- **TAILWIND FOR THE ENERGY TRANSITION**
  DLR's new research wind farm

About DLR

DLR is the Federal Republic of Germany's research centre for aeronautics and space. We conduct research and development activities in the fields of aeronautics, space, energy, transport, security and digitalisation. The German Space Agency at DLR plans and implements the national space programme on behalf of the federal government. Two DLR project management agencies oversee funding programmes and support knowledge transfer.

Climate, mobility and technology are changing globally. DLR uses the expertise of its 55 research institutes and facilities to develop solutions to these challenges. Our 10,000 employees share a mission – to explore Earth and space and develop technologies for a sustainable future. In doing so, DLR contributes to strengthening Germany's position as a prime location for research and industry.

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Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

EDITORIAL

Dear reader,

Quantum computers are set to bring about groundbreaking change in an array of fields from secure encryption techniques and artificial intelligence to materials research related to medicine, energy and transport and satellite-supported communications and navigation. Based on quantum technologies, they differ greatly from today's computers, enabling completely new, previously unimaginable information processing in research, science and industry. To ensure that quantum computers can really take off in Germany, DLR is embarking on a research initiative through which two consortia will be set up over the next four years together with partners from industry, small and medium-sized enterprises, start-ups and research institutions.

ESA astronaut Matthias Maurer will also be taking off in November, en route to the International Space Station. As part of his Cosmic Kiss mission, he will spend six months there conducting a wide range of scientific experiments. But the crew on board the SpaceX Dragon capsule are not the only ones who will be heading into space. In October, NASA's Lucy spacecraft will begin its 12-year journey to the Trojan asteroids of Jupiter. Researchers hope to find clues there as to how the outer planets of the Solar System could have been formed. It will be an eventful autumn.

A lot is also happening on the ground at DLR: a new research farm for testing wind turbines is being built in Krummendeich on the Elbe, the DLR Institute of Solar Research is celebrating its tenth anniversary and the new ISTAR research aircraft has passed its first tests. Read all about these topics and much more in this issue.

We hope you enjoy it!

Your DLRmagazine editorial team

A SPECIAL UNIFORM

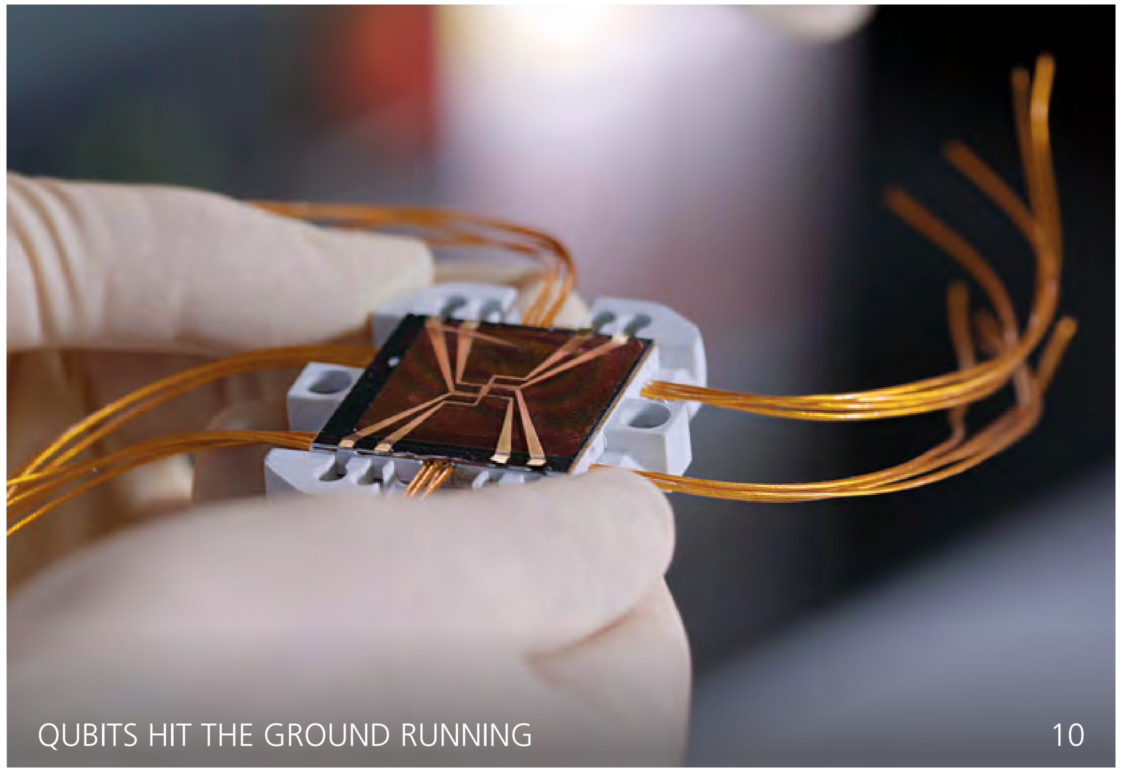
A stripe as blue as the sky, marked by an orange outline on a white fuselage – that is the livery of DLR's aeroplanes and helicopters. These colours indicate that the members of Europe's largest civilian fleet of research aircraft are not in normal scheduled service: Their orange ailerons, elevator and rudder are evocative of the very first flight tests. This is because in order to better observe the aircraft from the ground or to maintain a good view of the adjustable control surfaces from inside the aircraft, test and research aircraft were – indeed, often are – painted partially or completely in an eye-catching colour.

Some members of the DLR research fleet

On some DLR research aircraft, the colours on the outside also give a clue as to what is going on inside. One example is the newest member of the fleet, a Dornier 228, which is being converted into a modular hybrid-electric experiment carrier, the 'Electric Flight Demonstrator'. The distinctive blue stripes open up towards the tail, slowly changing to green and marked with streamlines in homage to the origins of research at DLR and its preceding organisations. In addition to the history of aeronautics, the airy uniform of the Do 228 also points to the future and towards greener air transport.

DLR's new Do 228, the Electric Flight Demonstrator.

DLRmagazine **168**



QUBITS HIT THE GROUND RUNNING 10

COSMIC HEARTBEAT 18

A JOURNEY INTO THE REALM OF THE TROJANS 22

RETHINKING TRANSPORT 34

TAILWIND FOR THE ENERGY TRANSITION 38

VIEW FROM ABOVE 48

TEAMING UP FOR SPACE 46

COUNTING AND COUNTED UPON 56

IN BRIEF 6

▶ **QUBITS HIT THE GROUND RUNNING** 10
Quantum computing 'made in Germany"

TAKING A NEW LOOK AT SPACE 14
A radar system keeps an eye on objects orbiting Earth

▶ **COSMIC HEARTBEAT** 18
Matthias Maurer will travel to the ISS

A JOURNEY INTO THE REALM OF THE TROJANS 22
NASA'S asteroid mission Lucy

STRATEGIES FOR REDUCING SOUND LEVELS 26
A future with less aircraft noise?

SHAKE, VIBRATE AND FLY! 30
ISTAR undergoes ground vibration tests

HOW IS COVID-19 CHANGING THE WAY WE GET AROUND? 32
DLR studies the impact of the pandemic on mobility

RETHINKING TRANSPORT 34
Better communication between modes of transport

▶ **TAILWIND FOR THE ENERGY TRANSITION** 38
Harnessing the full potential of wind energy

ON THE SUNNY SIDE 42
The DLR Institute of Solar Research turns ten

BREAKING NEW GROUND ON THREE FRONTS 44
Ideas for technological progress

TEAMING UP FOR SPACE 46
IRAS – a development platform for low-cost satellites

VIEW FROM ABOVE 48
Condition monitoring of solar power plants with DLR technology

THE IDEA HUNTERS 50
How DLR is bringing new ideas into the economy

YOUR QUESTIONS ANSWERED 51
Our researchers answer questions from the community

HAND IN HAND 52
DLR's Project Management Agency for Aeronautics Research and Technology is shaping the aviation of tomorrow

COUNTING AND COUNTED UPON 56
Female 'computers' kept research alive

IN THE PILOT'S SEAT 58
The National Museum of the United States Air Force

REVIEWS 60

AIR TRANSPORT – THE LIMITS OF THE COMPENSATION OBLIGATION

Since 2021, airlines have had to offset a portion of the emissions caused by their international flights. This is done with the help of carbon dioxide compensation projects – a quick and attractive solution for the aviation industry from an economic point of view. The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) programme obligates airlines to offset carbon dioxide emissions with compensation credits. Approved offset projects must be certified by established companies and non-profit organisations. In a study, a DLR team analysed the offers eligible under CORSIA and revealed that the majority of offsets are generated in projects that often do not meet these criteria. However, the climate impact of the credits depends strongly on the underlying project type. As a result, CORSIA's promise of climate neutrality is difficult to fulfil.

Image: DLR/Alejandro Morellon

Carbon dioxide offsets are an intermediate step on the way to more climate-friendly air transport

From 2050, ships should emit 70 percent less carbon dioxide than in 2008.

LESS SOOT AND CARBON DIOXIDE ON THE WATER

Global shipping is a major contributor to greenhouse gas emissions. For this reason, from 2050, the limit for carbon dioxide emissions resulting from shipping will be reduced by 70 percent compared to its 2008 level. DLR is working with its partners from industry and research on a climate-friendly energy supply for ships. The basis is a fuel cell system that will produce electricity and heat on board. The special feature of the cells is that they work with alternative fuels. A demonstrator suitable for use on ships is currently being developed under the leadership of the DLR Institute of Engineering Thermodynamics. The European Union is providing a total of 7.9 million euro of funding over four years to the Nautical Integrated Hybrid Energy System for Long-Range Cruise Ships (NAUTILUS) research project, which began in 2020. In addition to DLR, 15 leading shipping companies, ship owners, shipyards, shipping authorities and research institutions are involved in the project.

GREENHOUSE GASES CAUSE THE STRATOSPHERE TO CONTRACT

It is well known that greenhouse gases warm the lower atmosphere and thus drive climate change. The DLR Institute of Atmospheric Physics in Oberpfaffenhofen was involved in a study carried out by eight research centres in five countries that has now demonstrated that greenhouse gas emissions are also causing the stratosphere to contract. The stratosphere extends between altitudes of approximately 12 to 50 kilometres. The troposphere below is expanding due to climate change, while the stratosphere is in a sense 'sandwiched' between the layers above and below it as a result and is therefore shrinking. This contraction could lead to a disruption of GPS systems or have an impact on the trajectories of satellites. According to the authors of the study, the stratosphere is 400 metres thinner than it was the 1980s. By 2080, the stratosphere could contract by another 1.3 kilometres.

Measurement flight of a stratospheric balloon at an altitude of 36 kilometres. The balloon collected data to improve our understanding of the atmosphere's bromine flux and the resulting ozone depletion.

NEW DLR INSTITUTES BEGIN THEIR RESEARCH

In May, DLR inaugurated four new institutes with different research focuses. In Geesthacht in Schleswig-Holstein, researchers at the Institute of Maritime Energy Systems will look for solutions to reduce the emissions caused by shipping. Meanwhile, the new Institute for Solar-Terrestrial Physics in Neustrelitz in Mecklenburg will host researchers analysing interactions between solar activity and Earth's atmosphere and contribute to the establishment of a national space weather service. In Cottbus and Zittau, researchers at the Institute for Low-Carbon Industrial Processes are dedicated to the decarbonisation of industrial processes. They are developing alternatives to fossil fuels to make production in key industries more environment-friendly. In the far south of Germany, the DLR Executive Board inaugurated the Institute of Quantum Technologies in Ulm. Quantum technologies are seen as promising solutions for enabling long-term secure communication and very precise satellite navigation in future, among other things. Due to the COVID-19 pandemic, all openings took place virtually.

REGIONAL NEWS

BERLIN: No fewer than three missions are expected to fly to Venus within the next 10 years. The US space agency NASA is sending the VERITAS Venus orbiter and the DAVINCI+ spacecraft to our planetary neighbour, and in 2031 or 2032 the European Space Agency's EnVision mission will be launched. DLR is contributing a spectrometer to both EnVision and VERITAS, which will map the rocks and their mineralogy on Earth's sister planet. The goal of the missions is to gain a comprehensive understanding of Venus.

DRESDEN: The exhibition 'To the Stars – The Adventure of Space Travel' (Zu den Sternen – Abenteuer Raumfahrt) has been open at the Dresden Transport Museum since the end of May 2021. It includes 10 exhibits from the German Space Agency at DLR as well as part of the INNOspaceEXPO 'ALLtäglich!' and presents the cultural history of spaceflight, from the beginnings of astronomy to the conquest of space and on to the future of spaceflight and research. The exhibition will be open until 7 November 2021.

GÖTTINGEN: The DLR Institute of Aeroelasticity is working with the French national aerospace research centre ONERA (Office National d'Etudes et de Recherches Aérospatiales) on new concepts for wing structures for energy-efficient aircraft. In the Flexible wIng GUst REsponse (FIGURE) project, two models of a highly elastic wing that enable elongated wing shapes were tested. This is intended to reduce fuel consumption. One wing was developed at DLR and one by ONERA. Both models were built in Göttingen and tested in a wind tunnel in Paris at near-sonic flow velocity.

HAMBURG: The ITS World Congress, an international industry event in the field of intelligent transport systems and services (ITS), will take place from 11 to 15 October 2021 under the motto 'Experience Future Mobility Now'. The transport, logistics and IT sectors as well as political and union representatives will be present. DLR's stand is number B5220 and is located in Hall B5.

HANOVER: At the end of May, DLR and the Ecologic Institute presented Lower Saxony's Minister for the Environment, Energy, Construction and Climate Protection with the report 'New Paths – Paths to Sustainable Mobility in Lower Saxony' (NeueWege – Wege zur nachhaltigen Mobilität in Niedersachsen). In it, DLR transport researchers present a comprehensive picture of Lower Saxony's transport situation as well as opportunities and obstacles to achieving its decarbonisation. The guiding questions of the report are: Where does Lower Saxony stand regarding the energy and mobility transition? How far has the state come in making mobility climate neutral? What can be done to achieve the state's climate policy goals?

DLR.DE/EN:
VISIT THE DLR PORTAL FOR THE LATEST NEWS
All articles can be viewed online in the news archive with images or videos.

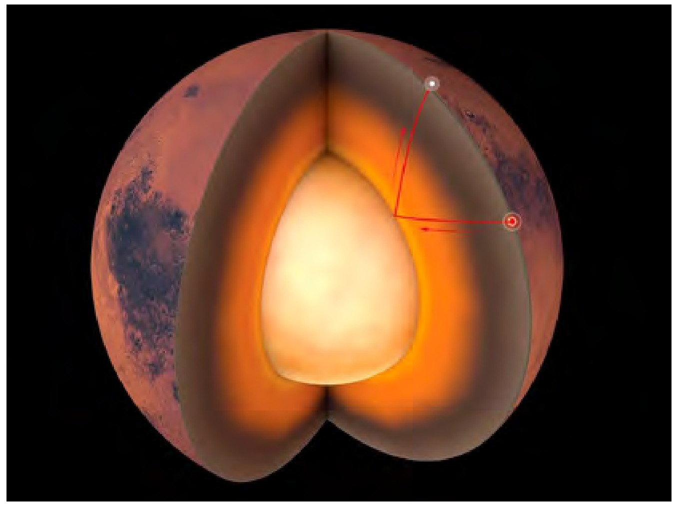
DLR.de/News

NEW MISSION CONTROL SYSTEM FOR EUROPEAN SPACEFLIGHT

On 22 July 2021, DLR Space Operations succeeded in commanding a satellite using the 'European Ground Segment – Common Core' (EGS-CC) software for the first time. EGS-CC is the future mission control system for European spaceflight. DLR is active in a European network that is building a common software infrastructure with EGS-CC. Until now, several different systems have been used for space missions, such as for the construction, integration into a network, testing and operation of a satellite. The European spaceflight community wants to change that. The DLR team from Oberpfaffenhofen, near Munich, has used EGS-CC to build a system to monitor and control spacecraft. For the first time, developers, manufacturers, operators and space agencies will share a common software language. Systems based on EGS-CC will enable the use of new technologies as well as closer coordination between users. DLR Space Operations intends to deploy the new command system to operate further satellites and the Columbus Control Centre is also expected to benefit from the new system.

Image: DLR

DLR Executive Board Chair Anke Kaysser-Pyzalla in the control room during the commanding test



Credit: Chris Bickle/SCIENCE

Marsquake waves reveal the planet's inner structure

SURPRISING INSIGHTS INTO MARS

While the surface of Mars is known in great detail through exploration using orbiting spacecraft, until now its interior structure could only be derived indirectly or simulated using computational models. As part of NASA's InSight mission, DLR has helped provide new insights into Mars using a seismometer developed under French leadership. The surprising discoveries show that the Martian core is larger (diameter of approx. 300 kilometres) and its crust thinner (19-90 kilometres) than previously thought. These findings now finally offer an anchor point for a global map of the Red Planet. The measurements also show that the Martian core must be molten – at least in its outer zone – and that extremely high pressure is only reached in Mars' iron core. The entire mantle of our planetary neighbour should therefore be dominated by the mineral olivine, similar to Earth's upper mantle. The results were obtained by analysing various seismic waves generated during Marsquakes and were published on 22 July 2021 in the journal Science.

WORLD CLIMATE REPORT

On 9 August 2021, the Intergovernmental Panel on Climate Change (IPCC) published a new report – 'AR6 Climate Change 2021: The Physical Science Basis'. DLR scientist Veronika Eyring was the coordinating lead author of the chapter entitled 'Human influence on the climate system'. The findings in the report are not surprising, but they are serious. Human activities are largely responsible for global warming and climate change. The report emphasises that newly acquired data and improved model simulations provide even more evidence for this than before. The challenge now is to reduce greenhouse gas emissions immediately, rapidly and drastically. Otherwise, the goal of limiting warming to 1.5 degrees Celsius compared to pre-industrial levels will be out of reach. All five scenarios in the report predict a 50 percent probability that global warming will reach this level in the next 20 years.

Credit: German Climate Consortium

Results of the IPCC report – humans have warmed the climate

CHANGE OF COURSE FOR SOFIA

Usually, the Stratospheric Observatory for Infrared Astronomy (SOFIA) explores the night sky of the southern hemisphere from New Zealand but due to pandemic-related travel restrictions, deployment from Christchurch was no longer possible. Instead, the DLR/NASA airborne observatory decided to conduct 20 research flights for about eight weeks from Tahiti International Airport in French Polynesia. On the trail of the causes of climate change and seeking answers to questions about star formation processes, SOFIA will observe astronomical sources that are not visible from the northern hemisphere. To do so, astronomers will use the German Receiver for Astronomy at Terahertz Frequencies (GREAT) for high-resolution spectroscopy and the US High-resolution Airborne Wideband Camera (HAWC+) to measure magnetic fields. One of the projects with the GREAT instrument includes new measurements of atomic oxygen in the Earth's upper atmosphere to help us better understand climate change. You can track SOFIA's flight campaign on Flightradar24 under N747NA.

Image: NASA/J.Spooner

SOFIA, NASA and DLR's globally unique airborne observatory, landed at Tahiti International Airport on 19 July 2021 at 13:42 local time.

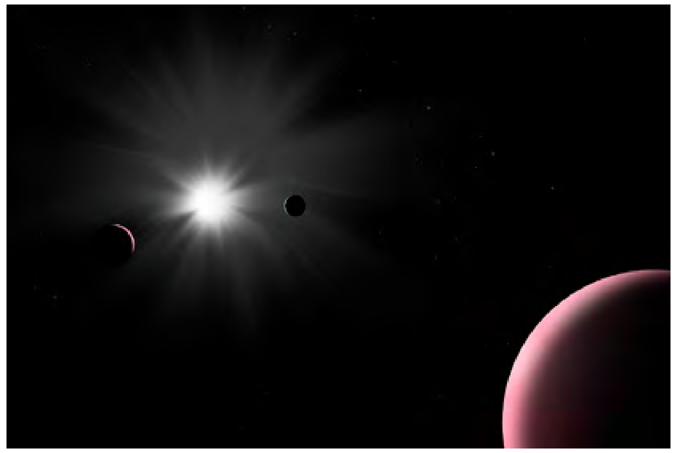
COSMIC RADIATION ON THE ZUGSPITZE

The Environmental Research Station Schneefernerhaus is located on the southern side of the Zugspitze at an altitude of 2650 metres above sea level

Timepix3 was developed to detect elementary particles at the European Organization for Nuclear Research (CERN). It was then carried up to the International Space Station (ISS), where it measures the radiation dose to which astronauts and equipment are exposed. DLR installed the small semiconductor sensor Timepix3 with an electronics box and a screen at an altitude of 2650 metres on the Zugspitze. Its mission was to detect secondary cosmic rays and radon decay products. It is also being used to investigate the relationship between atmospheric gravity waves in the mesopause region and particle flux at Earth's surface. The detector on the Zugspitze also monitors space weather, which can interfere with satellite operations as well as ground infrastructure. Timepix3, which was originally designed to conduct measurements in CERN's accelerator facilities, will remain operational for many years and could even be used for future interplanetary missions. Perhaps Timepix3 will visit Mars someday.

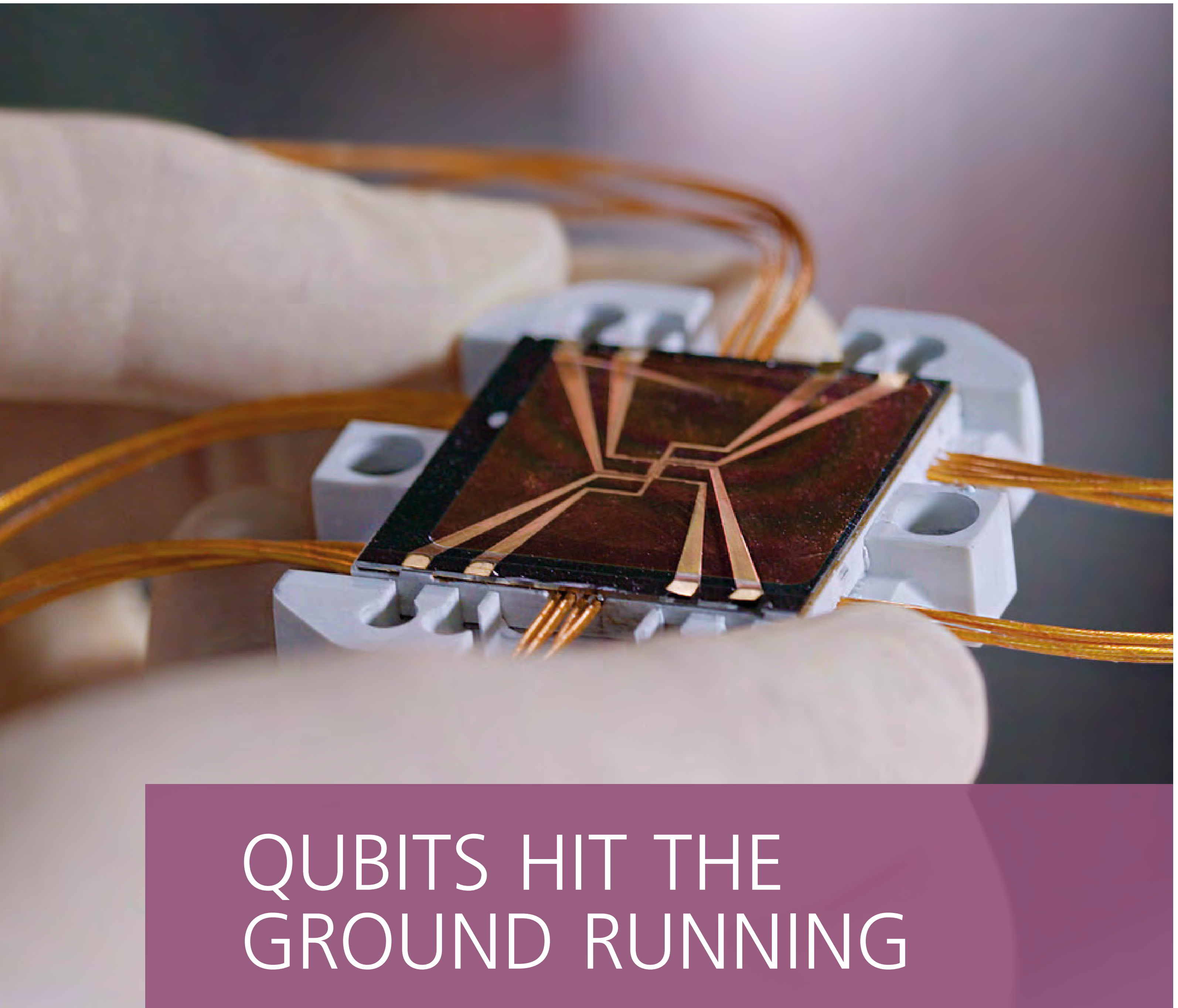
EXOPLANETS GALORE!

With the high-precision measurements performed by ESA's space telescope Characterising ExOPlanet Satellite (CHEOPS), the three planets of the planetary system surrounding the star 'v^2 Lupi' have been described in detail for the first time. The outermost of the three planets, 'v^2 Lupi d', has particularly extraordinary properties; it is what is referred to as a 'super-Earth', with an orbital period of 108 days and a high proportion of volatile substances. It will be the focus of further measurements in future. NASA previously identified the two inner planets, 'v^2 Lupi b' and 'v^2 Lupi c', as transit planets using their Transiting Exoplanet Survey Satellite (TESS). This means that when they are observed from Earth, they pass in front of the star's disc at regular intervals, dimming the star's brightness in the process. Planetary transits create a valuable opportunity to study a planet's atmosphere, orbit, size and interior. Studying exoplanets offers insights into their composition and the underlying rules that govern the formation of planetary systems.



Credit: ESA

This artist's impression shows the 'v^2 Lupi' planetary system recently studied by CHEOPS, ESA's exoplanet space telescope.



QUBITS HIT THE GROUND RUNNING

A new research initiative supports quantum computing ‘made in Germany’

By Tim Suckau

Today’s most cutting-edge high-performance computers still operate based on the ones and zeroes of conventional digital ‘bits’, but this might not be the case for much longer. DLR is leading an initiative to develop a prototype quantum computer in Germany based on quantum bits (qubits) that, in addition to being a revolutionary technological leap, will open up new opportunities for industry, science and society. This is the goal of a recent decision by the German Federal Government, which approved a total of two billion euros in funding to promote quantum technology in Germany. DLR will receive 740 million euros of this for the purpose of establishing the necessary scientific and industrial framework, together with partners from industry, start-ups and research groups, as part of the DLR Quantum Computing Initiative.

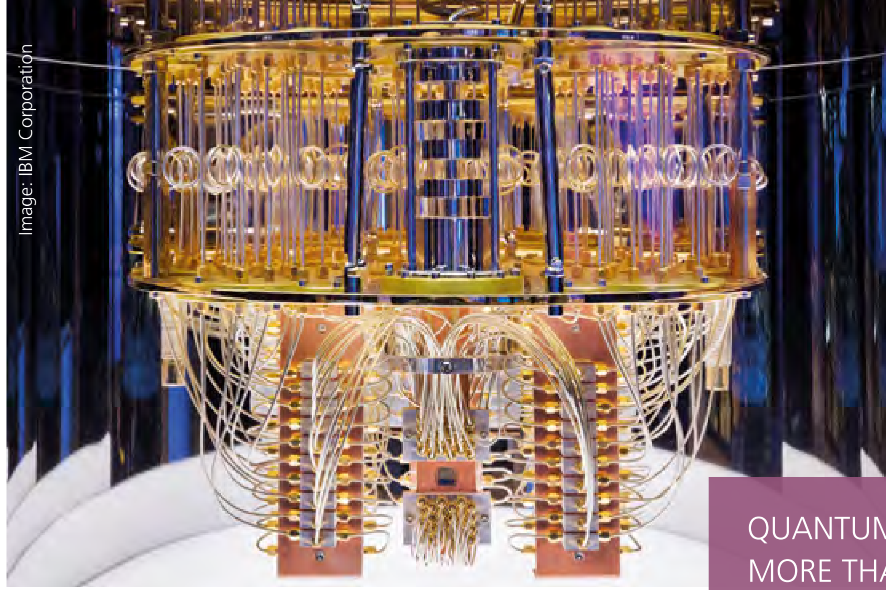


Image: IBM Corporation

The 27 qubits of the IBM Q System One are the heart of the quantum computer at the Fraunhofer Competence Center ‘Quantum Computing Baden-Württemberg’ in Ehningen near Stuttgart. DLR uses the quantum computer to simulate atomic processes in batteries in order to increase their performance and energy density.

Quantum computing dates back to the 1980s. In 1982, the US-American physicist Richard P. Feynman proposed a theoretical concept for quantum computers, with the aim of making it possible to accurately simulate and study quantum physical phenomena. The first quantum algorithms were developed in the 1980s and the first laboratory quantum computers with a few qubits were built in the 1990s. Today, the international race for the development and construction of quantum computers is well under way. Major US corporations have already demonstrated experimental quantum computers, which are being used by research institutions such as the Fraunhofer Society and DLR.

QUANTUM COMPUTERS – MORE THAN 0s AND 1s

A quantum computer works differently from a normal computer. Its quantum bits, or qubits for short, obey the laws of quantum physics. This describes the phenomena taking place on the atomic scale. The bits of a conventional computer can have only two states – 0 and 1. Qubits, by contrast, can take on an infinite number of intermediate values. Quantum physics also enables novel algorithms that are not possible with conventional computers. Quantum computers are thus able to solve problems which traditional computers cannot. Quantum physical objects, such as electrons, atoms, ions or photons, serve as qubits. Quantum computers will enable entirely new, hitherto unimaginable information processing techniques for research, science and industry.

The fast-paced world of qubits

The new quantum computers are expected to deliver unprecedented computing power, opening up new economic and social opportunities and increasing Germany’s international competitiveness. Quantum computers offer advantages for data and information processing, interception-proof cryptography techniques, artificial intelligence, materials research, medicine, the energy and transport sectors, and satellite-based communications and navigation. German businesses and industry therefore have a strong interest in the development of these technologies, solutions and applications in Germany, as this would ensure that the usage and patent rights also remain in the country.

This new technology is simply unbeatable in highly complex calculations. A quantum computer would be able to quickly solve problems that could take conventional high-performance computers years. The ability to precisely simulate highly complex quantum systems with a large number of interacting atoms, ions and electrons is particularly exciting. Such systems include the active ingredient molecules in medications or the quantum chemical processes occurring in battery electrodes or fuel cells. The aim would be to draw conclusions about macroscopic characteristics from the quantum mechanical processes taking place at the atomic scale. Among other things, it is hoped that this will accelerate the future development of new medications or high-tech materials. Quantum computers thus have enormous potential to facilitate innovations in many fields from fundamental research to industrial applications.

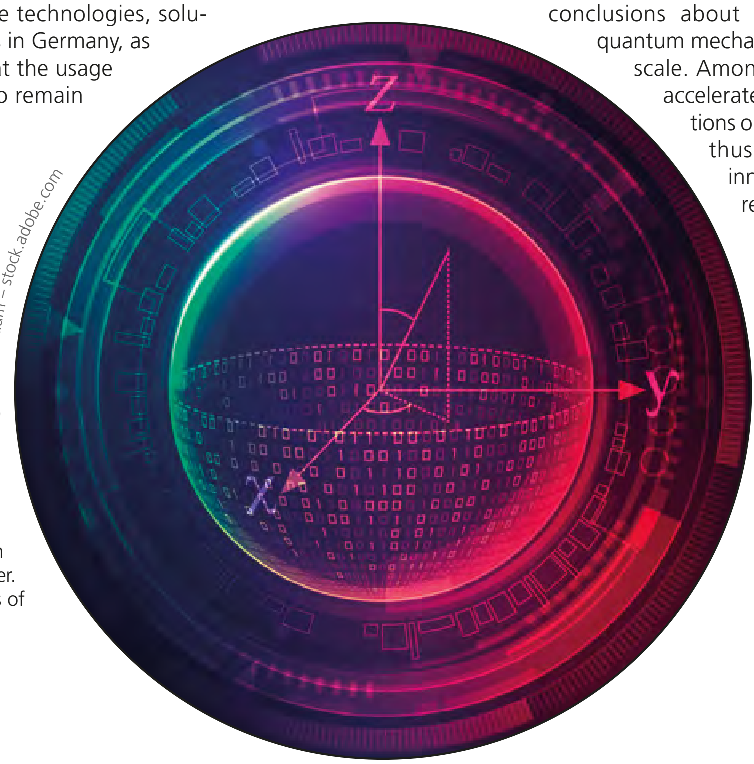


Image: Jackie Niam – stock.adobe.com

Qubits are the smallest computing and information unit of a quantum computer. They are based on the laws of quantum physics.

READY FOR A QUANTUM LEAP

Three questions for Anke Kaysser-Pyzalla, Chair of the DLR Executive Board

What potential does quantum computing offer industry, science and society?

: In modern society, we are exposed to a vast and heterogeneous flood of data. Its effective processing requires enormous computing power. Quantum computing will enable us to better adapt to this situation. This technology has the potential to revolutionise computing by significantly accelerating the solution of complex problems that are often impossible to address using conventional computers.

What is DLR's role?

: DLR will draw on its experience of managing large-scale projects by leading the Quantum Computing Initiative. This involves using the funds made available by the German Federal Ministry for Economic Affairs and Energy (BMWi) to finance projects conducted by industry, start-ups and research groups, and driving forward the ongoing development of quantum computers in a coordinated manner. This will involve the development of quantum hardware, software and, of course, the applications themselves. Only within the framework of such networking and with strategic coordination will we jointly achieve the goal of developing and testing the first German quantum computer prototypes.

What priorities will DLR set in order to establish the necessary economic and research environment?

: We are focusing on pursuing a range of technological approaches in order to be able to evaluate them and use them for the relevant applications. Only in this way is it possible to explore the advantages and disadvantages of different architectures for quantum computers. To this end, we will create the necessary ecosystem to facilitate cooperation between partners. Researchers, industry and start-ups can complement each other's skills by sharing their expertise. As a result, Germany will build up extensive knowledge in the field of quantum computing and achieve the greatest possible level of independence.

… and for Robert Axmann, Head of the Space Research and Technology Programme Strategy Department at DLR

Which quantum computing applications are DLR institutes and facilities researching today?

: In recent years, DLR has significantly expanded its expertise and infrastructure in the area of quantum computing. In addition to several newly founded institutes and facilities, this topic is also the subject of research for many of our well-established institutes (see info box for list of institutes), which are primarily concerned with the use of quantum computers to improve and accelerate modelling, simulation and optimisation. Our Institute for Software Technology, which has been researching algorithms and software for early quantum computers since 2015, is set to play a pioneering role, as is the Institute of Communications and Navigation. However, DLR's resources alone are not sufficient for the comprehensive implementation of quantum computing. This can now be achieved through a collaborative effort as part of the Initiative.

The DLR Quantum Computing Initiative is expected to run for four years. What are the main objectives during this period?

: The Initiative pools our resources and areas of expertise in order to develop various quantum computer prototypes and their components, including applications for scientific, industrial and security-related issues within the designated period. Market analysis by DLR has shown that hardware, software, applications and the necessary supply chains must all be considered.

How can interested companies, start-ups and research partners get involved?

: Based on its market survey, DLR will issue invitations to tender; potential partners can respond to these with their proposed projects. Our first task will be to evaluate the submitted proposals. We will then bring partners from industry and start-ups together with the research institutions in cases where their approaches and areas of focus complement one another. As a rule, the partners will be involved by the commissioning of research and development services, the purchasing of existing research results or joint research at innovation centres in return for a fee.

INSTITUTES AND FACILITIES INVOLVED IN QUANTUM RESEARCH

- DLR Institute of Quantum Technologies
- DLR Institute of Satellite Geodesy and Inertial Sensing
- DLR Institute for Software Technology
- DLR Institute of Engineering Thermodynamics
- DLR Space Operations and Astronaut Training
- DLR Institute of Materials Research
- DLR Institute of Communications and Navigation
- DLR Institute of Data Science
- DLR Institute of Optical Sensor Systems
- Galileo Competence Center
- Institute of AI Safety and Security

Quantum technologies at DLR

In the DLR Quantum Computing Initiative, research institutes, industry and start-ups will work together to develop quantum hardware, software and applications. DLR is contributing its wide-ranging expertise in quantum research, with almost a dozen institutes and facilities conducting research in the field of quantum technologies. The Institute of Quantum Technologies in Ulm and the Institute for Satellite Geodesy and Inertial Sensing in Hanover have recently been established. Among other things, they are working on the use of quantum sensors on board the International Space Station (ISS). At the Galileo Competence Center, research is being carried out on high-precision optical clocks for satellite-based navigation.

Until a German quantum computer is built, the DLR Quantum Computing Initiative will also implement hybrid systems. In this way, conventional high-performance computers can incorporate individual components of quantum computers in order to be able to use the enormous potential of quantum computing for research.

Tim Suckau is an editor in DLR's Communications department.

Quantum metrology enables time measurements of unprecedented accuracy – for much more precise navigation systems, among other things.

Quantum cryptography can be used to encode data in an interception-proof manner. Among other things, DLR is researching optical communication systems for small satellites, as here with PIXL-1.

Quantum technologies in space – but also for use on Earth. In the Bose-Einstein Condensate and Cold Atom Laboratory (BECCAL) project, DLR is working with NASA to investigate ultracold quantum gases such as Bose-Einstein condensates on Earth and in microgravity on the International Space Station (ISS).

More information –
DLR dossier: Quantum Computing

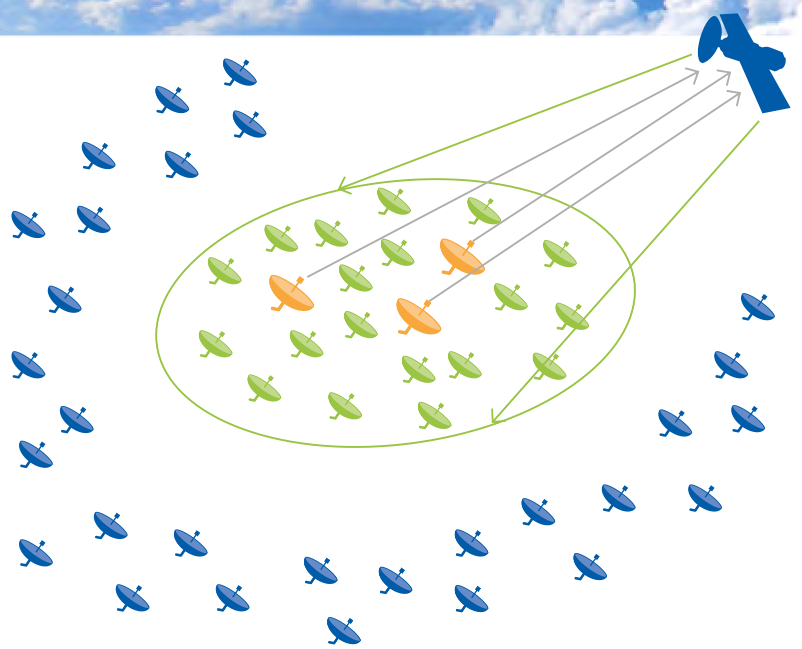
s.dlr.de/ZhEYH

TAKING A NEW LOOK AT SPACE

A radar system keeps an eye on the objects orbiting Earth

By Markus Peichl

For some time, the stars have shared the night sky with an ever-increasing number of artificial satellites orbiting Earth. One prominent addition is SpaceX's Starlink constellation, which attracted attention last year as its satellites gleamed in the darkness overhead like a string of celestial pearls. However, the physical condition of individual satellites often remains unknown; their status data tell us nothing about whether a piece of the solar panel has broken off, or if the satellite bus has been dented by a chunk of space debris – and operating companies often only learn that their satellite is defective when the subsystems fail. To continuously document the condition of space objects and identify failures at an early stage, DLR researchers are developing a new concept comprising multiple transmitter and receiver units, with the aim of creating a system capable of maintaining continuous, high-quality surveillance of these new celestial bodies.



Sender
Monostatic receiver
Bi-/multistatic receiver

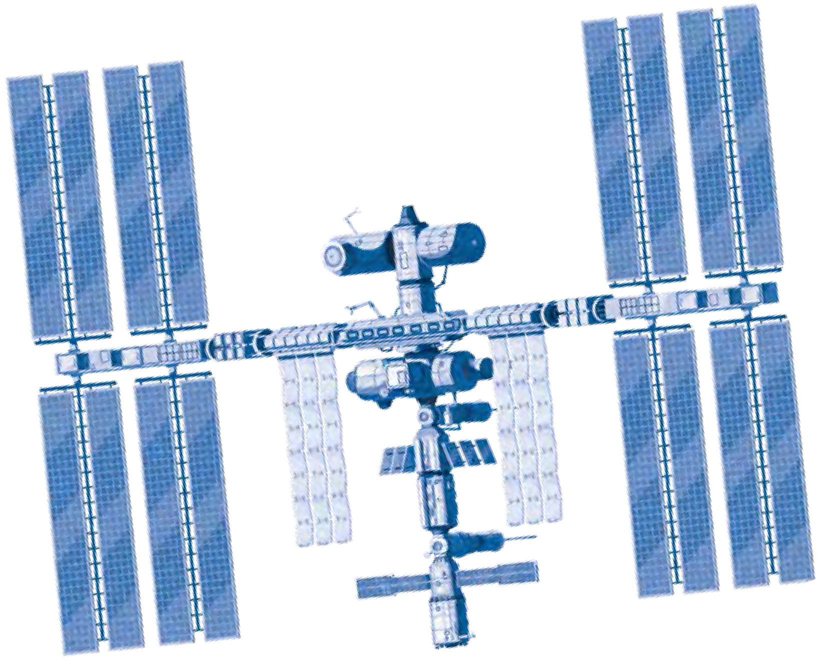
The IoSiS concept consists of a networked radar system with distributed antennas, comprising a few transmitters (in orange) with small antennas of a few metres in diameter and many distributed receivers (green and blue) with very small antennas measuring around one metre across. The green receivers are positioned so close to the transmitting antennas that they can capture monostatic images, while the more distant blue receivers can record multistatic radar images.

The decade prior to 2021 saw a record-breaking number of satellite launches. While the number of satellites in orbit initially climbed slowly following the launch of Sputnik 1 in 1957, almost 700 satellites were launched into space in 2010, and 2020 saw the launch of over 1200. This exponential growth shows no signs of stopping and has been spurred on by the increasing privatisation and commercialisation of space – the 'New Space' era. For decades, spaceflight was largely the preserve of a few state institutions with predominantly scientific and military interests. However, more and more companies and start-ups are now staking their claim to space for the civilian market. The range of applications is broad, covering everything from Earth observation to broadcasting, communications and navigation. Space has been transformed into an economic sector, and now hosts critical infrastructure. This is particularly noticeable in low Earth orbit (LEO), the region of space reaching up to an altitude of 2000 kilometres. Around 7000 artificial objects have been put into LEO so far, most of which are still there. Space transport has brought with it countless pieces of contaminating debris. There are thought to be 100 million pieces of space debris orbiting Earth, measuring between one and ten millimetres in size – an increasingly serious problem.

Monitoring more than debris

Space Situational Awareness (SSA) is all about keeping a watchful eye on both space debris and functioning satellites. SSA is as old as spaceflight itself and instruments for this purpose were developed at the very early stages of our forays into space, as monitoring flight trajectories from the ground during rocket launches or locating objects in orbit was necessary from the very beginning. Today, we monitor the situation in space using optical systems and radar instruments that detect space objects, track their paths, and provide information about their size, design, composition and possible rotation (via radar imaging). Leading systems include HUSIR (devised by the US Air Force and the Massachusetts Institute of Technology), the German GESTRA (German Space Agency at DLR) and TIRA (the Fraunhofer Institute for High-Frequency Physics and Radar Techniques), and GRAVES (the French Air and Space Force). All use very large antennas – usually around 30 metres in diameter – and low-frequency microwaves. Depending on their size, they can identify objects at a range of up to a few thousand kilometres. With the exception of GRAVES, they are also exclusively monostatic, with the transmitter and receiver located in the same place.

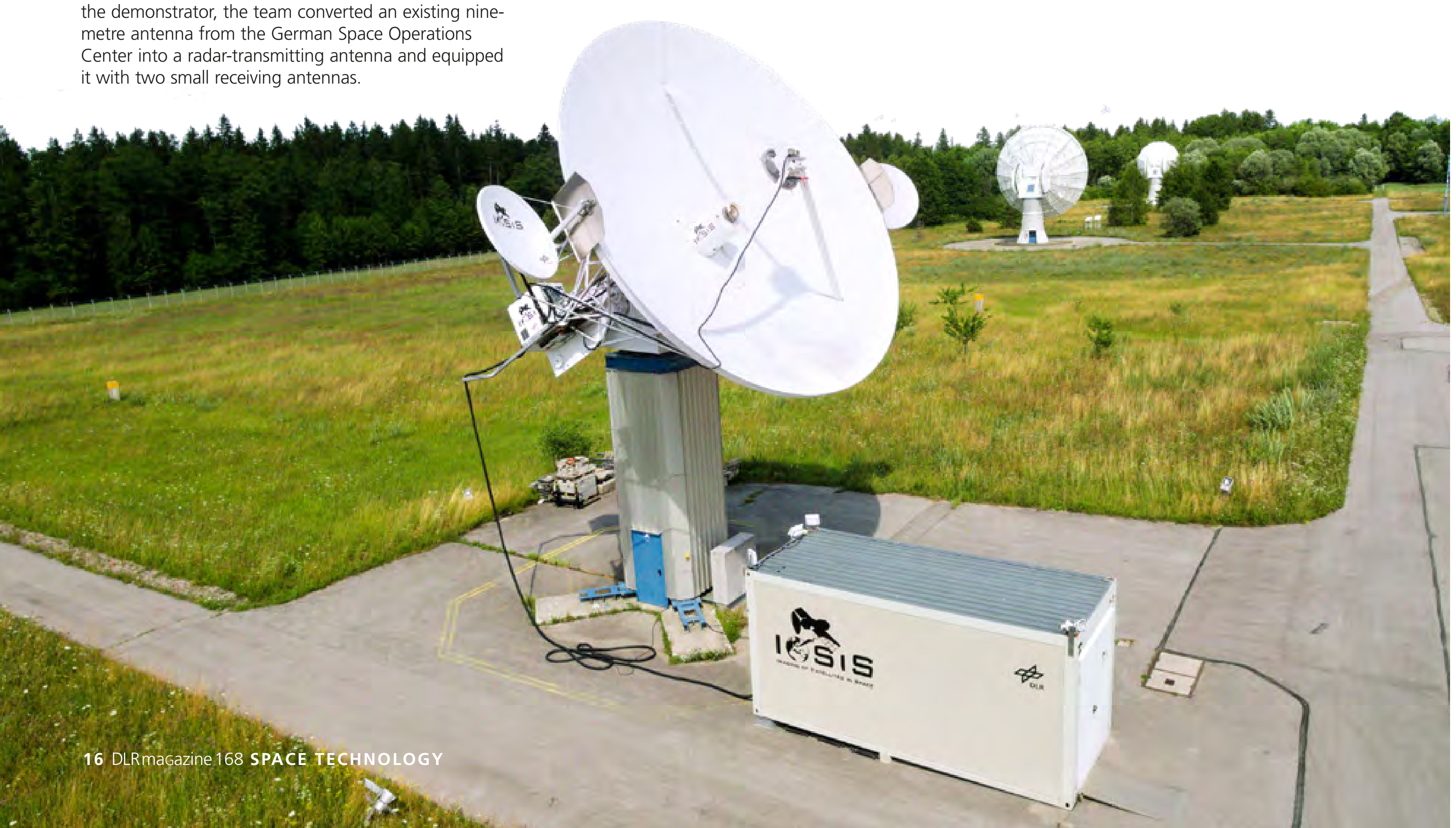
In addition to our urgent need to detect and determine the trajectory of space debris, in future active space objects will also need to be identified, classified and monitored with high precision. This would allow changes in flight behaviour or signs of ageing to be detected, and functional failures predicted in good time. This is particularly relevant for the concept of Responsive Space (see article in DLRmagazine 166), which aims to detect and replace defective satellites as quickly as possible – ideally within a few days. Given that it currently takes years to replace satellites, this would be truly revolutionary for the space sector. In the future we may also be faced with an increasing number of (intentionally) unknown space systems, which we must bear in mind when developing new ways for professional SSA to pinpoint their position and function.



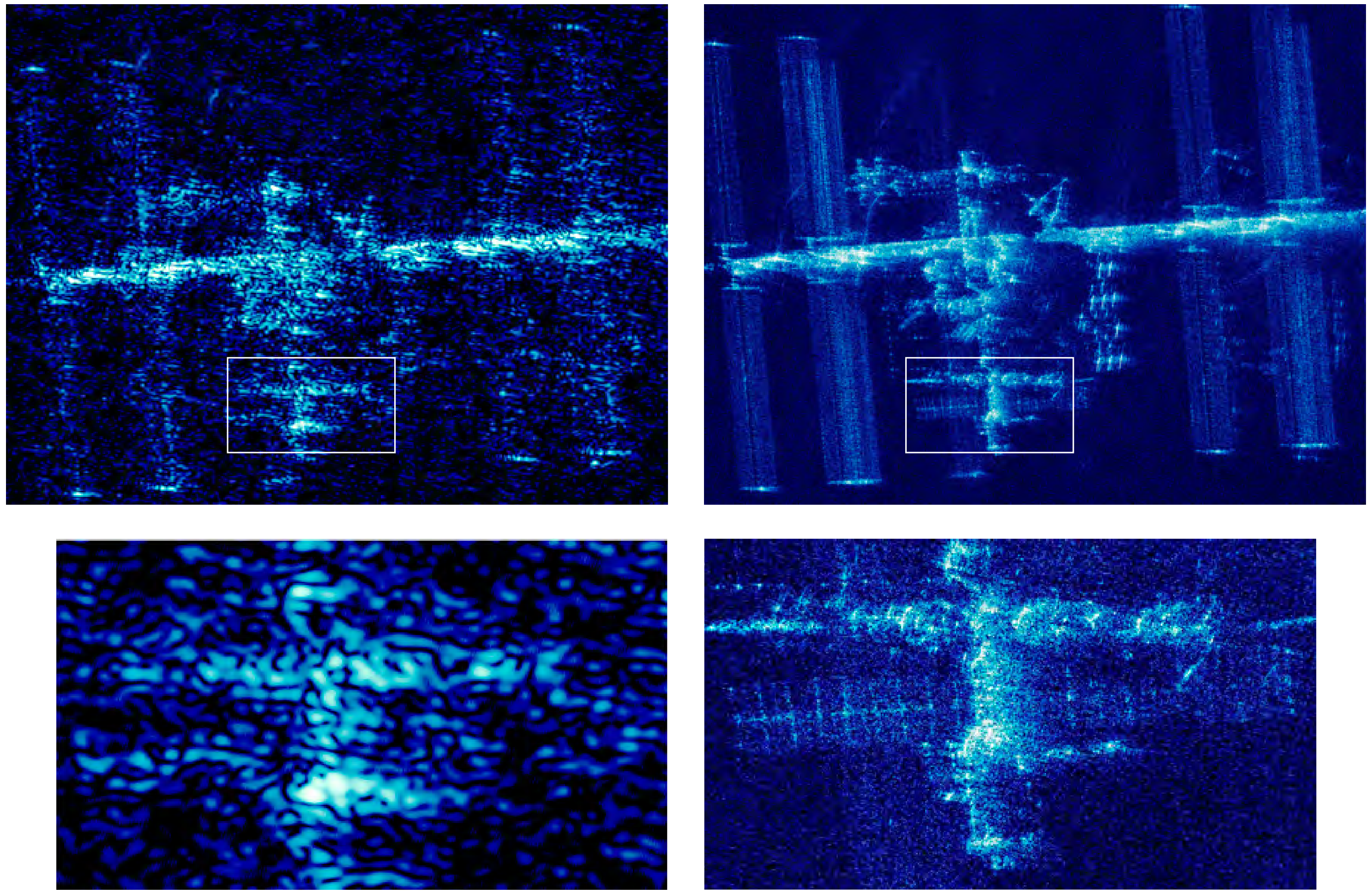
An agile antenna swarm

As current observation systems can only be expanded upon or improved to a limited degree, DLR is developing the new 'Imaging of Satellites in Space' (IoSiS) concept for future radar-based space situational awareness. Unlike today's systems, IoSiS is an experimental system concept in the form of a multi-instrument network. Instead of large, individual antennas, the researchers rely upon a 'swarm' of transmitting and receiving systems. One or more transmitters with an antenna measuring less than 10 metres across will be combined with a number of distributed receiving antennas, each with a diameter of around one metre. In contrast to their predecessors, these systems operate at a significantly higher frequency of around 100 Gigahertz and, in theory, can achieve a spatial resolution of just a few centimetres. As all the transmitters and receivers work together, the system can create both truly monostatic three-dimensional images – using transmitters and receivers located close together – and multistatic images – using transmitters and receivers spaced further apart to allow for a wide-angle view of an object. Multistatic images reveal structures that are often hidden from monostatic radar.

DLR's Weilheim site is home to the IoSiS radar system demonstrator, which operates in the X-band. To create the demonstrator, the team converted an existing nine-metre antenna from the German Space Operations Center into a radar-transmitting antenna and equipped it with two small receiving antennas.



In 2017, IoSiS had a resolution of 50 centimetres (left); today, this has improved to five centimetres (right). The width of the upper images corresponds in reality to about – the length of the ISS of about 110 metres – and the enlarged areas (bottom row) are about 25 metres wide.



Having a system with thousands of receivers has many other benefits, too. For one, the large quantity of antennas required makes them suitable for industrial series production. Current SSA systems tend to be highly specialised and custom-made products, but IoSiS has greater flexibility. Depending on the financial circumstances, the overall system can be expanded piece by piece, with each addition increasing overall performance. If a receiver fails, it can easily be replaced. And advanced or novel hardware can be integrated directly into every new receiver. Current systems are rather inflexible and have only a limited capacity for technological upgrades. Additionally, approval procedures for the location of the IoSiS antennas, which measure around one cubic metre, are simpler than for the large antennas of current systems, which can measure over 30,000 cubic metres. In addition, it is virtually impossible for the entire system to fail at once.

Surveying space from Weilheim

A team at the DLR Microwaves and Radar Institute in Weilheim has set up an initial demonstrator of the IoSiS concept, comprising a transmitter and two receivers currently operating at around 10 Gigahertz (for technical reasons). The radar system maps objects in LEO at a very high resolution and can process almost any type of signal. The demonstrator was first used to image the International Space Station (ISS) in 2017, and the team has been continuously developing its hardware and software since. Whereas four years ago the images had a spatial resolution of 50 centimetres, today the system produces radar images at a five-centimetre resolution. This not only allows very small objects to be examined, but also makes it possible to record signs of degradation in larger structures.

IoSiS can also observe larger objects, such as disused rocket stages. These are relatively easy to detect but require precise condition monitoring. The larger an object the faster it degrades, as it is more likely to collide with something and be damaged. To assess the situation accurately, it is important to determine when a large object has broken into two smaller pieces of space debris.

A multifaceted concept

The DLR team is currently working on the concept for the next generation of IoSIS (IoSiS-NG), and thus on improving the system's spatial resolution and three-dimensional imaging capabilities. Three dimensional images of Earth's surface can be created using conventional radar interferometry methods. Here the third dimension is calculated using the phase differences of two partial images. However, this method reaches its limits with very complex objects such as the ISS. The multistatic receivers of the IoSiS system, on the other hand, can receive information from different perspectives, enabling researchers to create a real three-dimensional image.

The experimental IoSiS system is currently only in use in Weilheim, but plans are underway to gradually roll it out across Germany.

Markus Peichl is a Group Leader at the DLR Microwaves and Radar Institute and IoSiS Project Manager.


Image: ESA

COSMIC HEARTBEAT

German ESA astronaut Matthias Maurer will launch to the ISS in October

By Elke Heinemann

3---2---1---0: Ignition and lift off!" These are the words we hope to hear from the Control Centre in Cape Canaveral, Florida, in November 2021. This will mean everything has gone as planned and Crew-3 is on its way to the International Space Station (ISS). On board the Dragon capsule will be ESA astronaut Matthias Maurer, alongside NASA astronauts Raja Chari, Thomas H. Marshburn and Kayla Barron. Maurer is expected to spend around six months on the Space Station. The German Aerospace Center is involved in the mission in a number of ways: The German Space Agency at DLR is responsible for selecting and coordinating the experiments and contributions from Germany, DLR researchers are performing their own experiments and the German Space Operations Center (GSOC), located at the DLR site in Oberpfaffenhofen, is responsible for planning and running the experiments taking place in the European Columbus module on the ISS.


Image: SpaceX

Matthias Maurer (left) and French ESA astronaut Thomas Pesquet training together in the SpaceX Crew Dragon cockpit in California

The Saarland native with a doctorate in materials science will be taking a large number of 'work packages' with him. In his programme are 35 German experiments alone. In addition, he will be supervising ESA and NASA experiments. They range from fundamental research to applied science. Fundamental physics questions, for example, will be examined using ultracold atoms or the crystallisation of different concrete mixtures. Other experiments will test non-invasive diagnostic applications or new antimicrobial surfaces. Technology experiments with AI-supported assistance systems are intended to demonstrate the possibilities of human-machine interaction. Also on the mission plan are numerous biological and human physiological experiments – in particular on the effects of long-term microgravity, increased radiation exposure and extended periods of isolation on the human body and its metabolism. Inspiring younger generations about space and motivating more of them to pursue careers in scientific and technical fields is of great concern at DLR, and this is reflected in the mission. A wide range of activities has been planned for this purpose. They include hands-on experiments, special competitions in which school classes work on potential climate protection concepts and radio exchanges between schools and the ISS.

All good things come in ...

... "3---2---1" – these numbers do not just represent the countdown to the launch of Matthias Maurer's mission. **Three** European astronauts will live and work on the ISS consecutively – Maurer will take the place of his French colleague Thomas Pesquet, who has been on the Space Station since 23 April 2021, and the Italian ESA astronaut Samantha Cristoforetti is expected to follow Maurer in April 2022. Matthias Maurer is also the **second** ESA astronaut to fly to the ISS on board a SpaceX capsule as part of NASA's Commercial Crew Program, and the **first** German astronaut to do so. It is also his **first** space flight).

This fact has substantially affected the duration of his flight preparation. The training for a launch with the Dragon capsule lasts around 18 months instead of the two years typically required for a flight in a Russian Soyuz capsule. Maurer's mission preparation was anything but routine, likewise for the joint DLR-ESA team. The COVID-19 pandemic, of course, impacted the training – requiring the mandatory wearing of masks and the limiting of physical human contact for the astronauts long before the launch. This is vital to prevent any germs from entering the isolated outpost in space.


Image: ESA/NASA – T. Pesquet

The solar panels of the ISS, photographed through the window by ESA astronaut Thomas Pesquet during his Alpha mission.

Next stop: International Space Station

Crew-3 will reach the International Space Station after a flight lasting up to 24 hours. For almost 21 years, this unique laboratory, which orbits Earth at an altitude of approximately 400 kilometres and a speed of just under 29,000 kilometres per hour, has been providing opportunities for science and industrial research that do not exist in any scientific facility on Earth. The ISS experiences microgravity around the clock – this means no sedimentation, no buoyancy and no convection. As such, entirely new materials can be developed and tested here. The results are usually then incorporated into computer models to optimise industrial production processes on Earth, for example. However, the environmental conditions on the ISS also have serious effects on the human body: muscle and bone mass are reduced, the immune system is weakened and the elevated radiation poses health risks. The radiation also makes microbes more dangerous as they can mutate faster. Appropriate measures must therefore be developed to protect the astronauts and to maintain their health to the greatest extent possible. This is particularly essential with future long-term missions to the Moon or Mars in mind. These new technologies can also be used for therapies, training and rehabilitation on Earth, as can developments in the area of non-invasive diagnostics, telemedicine and wearables.

ESA astronauts Matthias Maurer (left) and Thomas Pesquet in front of a SpaceX rocket in the USA


Image: ESA

Matthias Maurer and Thomas Pesquet carried out some of the preparation for their missions on the ISS together and completed training modules at ESA's European Astronaut Centre (EAC) in Cologne, NASA's Johnson Space Center in Houston, the SpaceX Crew Dragon cockpit in California, as well as in Russia, Japan and Canada. It is Pesquet's second stay on the ISS. When Maurer boards the station, the Frenchman will be commander of the ISS. The two astronauts will then spend a week together in space, during which they will perform Franco-German experiments.

Earth, the ISS, the Moon and then ...

Matthias Maurer chose 'Cosmic Kiss' as the name of his mission. It is a declaration of love to outer space, to the International Space Station as a link between Earth's inhabitants and the cosmos, and to all human activity there now and in the future. At the centre of the logo is the ISS, which is connected to Earth and Moon by a human heartbeat. The heartbeat is intended to symbolise the passion and curiosity that drives the exploration of space and the life science experiments that the Space Station makes possible. Cosmic Kiss also represents the value of the collaborative exploration of space with a view to more distant targets such as the Moon and Mars, and a respectful and sustainable use of our home planet.

Elke Heinemann is an editor in the DLR Communications Department.

THE MISSION

For the mission's logo, Matthias Maurer was inspired by the Nebra sky disc (the oldest known representation of the night sky) and the discs of the Pioneer and Voyager spacecraft (carrying the assembled knowledge of humankind). They represent humankind's fascination with space and the desire to learn more about the origins of life, the Universe and our place in it. The mission patch also includes other cosmic features such as Earth, the Moon, the Pleiades star cluster and Mars.

EDUCATION PROGRAMME

Among the educational activities aimed at schools is the 'Hand in hand around the world' campaign. In the run-up to the mission, more than 1000 primary school children have painted 'class selfies' that will accompany Maurer on the flight, some of which will be stitched together to form a 10-metre long picture strip and others stored in electronic form. The AI assistant CIMON-2 will also answer questions from school classes and invite young viewers to join a guided tour of the ISS with Maurer. The German Space Agency at DLR's school competition 'Protectors of the Earth – Space for Change' is seeking creative ideas for climate protection. Schoolchildren aged from 12 to 14 are invited to develop sustainable projects that use Earth observation data to protect the environment.

COLUMBUS CONTROL CENTRE

The Columbus Control Centre (Col-CC) of the German Space Operations Center (GSOC) at the DLR site in Oberpfaffenhofen is responsible for all the experiments conducted in the European Columbus laboratory of the International Space Station. DLR and ESA work together closely at GSOC and are in constant contact with the control centres elsewhere in the world and the astronauts on the ISS. The planning and integration of new experiments starts here long before the mission. The Col-CC thus forms the interface between the Columbus experiment facilities on the ISS and the scientists in the European user centres.

COSMIC Q&A

What are you most looking forward to during your mission?
: The launch and the first 10 minutes of the rocket ride. Then, on the International Space Station, the first 90 minutes in the Cupola, our window to space on the ISS. I want to fully absorb and soak up the beauty of our planet during an entire journey around Earth.

What does KI5KFH stand for?
: This tongue twister is my call sign on the ISS. I would have preferred 'Space Pirate' ;-)

Which experiments are you particularly excited about?
: As a materials scientist, I'm especially excited about the many materials experiments we conduct in space. Whether in the levitation melting furnace to investigate the solidification behaviour of metals and to obtain important materials science data during the transition from liquid metal melt to solid alloy. I'm also very interested in the numerous medical experiments. The aim is to understand the changes in the human body that occur in microgravity and which often resemble typical medical conditions on Earth. Through this, we can gain many important insights for the treatment of earthly diseases.

How do you keep out of each other's way in such a limited space?
: The ISS is actually very large, and you can spend the whole day on your own if you want. In the autumn, two Russian modules will be added, making the Station even bigger.

What is the ISS still lacking? (If space and money were no object)?
: A shower, a washing machine, a proper pizza or baking oven (we only heat food up to 70 degrees Celsius), a microwave for quickly heating up food, a coffee machine that makes milk froth, a yoghurt machine. In the long term, a 3D printer for really good food.

What was the craziest moment of your astronaut training?
: When, after two weeks of 'survival training at sea' in China, I was suddenly asked whether I could swim just before the final exercise.

To which year would you set your time machine and why?
: I would jump forward 1000 years to see what we have learned about the Universe by then and whether Earth is still habitable.

To which place in the Universe would you like to travel?
: To the nearest Earth-like exoplanet.

What would your first words on a new planet be?
: "We come in peace for all humankind." OK, that's stolen from Apollo 11, but it's timeless.

Why is it important that we take care of space?
: Space is an important resource, much like the oceans. We need rules and policies for managing them, but also for protecting this resource so that the generations that follow can access and use it. Our economy and daily lives are already closely linked to the use of space systems – be it through telecommunications, weather forecasting or positioning data. These satellite-based systems are critical to our infrastructure and must be protected.

Follow DLR's social media channels for mission updates:

@DLRen @germanaerospacecenter @DLR_en

Matthias Maurer has been a member of the European Space Agency's astronaut corps since July 2015. He completed his 18-month basic training in September 2018. In December 2020, Matthias was officially assigned to his first International Space Station mission, known as 'Cosmic Kiss'. Maurer, born in St. Wendel in Saarland, Germany, is a materials scientist and graduated with a doctorate in materials science engineering from the Institute of Materials Sciences of the Technical University of Aachen, Germany. The topic of his dissertation was 'Lightweight composites made of aluminium foam with thermally sprayed coatings'.

Image: ESA/N.Fischer/Hintergrund: Sabine Grothues

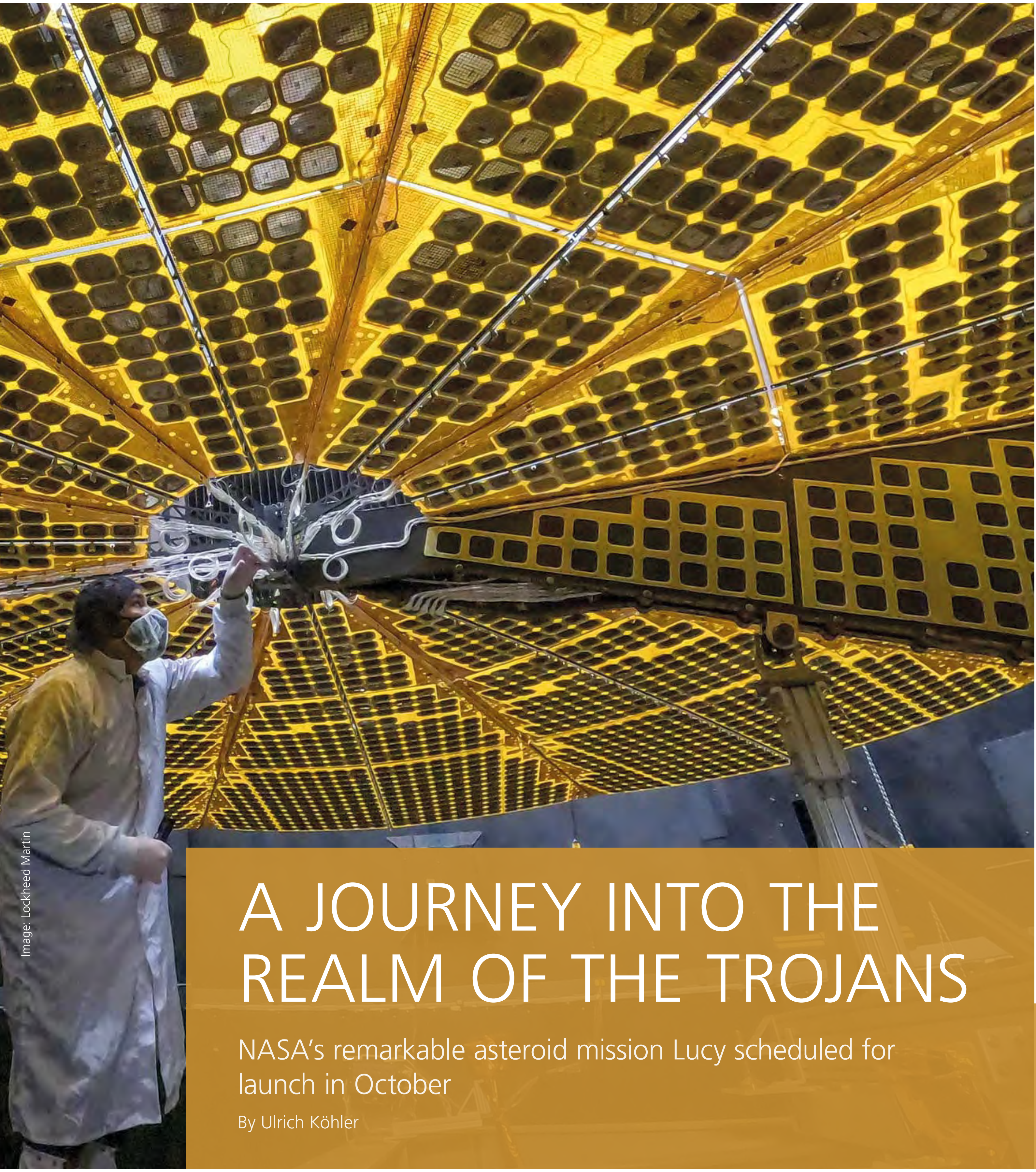


Image: Lockheed Martin

A JOURNEY INTO THE REALM OF THE TROJANS

NASA's remarkable asteroid mission Lucy scheduled for launch in October

By Ulrich Köhler

In early 2021, the deployment of the two 7.3-metre-diameter solar panels was tested under space conditions.

How did the Solar System form? Why did the planets develop so differently from one another? Planetary research now has an idea of how matter in the disc of gas and dust orbiting the young Sun agglomerated to form the first protoplanets 4.5 billion years ago. However, many questions have yet to be answered, not least those relating to the origin of life on Earth. Where did Earth's water come from? How about the building blocks of life? Were they on Earth from the beginning, or were they carried there at a later stage by small celestial bodies, asteroids and comets? In October 2021, NASA's Lucy spacecraft will embark on a 12-year journey to answer these and more questions – and DLR will be right there.

Image: NASA

In the laboratory at NASA's Goddard Space Center in Greenbelt, Maryland, two researchers work on L'Ralph, the most complicated instrument on the Lucy mission. It comprises a camera that will take colour images and an infrared spectrometer.

Lucy's targets are the Jupiter trojans, small bodies up to 250 kilometres in diameter located in two regions that precede or follow Jupiter, the largest planet in the Solar System, by a fixed distance along its orbit. The locations at which this is possible are called Lagrange points. These are positions in space where the gravitational forces of a two-body system like Earth and the Sun balance out. There are five such points, numbered from Lagrange-1 (L1) to Lagrange-5 (L5) and named after the Italian-French astronomer and mathematician Joseph-Louis de Lagrange (1736–1813). Two of these Lagrange points, L4 and L5, are always stable and each form the third apex of an equilateral triangle with 60-degree angles to the Sun and Jupiter. This will be the first time that bodies orbiting the Sun at Lagrange points along a planet's orbit have been visited by a spacecraft. Achieving this has been a top priority in planetary research for many years.

The somewhat different asteroids

Although the existence of asteroids has long been common knowledge, the first observation of an asteroid took place just 220 years ago. On the night of 1 January 1801, while looking for an unknown planet, the director of the observatory in Palermo, Giuseppe Piazzi, observed a 'star' in the unusually large 'void' between the orbits of Mars and Jupiter, in the Taurus constellation. He noticed that its position changed on the nights that followed. Piazzi had discovered the asteroid Ceres, the largest body in the expanse between the two planets.

More discoveries soon followed. Today, we know of more than one million small bodies in the Main Asteroid Belt. These are thought to be the remnants of the planet-forming process: debris made of rock, metals and – in the farthest reaches of the Solar System – ice, which could not agglomerate to form a planet due to the disruptive effect of Jupiter's gravitational pull. The countless craters on Mars, the Moon and Mercury tell us that Jupiter, which has 2.5 times more mass than all other planets combined, regularly redirects bodies from the Main Asteroid Belt into the inner Solar System. There they collide with the terrestrial planets, forming craters – far more frequent billions of years ago than today. On Earth, these traces have been almost completely erased by the dynamic processes occurring on the surface. At the same time, Jupiter is forcing the majority of the asteroids onto stable orbits – a process that may have even ensured the survival of life on Earth.

Spaceflight makes it possible to observe asteroids up close. In the 1990s, the Galileo spacecraft flew past the asteroids Gaspra (1991) and Ida (1993) on its way to Jupiter. Between 2011 and 2018, NASA's Dawn orbiter observed the asteroids Vesta and Ceres at close range for many months from different orbits, using a camera developed by DLR and the Max Planck Society. Ceres, which measures almost 1000 kilometres across, has since been 'promoted' to the status of dwarf planet. The two Japanese Hayabusa spacecraft even touched down on asteroids and collected samples. NASA's OSIRIS-REx is currently on its way back to Earth, carrying dust from the asteroid Bennu.

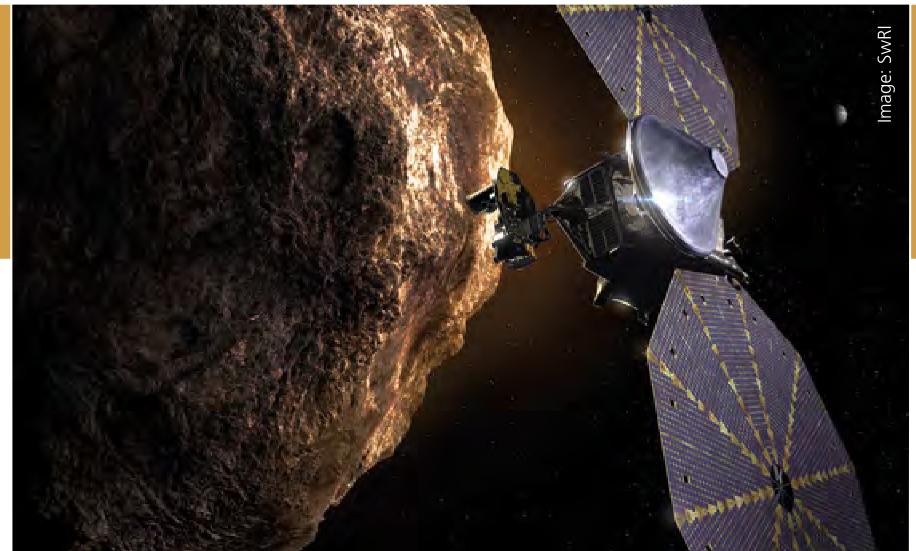
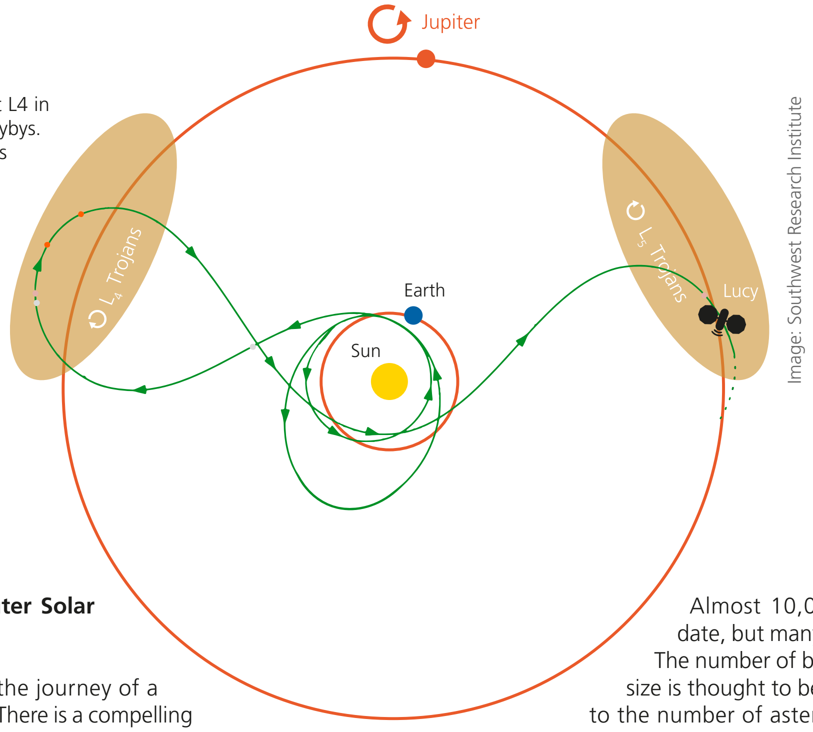


Image: SwRI

Artist's impression of the Lucy spacecraft flying past one of the Trojan asteroids

Lucy will reach Jupiter's Trojans at L4 in April 2025 following two Earth flybys. There, it will observe the asteroids Eurybates, Polymele, Leucus and Orus from close range before returning towards Earth in 2029. The spacecraft will use Earth's gravity to accelerate again in 2030/31 and fly to the L5 point to investigate the asteroid Patroclus in 2033.



Time capsules from the outer Solar System

Lucy is about to embark on the journey of a lifetime to the Jupiter Trojans. There is a compelling scientific reason for the mission: researchers believe that, unlike the main belt asteroids, these Trojans have less in common with the bodies of the inner Solar System and more in common with its outer regions. The realm of the gas giants and their ice moons begins with Jupiter, at almost five times the distance from Earth to the Sun. Even further out, beyond Neptune, stretch the regions where the comets, bodies of dust and ice, once originated. This is the zone of the trans-Neptunian objects, including Pluto.

Just as the main belt asteroids are remnants of the formation of the four terrestrial planets, the Jupiter Trojans are likely to be remnants of the source material of the outer planets, which formed at very different distances from the Sun. Like the comets, these asteroids are 4.5 billion-year-old 'time capsules' from the age of planetary formation. They may even contain organic molecules made of carbon and hydrogen that later made their way from there into the inner Solar System, and thus to Earth. These substances could have played an important role in the emergence of life almost four billion years ago. They may also harbour tholins, the red-brown, organic nitrogen compounds discovered on Pluto and its companion Charon. Until now, the Trojans have only been observed with telescopes. This is difficult, as they are made of very dark material and are much further away from Earth than the main belt asteroids. Yet even these studies indicate that the Trojans must be very different in nature.

Almost 10,000 Trojans are known to date, but many more are believed to exist. The number of bodies over one kilometre in size is thought to be close to a million – similar to the number of asteroids in the Main Asteroid Belt. The Heidelberg astronomer Max Wolf (1863–1932) discovered the first Trojan on Jupiter's orbit in 1906. He named it after Achilles, the supposedly invincible Greek hero (if only it hadn't been for his heel!) from the mythical battle between the Hellenes and Troy. This is how the Trojans got their collective name. Inspired by Homer's epic, The Iliad, the assembly of asteroids known as the 'Greeks' form an 'army camp' at the L4 point on Jupiter's orbit, hurrying ahead of the planet, and the 'Trojans', intent on defending their city, Troy, are located at L5. Jupiter's gravitational pull creates a particular dynamic within both camps, but there is no transfer between them. This back and forth is not yet well understood.

Setting a course into the unknown

NASA selected Lucy as the successful Discovery class mission in 2017, along with another asteroid mission called Psyche. The latter will embark on a journey to the 220-kilometre main belt asteroid Psyche, a body made almost entirely of metal, in August next year. The name Lucy is not an abbreviation, as is so often the case with NASA missions. It refers to one of the most important discoveries in anthropological research: that of the 3.2 million-year-old partial female skeleton of Australopithecus afarensis in Ethiopia, known as an 'early human'. Palaeontologist Donald Johanson, who discovered Lucy, celebrated by throwing an exuberant party with his team on the evening of that November day in 1974. As the night wore on, the Beatles' perennially popular song Lucy in the Sky with Diamonds played repeatedly on the tape recorder. There is still some speculation over the initial letters of the three title nouns, but the skeleton needed a name. With her bones, scientists were able to decipher the origins of humankind. The NASA spacecraft is also intended to help, in a figurative sense, decode the origins of the Solar System.

The Lucy mission will see a number of striking milestones. Following the launch of the 1.5-tonne spacecraft and two Earth flybys, its first destination will be the four-kilometre asteroid 52246 Donaldjohanson, named after the palaeontologist who discovered Lucy, located in the Main Asteroid Belt. Johanson, born in 1943, is still a professor at Arizona State University today. Although the flyby will be used to test Lucy's instruments and operations, Donaldjohanson is also of scientific interest, as it belongs to a rare class of asteroids. Only after this visit will Lucy approach Jupiter's orbit and the L4 point, home to the 'Greeks'. Five close flybys are planned here between 2025 and 2028, the first at Eurybates, named after the herald of Odysseus, and its moon, Queta. Then, in a spaceflight first, it will return from Jupiter's orbit back to Earth to build the momentum to reach its next destination. Lucy will then visit the 'Trojans' at L5 and examine the 122-kilometre binary system of Patroclus and Menoetius.

The mission will officially end there, in 2033. By then, Lucy will have made three and a half large loops around the Sun and travelled four billion kilometres in between the orbits of Earth and Jupiter. The team speaks enthusiastically about Lucy's 'resourceful trajectory' – calculated through careful planning and some good fortune – that will make it possible to fly past seven of the most primordial bodies in the Solar System with a single spacecraft. This promises a rich scientific yield from a class of bodies that could give us decisive answers to big questions about the early days of the distant outer planets, and should also provide insight into Earth's early history.

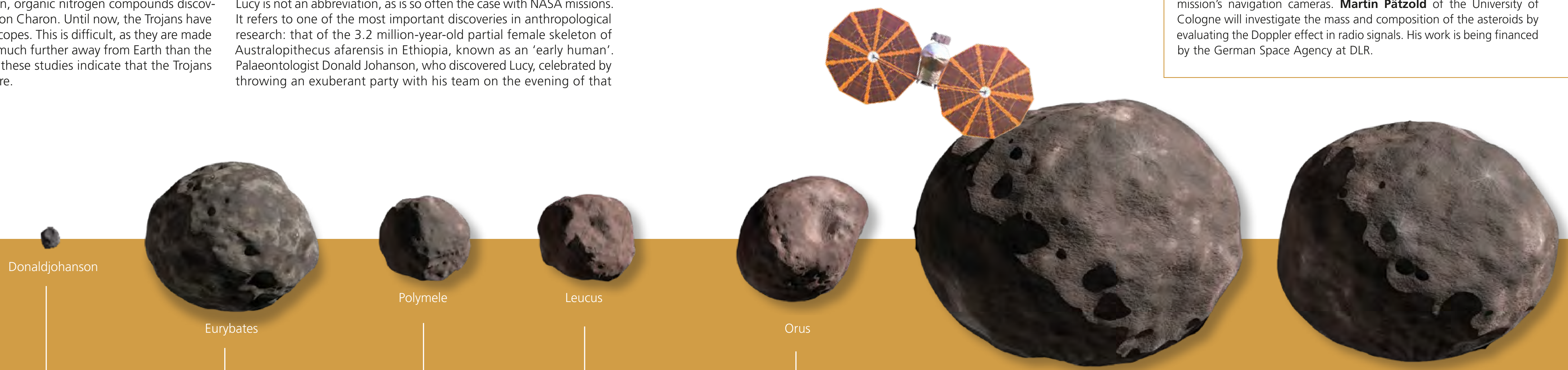
Ulrich Köhler is a planetary geologist at the DLR Institute of Planetary Research, where he is also responsible for public outreach. In his more than 30 years at DLR, he has seen asteroids become increasingly important for Solar System research.

LUCY – A NASA DISCOVERY CLASS MISSION

Lucy is being built by Lockheed Martin Space in Denver, Colorado. Its launch mass is 1550 kilograms, of which 729 kilograms are propellant. The launch vehicle will be an Atlas V 401. Power will be generated by two solar panels that provide 504 watts at the greatest distance from the Sun of around 1.4 billion kilometres – a record for this distance. The mission will be controlled from NASA's Goddard Space Flight Center. Harold F. Levison of the Southwest Research Institute in Boulder, Colorado, is the Principal Investigator. The scientific payload consists of a high-resolution panchromatic (black-and-white) camera, a multispectral camera, an imaging infrared spectrometer as well as a spectrometer for measuring the thermal radiation of the asteroids.

On 4 January 2020, members of the Lucy science team, including DLR planetary scientist Stefano Mottola (to the right of the pillar, behind team leader Harold Levison, with beard), discovered that the target asteroid Eurybates has a satellite barely one kilometre in size – Queta.

DLR is represented in the Lucy science team by **Stefano Mottola** from the DLR Institute of Planetary Research. Mottola was heavily involved in the Rosetta, Dawn and Hayabusa2/MASCOT missions and studies the light curves of asteroids using ground-based telescopes. The planetary researcher, who specialises in asteroids and comets, will support Lucy with telescope observations of the target asteroids to optimise the flybys. He will also assist the mission with calculations of the shapes of celestial bodies, image mosaics, atlases and mapping their brightness and composition. The shape of the asteroids will be derived using the mission's navigation cameras. **Martin Pätzold** of the University of Cologne will investigate the mass and composition of the asteroids by evaluating the Doppler effect in radio signals. His work is being financed by the German Space Agency at DLR.



from 21 October 2021
Launch
(three-week launch window)

16 October 2022
first Earth flyby

13 December 2024
second Earth flyby

2031
third Earth flyby

(artist's impression)

20 April 2025
52246 Donaldjohanson
(Ø ~4 km)

12 August 2027
3548 Eurybates (Ø ~72 km)
with Queta (Ø < 1 km)

15 September 2027
15094 Polymele
(Ø ~21 km)

18 April 2028
11351 Leucus
(Ø ~42 km)

11 November 2028
21900 Orus
(Ø ~51 km)

~2 March 2033
617 Patroclus (Ø ~122 km)
and Menoetius

If enough fuel remains, a return to the L4 asteroid cloud may be possible in 2039; otherwise, Lucy will continue on a stable six-year solar orbit between Earth's orbit and the Trojans for 100,000 years.

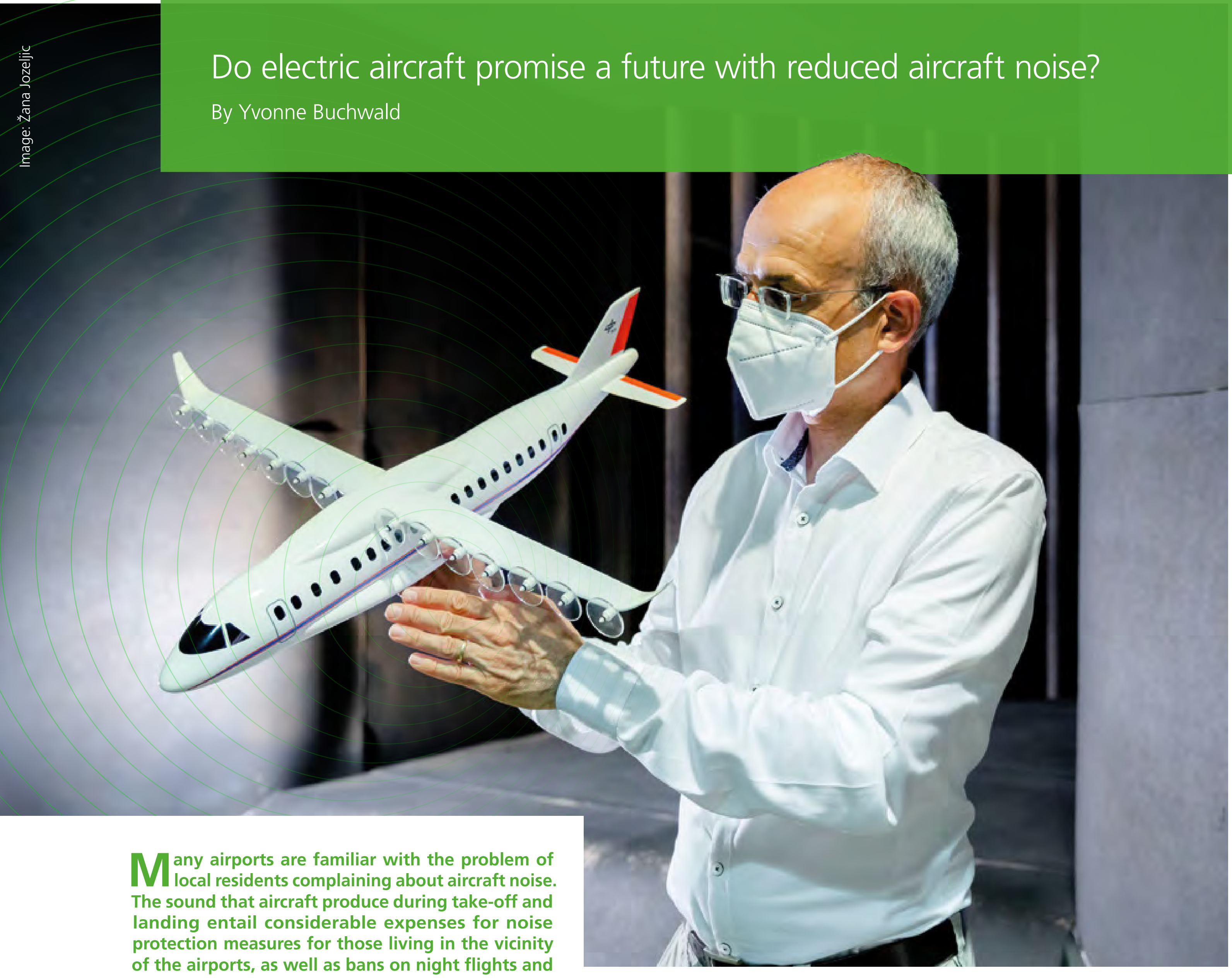
STRATEGIES FOR REDUCING SOUND LEVELS

In order to make aircraft quieter, tests are carried out using elaborate measurement technologies in facilities such as the Braunschweig DNW low-speed wind tunnel.

Do electric aircraft promise a future with reduced aircraft noise?

By Yvonne Buchwald

Image: Žana Jozeljic



Many airports are familiar with the problem of local residents complaining about aircraft noise. The sound that aircraft produce during take-off and landing entail considerable expenses for noise protection measures for those living in the vicinity of the airports, as well as bans on night flights and other restrictions on flight operations. Researchers at DLR are therefore looking for solutions to make flying as quiet as possible.

Using a model of a hybrid-electric aircraft with distributed propeller drives in the Aeroacoustic Wind Tunnel Braunschweig, Olaf Brodersen explains what future aircraft might look like.

Olaf Brodersen is a researcher at the DLR Institute of Aerodynamics and Flow Technology in Braunschweig. When he envisions the mobility of the future, what matters to him are research results and facts: "We should not fool ourselves when it comes to noise," he says. "An electric propulsion system alone will not make a vehicle completely silent, whether on the road, in the air or on rails." Ever the researcher, he demonstrates this by driving his electric car on the motorway. From a speed of approximately 60 kilometres per hour, his electric car is just as loud as any other passenger vehicle, as this is the point at which the noise from the tyres becomes the dominant sound. And it gets louder from there; at over 100 kilometres per hour, the air flowing around the car produces most of the noise, as it does for conventional vehicles.

Go faster, be louder

Back in the office, Brodersen starts up his computer. "Of course, an aircraft is much faster than a car," he says. Futuristic-looking aircraft designs appear on the screen. "This means that pollution-free, climate-neutral flight that makes as little noise as possible represents a far greater challenge for aviation than for road transport." The scientists at the Institute address this challenge every day. For several years now, they have also been investigating electric and hybrid-electric aircraft concepts.

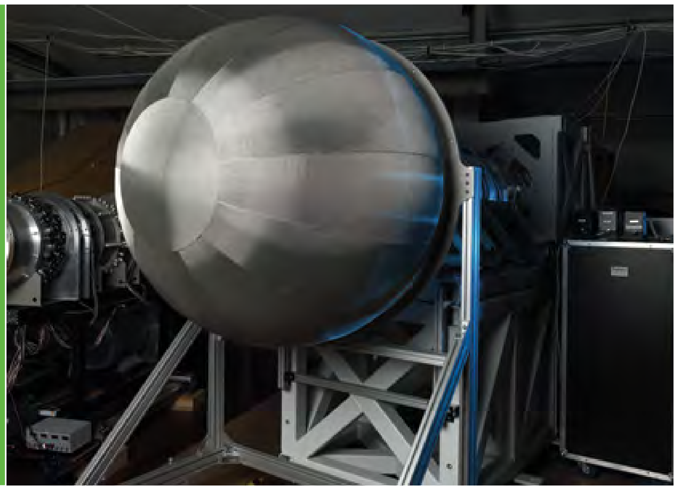
What might the electric or hybrid-electric aircraft of the future look like? How would they have to be designed in order to fly as pollution-free, quietly, safely and efficiently as possible? "There may well be potential for this form of flying for certain aircraft sizes. Here at DLR, we are developing numerous new technologies for this," enthuses Brodersen. Society has high expectations not only with regard to the performance of such technologies, but also when it comes to reducing aircraft noise. But if aviation noise is primarily caused by aerodynamic factors, how can anything be done about it?

Where the noise comes from

This is where Brodersen's colleague, Jan Delfs, who heads the Technical Acoustics Department at the Institute, comes in. "Noise is generated in three main areas of the aircraft," he explains. "These are the propulsion system, in the form of the propellers or jet engines, together with the flow around the airframe and, finally, the aerodynamic interaction between the propulsion system and the airframe." Delfs continues "The potential for noise reduction therefore lies primarily in the design." He casts an eye over the new concept designs from Brodersen's department. Electric aircraft tend to have a more delicate appearance than conventional medium-haul aircraft. The wings are usually narrow, long and lightweight and they often have multiple power units, spread out in the interests of better weight distribution and control. But the large number of propellers can also mean more noise, as many small propellers produce a different noise than two large ones. Delfs and Brodersen discuss the ongoing work at the Institute. "We are working on many new concepts. A radically different arrangement of propulsion units could not only reduce the emission of sound towards the ground, but also facilitate the integration of quieter engines with larger diameters," explains the acoustics expert.

The main concern when it comes to noise pollution is the sound that can be heard near airports during take-off and landing. Once the aircraft reaches an altitude of 10 kilometres, it is no longer loud enough to disturb those on the ground. During take-off, when operating at full power, the engines produce most of the noise. During landing approach, it is the airflow around the wings, flaps and landing gear that makes an aircraft noisy.

Microphone arrays are used to precisely measure the sound produced by aircraft or individual aircraft components.



New propulsion concepts can be tested as early as the prototype stage on the CRAFT test stand at the DLR Institute of Propulsion Technology in Berlin.

NEW TECHNOLOGIES FOR ELECTRIC AIRCRAFT

Since the beginning of 2020, 45 researchers from 20 DLR institutes have been working together on the Exploration of Electric Aircraft Concepts and Technologies (EXACT) project, which is developing new technological components for an environmentally friendly commercial aircraft. The project therefore also addresses aircraft design and energy efficiency analysis of hybrid-electric and hydrogen-based aircraft configurations.

The goal of the project is to have an eco-efficient aircraft, with at least 70 seats and a range of 2000 kilometres, in operation by 2040. The EXACT team is identifying and developing the necessary technologies. To this end, different hybrid-electric propulsion concepts and possible aircraft configurations are being investigated during the initial stage. Interactions with airport infrastructure must also be considered, along with how new types of propulsion systems affect the atmosphere and thus the climate. An article about the EXACT project was published in DLRmagazine 164 (April 2020).

A direct connection between Braunschweig and Berlin

With a few clicks, Delfs initiates a video call, and his Berlin-based colleague appears on the screen. Lars Enghardt from the DLR Institute of Propulsion Technology greets us. The engine noise researcher is looking forward to regular exchange with his colleagues in Braunschweig and confirms that very little can be done to reduce aircraft noise through pure electrification – that is, the thought experiment that envisages the radical replacement of combustion components in current engines with electric motors. This is because some 90 percent of the thrust from modern turbofan engines is generated by the shrouded fan at the front, directly at the intake. Its comparatively slow thrust stream surrounds the hot core outflow. The latter would be absent without combustion, but today it is only responsible for 10 percent of the propulsion. It follows that the sources of noise from today's engines, especially during take-off and landing, are dominated by the fan, which would be retained as a thrust generator in purely electric propulsion systems. "Unfortunately, it is not that simple," Enghardt says, confirming the reservations of his two colleagues. He too believes that the future of air transport lies in a radical rethink of the airframe design and the integration of the propulsion system components.

For landing, the high-lift devices and landing gear would have to be designed differently in order to avoid unfavourable aerodynamic effects. "Electrically powered aircraft allow us to completely rethink the arrangement and distribution of engines on the aircraft. The entire aircraft can be designed much more freely in conjunction with the installation of small, widely distributed electric propulsion units," explain Delfs and Brodersen. Enghardt backs up his Braunschweig-based colleagues by confirming that this could allow the use of new types of noise cancellation between multiple units as an alternative to or in combination with the careful integration of even larger, assistive propulsion units with fan blades that rotate more slowly, thus ensuring significantly less noise.

This is what a hybrid-electric aircraft concept with distributed propulsion units might look like. The design comes from the SynergIE (Synergetische Integration von verteilten hybrid-Elektrischen Antrieben) research project funded by the German Aeronautics Research programme of the Federal Ministry for Economic Affairs and Energy.

A detour into the realm of acoustics

Aircraft noise is the number two source of transport noise in Germany, according to a recent survey by the Federal Environment Agency. Over 40 percent of respondents have felt disturbed by noise emissions from aircraft in recent years. As is well known, however, noise is not just a physical phenomenon, but also a matter of perception. As Kurt Tucholsky said: "Your own dog never makes any noise – it just barks."

Sound, or sound pressure to be more precise, is characterised in levels. It is measured on a logarithmic scale and expressed in decibel (dB) units. The threshold of human hearing is zero decibels. While at around 40 decibels the sound of a home refrigerator may be barely noticeable, a dripping tap at night can be a real source of annoyance, although it is just 20 decibels. For example, the sound level meter could register the same reading when an aircraft flies over it and when a train passes by, yet many of those affected would rate what they hear differently. Only at this point does one talk about (perceived) noise in the sense of a nuisance. At German airports, the equivalent continuous sound pressure level is recorded. This is the constant noise level that would result in the same total sound energy being produced over a given period.

To protect against aircraft noise, the World Health Organization and the German Federal Environment Agency recommend maintaining a 24-hour equivalent continuous sound pressure level of 45 decibels. The EU Commission has also set itself a major target in Flightpath 2050 of reducing aircraft noise by 65 percent for every type of flight by 2050. "In all of this, we should not forget that we have made much technical progress over the last few decades and that most aircraft today are well below the applicable noise limits," explains Delfs. "The latest generation of aircraft are around 80 percent quieter than they were 60 years ago."

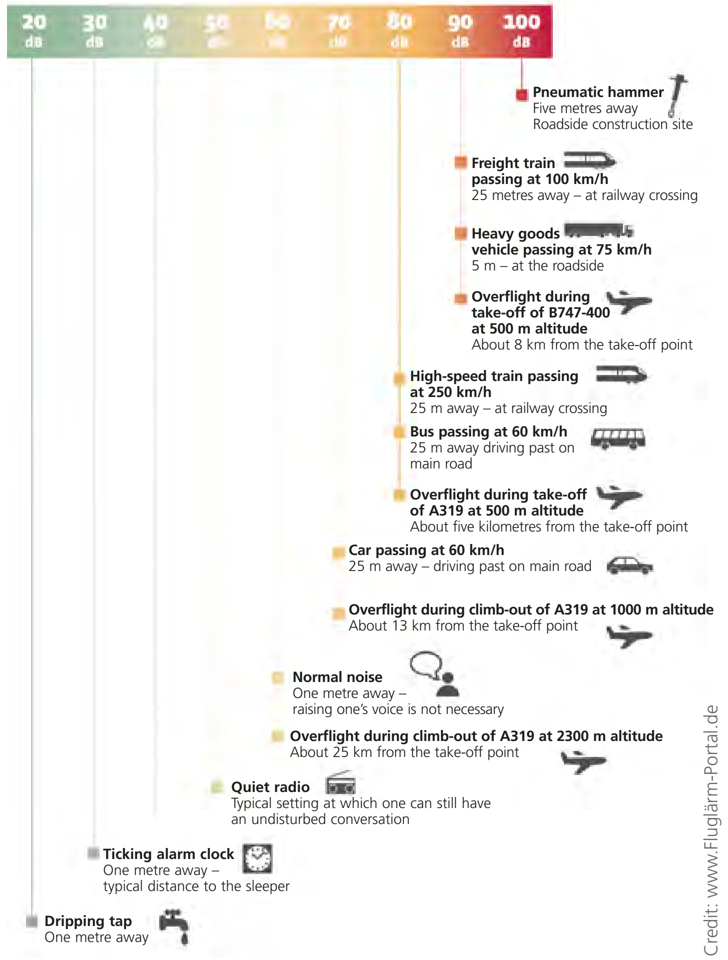
Research for commercially viable electric aircraft

In their quest for ways to increase efficiency and reduce noise, and to come as close as possible to the highly ambitious goals set by the EU Commission, Jan Delfs, Olaf Brodersen and Lars Enghardt are working across disciplines on new propulsion system and aircraft concepts as part of several projects and in cooperation with a number of DLR institutes. The aim is for short- and medium-haul aircraft with electric or hybrid-electric propulsion systems and new aircraft configurations to meet mobility requirements and increasing passenger numbers with the lowest possible impact on flight costs. If restrictions on night flights, the construction of noise protection measures and noise charges at airports could be significantly reduced, electric aircraft – which are currently much more expensive – could become commercially viable, particularly with additional operating hours.

The DLR scientists are convinced that future electric and hybrid-electric aircraft could look very different from those of today. They will probably have several propulsion units, but smaller wings, high-lift systems and tail units. With the right power supply technology in place, they will be able to fly with less impact on the environment. New concepts will open up opportunities to do this more quietly, although not altogether silently.

Yvonne Buchwald is responsible for communications at the DLR Institute of Aerodynamics and Flow Technology in Braunschweig.

COMPARISON OF SOUND PRESSURE LEVELS



Credit: www.Fluglärm-Portal.de

In addition to wind tunnel tests, flight tests and simulations play an important role in acoustics research. For example, during flight tests with the Do 228, DLR researchers examined the sound emissions of propellers synchronously on the ground and in the aircraft for the first time.

SHAKE, VIBRATE AND FLY!

All aircraft vibrate in flight, but certain critical thresholds must not be exceeded. For this reason, ground vibration tests are a key milestone in the aircraft airworthiness certification process. In June, the DLR Falcon 2000LX In-flight Systems & Technology Airborne Research (ISTAR) aircraft was put through its paces in Braunschweig.

For the tests, elements such as the tail unit, wings, fuselage and control surfaces were fitted with shakers. Over 200 accelerometers recorded even the smallest movements. The computer model of ISTAR was updated using data from the tests. The model can be used, for example, to simulate modifications required for research campaigns before they are installed on the aircraft itself. ISTAR is the newest member of the DLR research aircraft fleet. Once it has been fully upgraded, it will be able to test the characteristics of new aircraft designs – whether physical or virtual, crewed or uncrewed – under realistic operating conditions. With ISTAR, DLR will also create a digital twin for an entire aircraft for the first time, which will accompany it over the course of its life.

For more information on the vibration tests, see:

s.dlr.de/J8bVI

Image: Adobe Stock

HOW IS COVID-19 CHANGING THE WAY WE GET AROUND?

In a series of studies, DLR is investigating the impact of the pandemic on mobility.

By Denise Nüssle

Empty streets and motorways, radio traffic bulletins with nothing to report, and a sparse handful of passengers on buses and trains. Such a scenario would have been inconceivable before spring 2020, when the COVID-19 pandemic swept through society. In an interview with DLRmagazine, Claudia Nobis of the DLR Institute of Transport Research gives us an insight into how this period has changed mobility behaviour in Germany. Over the course of four studies conducted between April 2020 and May 2021, she and her team asked around 1000 people which means of transport they were using during the crisis, and how comfortable they felt. They also looked at how mobility-related behaviour has changed when it comes to work, shopping, leisure and travel.

Why is mobility in times of the Coronavirus pandemic such a fascinating topic?

: Our everyday lives have changed massively as a result of the pandemic. It has impacted the ways in which we get around, too. We initiated our first survey back in April 2020, during the first lockdown. Mobility was at its most limited at that point, and analysis of mobile phone data revealed that the traffic volume fell by 40 percent. Our second survey, in the summer, served as a snapshot of the period following the lockdown. We noticed a certain uptick in the amount of traffic and were able to discern some initial long-term changes in mobility behaviour. This trend was shown to have stabilised in the third and fourth surveys, carried out just before Christmas in 2020 and in May 2021.

What were your main findings? What has changed?

: Before the crisis, about half of the adult population used a car on a daily basis. This proportion jumped to two-thirds by the time of the first survey, levelling off at around 60 percent by the time of the third and fourth surveys. Increasing car use seems to be becoming the new status quo. By contrast, the number of people who use a range of means of transport in everyday life has sharply declined.

As such, public transport has been one of the big losers over the last year. This trend seems to be cementing itself, too. A little over half of those questioned felt rather uncomfortable in public places and would avoid them for that reason – including planes, trains and local public transport. Around 15 percent of those who had an annual ticket for local public transport before the pandemic have since cancelled it, with three-quarters saying that the pandemic had played a major role in their decision.

What will happen when the Coronavirus pandemic comes to an end? Will everything return to the way it was?

: The entirely new situation we have been living through for over a year now has led to the emergence and consolidation of new mobility practices, with more of a focus on means of transport that are perceived as safe, such as cars and bicycles. The latter could be further encouraged by improving cycling infrastructure, for instance. The outlook for public transport is likely to be rather bleak for some time. The pandemic has put the brakes on the mobility transition, but people have really missed travelling and going on trips. We expect to see a certain amount of catching up for lost time – but cars, rather than public transport, are set to remain the preferred means of travel.

How can we boost public transport again?

: The most important thing is restoring trust. People have to feel comfortable using public transport again. In the long run, we will only manage to reduce reliance on cars if there are good alternatives. Generally speaking, hygiene remains paramount in people's minds and there is an ever-present fear of infection. These concerns must be taken seriously. At the same time, good communication is key – making it clear that regular cleaning is being carried out, for instance. Special offers and tariffs can also provide an incentive to switch to public transport again.

Has the coronavirus pandemic sparked any positive developments in terms of mobility?

: The crisis has shown that working from home is suitable for many employees. Many are hoping that they will be able to carry on performing some of their activities from home in future. Online meetings have largely replaced business trips. As such, there is a high likelihood of a fundamental shift in work-related mobility. This could flatten the traffic peaks on the roads and on public transport seen during rush hour in major cities and metropolitan areas.

Our shopping behaviour has also undergone a massive change. Before the crisis, less than half of those questioned had shopped online in the last four weeks. During the crisis, this rose to over 80 percent, and has stayed there. Delivery traffic increased accordingly and remains very high. If things remain this way, we are looking at significant consequences for retail, the layout of inner cities and our transport habits. All in all, it is an exciting development, and we will definitely continue to study this area in future projects at the Institute.

This interview was conducted by **Denise Nüssle**, Media Relations editor at DLR.

During the pandemic, many switched to cycling as a mode of transport.

Public transport is one of the losers in the pandemic. The trend to use the private car seems to be consolidated.

Image: DLR

About the interviewee

Claudia Nobis studied ecology and environmental education, and investigated the mobility behaviour of children and young people for her master's thesis. She was subsequently responsible for the subject of mobility during the construction of Vauban, a car-free residential area in Freiburg. She has led the Mobility Behaviour group at the DLR Institute of Transport Research in Berlin since 2013. Together with her team, she investigates new mobility trends, attitudes and behaviours with a view to making mobility more sustainable in future. Outside work, she enjoys cycling, both for exercise and for getting around.

RETHINKING TRANSPORT

As road, rail, water and air transport become increasingly interlinked, reliable communication is key.

By Anika Lobig and Jasmin Begli

Pedestrians, cars, trains, ships, parcel drones and air taxis – in the future, traffic on the ground and in the air will have to share a common space. But how can this best be achieved, and how can these different modes of transport 'learn' from one another? One thing is clear: as the domains traditionally reserved for road, rail, water and air vehicles become blurred, interactions between vehicles on the ground and in the air will become far more complex, making it increasingly urgent to connect them in an intelligent way. DLR's cross-sectoral Transport 5.0 project harnesses the expertise of three of its major programme areas – aeronautics, space, energy and transport – to improve coordination, cooperation and communication between different modes of transport.

Communication is everything

Bringing old and new technology together poses a number of challenges – but there are a great many advantages to networking various modes of transport more closely. Air taxis and drones, including freight drones, must be able to land on the road in a controlled manner at any time in the event of an emergency. Rescue helicopters – and thus the general public – would benefit from direct communication between all parties. In the event of serious accidents, pilots would be able to safely coordinate their landing site with cars on the road, to allow relief services to reach the site more quickly and reduce the time wasted during landing and take-off. Where road meets rail, reliable communication between trains and cars at technically secured level crossings would reduce waiting times, increase convenience and ensure safe crossings. Of course, safety is the top priority in all scenarios.

Increasing digitalisation plays into the hands of the Transport 5.0 project, which will develop new mobility solutions for future transport (including automated and networked road, rail, airborne and seaborne vehicles). Twelve DLR institutes are conducting joint research into cross-sectoral networked transport, which must be cooperative, self-organised and resilient. Researchers are also investigating the technical feasibility of interdisciplinary communication and cooperation for specific use cases.

LANDING SITES FOR RAPID RESCUE OPERATIONS

According to ADAC Air Rescue, approximately 54,000 air rescue operations took place in Germany in 2018 – and around 11 percent of those were due to traffic accidents. Air rescue was often on site before the scene could be made properly safe on the ground or a suitable landing site cordoned off. As rescue helicopters often need to land on the roadway in the event of serious accidents, they must wait in the air until cars have been sufficiently cleared for them to land. This takes time and can cost lives.

As part of Transport 5.0, researchers are linking currently incompatible communications networks in the air and on the ground, by conveying information logs such that they are comprehensible for all forms of transport. During the project's initial tests, the DLR researchers simulated the helicopter using a drone. The drone requested a landing zone. Networked vehicles moving within the DLR test site received the appropriate information, stopped before they arrived at the indicated area, and thus blocked the roadway to any subsequent traffic. As soon as the drone had completed its mission and taken off again, the vehicles cleared the landing zone. Thanks to this method, a crisis situation could be greatly assisted by a relatively small number of vehicles with the right networking technology. In the wake of these initial tests and further research, the team is now planning tests with real helicopters.

DRONE-ASSISTED PARKING

If drones and vehicles within a city are to interact, they must be able to reliably communicate with one another. The results of other research projects on this topic have been incorporated into the Transport 5.0 project. One example is the AUTOPILOT project, in which researchers tested an automated, drone-assisted car parking procedure. The driver parked the vehicle at the entrance to the car park, before using a smartphone app to ask the car to park itself. A drone flew over the car park, identifying free parking spaces and obstacles. It then transmitted this information to the vehicle via a shared IT platform. The vehicle also interacted with the platform and received a message indicating which free space to park in. It then planned the route, drove there and parked autonomously.

CAR-BARRIER COMMUNICATION

In further tests, the researchers joined a consortium that included researchers from Siemens Mobility GmbH to study the exchange of information at a technically secured level crossing. It is not uncommon for serious accidents to occur there – almost all caused by road users. This is where Rail2X comes in. The basic idea: railway infrastructure and road users must communicate with each other. Some infrequently used crossings are currently secured by an on-call barrier. These are often positioned in remote locations, and often out of sight of the nearest level crossing attendant or on-duty traffic controller.

Rail2X will reduce the pressure on staff by automatically checking road users in and out and detecting when they have left the area. The barrier and the vehicle directly exchange information about whether a crossing can be made. Drivers no longer have to stop in front of the barrier to communicate their wish to cross. Instead, the vehicle can register 500 metres before the barrier and the system automatically allows the crossing, if possible. This makes traffic flow more smoothly and reduces waiting times. Simplifying how on-call barriers operate also increases their cost-effectiveness. The Rail2X technology has already been successfully tested at Markersbach in the Ore Mountains.

Beyond the scope of the project such communication between road and rail traffic also offers great potential for other applications. For example, the system can prioritise emergency vehicles over trains when crossing, so that they can reach the scene of the accident more quickly. At the moment, this is not possible due to long braking distances on the rails. Furthermore, the passing of a barrier by road vehicles can be directly included in the route planning of vehicles. In doing so, the crossing request for the calculated arrival time at the level crossing is already registered at the beginning of the journey.

On water, on land and in the air – what's next?

The research started by the Transport 5.0 project is set to continue. In addition to the use cases presented here, which will continue to develop, DLR is already working with industry partners and public authorities to set up a digital test field for autonomous inland waterways on the Oder-Spree Canal. Among other things, the researchers will investigate the use of autonomous inland waterways for urban freight transport, with the aim of using digital assistance systems to improve the energy and resource efficiency of waterway navigation and minimise the risk of accidents.

Cross-disciplinary rescue operations are another area that could see improvements. For example, here, it would be vital to define common communication standards and to establish the legal basis for, for example, authorising vehicles to block a road on behalf of an airborne rescue service. DLR is planning more activities in this area in collaboration with stakeholders from rescue organisations.

Anika Lobig works at the DLR Institute of Transportation Systems and coordinates the cross-sectoral Transport 5.0 project. **Jasmin Begli** is responsible for communications at DLR's sites in Braunschweig, Cochstedt, Stade and Trauen.

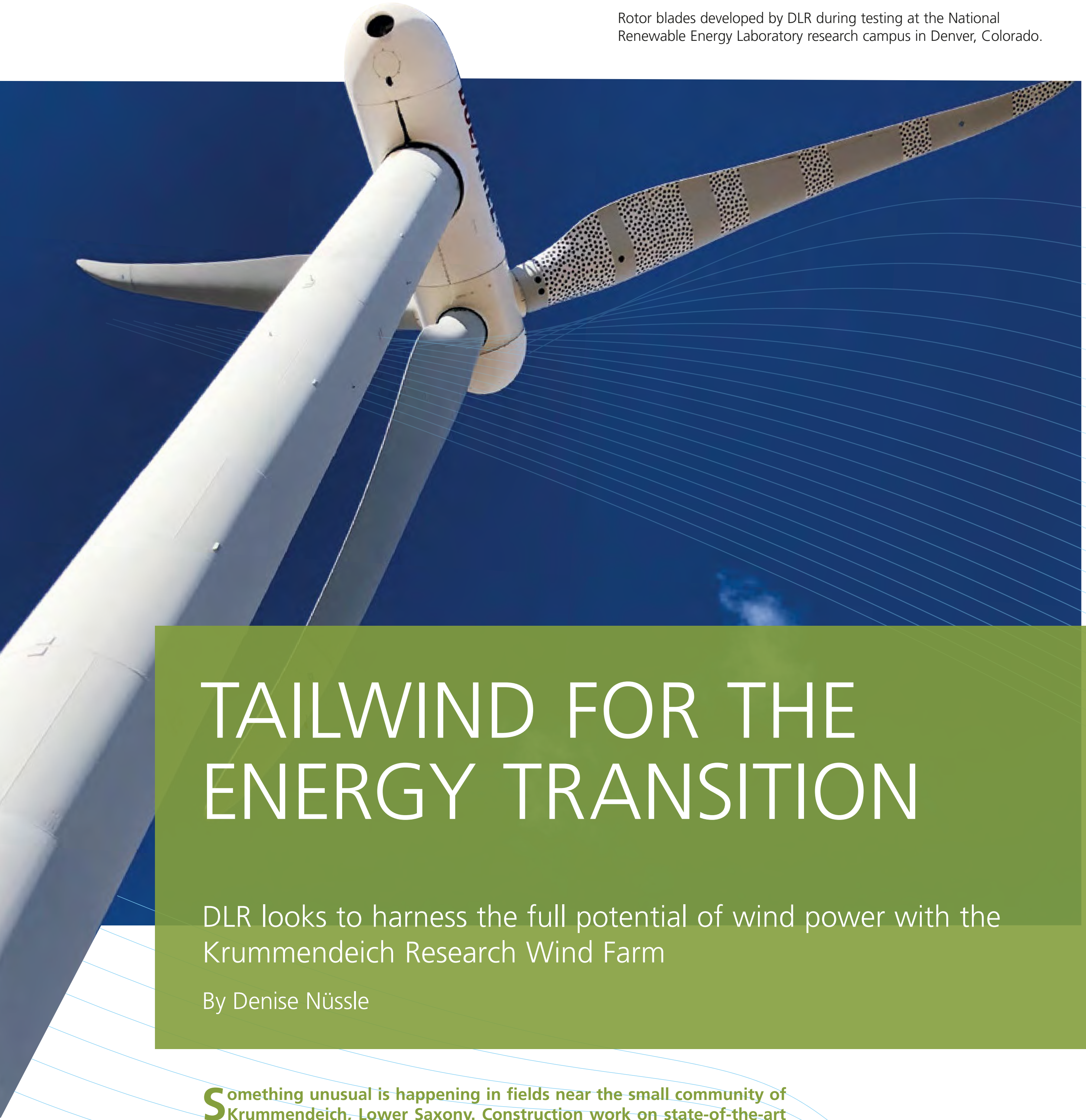
THE CROSS-SECTORAL TRANSPORT 5.0 PROJECT

Duration:
01/01/2018–31/12/2021

Total budget:
approx.12.6 million euro (over the entire project lifetime)

Participating DLR institutes and facilities

- Institute of Transportation Systems
- Institute of Optical Sensor Systems
- Institute of Vehicle Concepts
- Institute of Transport Research
- Institute of Flight Guidance
- Institute of Air Transportation Systems
- Space Operations and Astronaut Training
- Institute of Communications and Navigation
- Institute of System Dynamics and Control
- Institute of Aerodynamics and Flow Technology
- Institute of Engineering Thermodynamics
- Institute of Robotics and Mechatronics



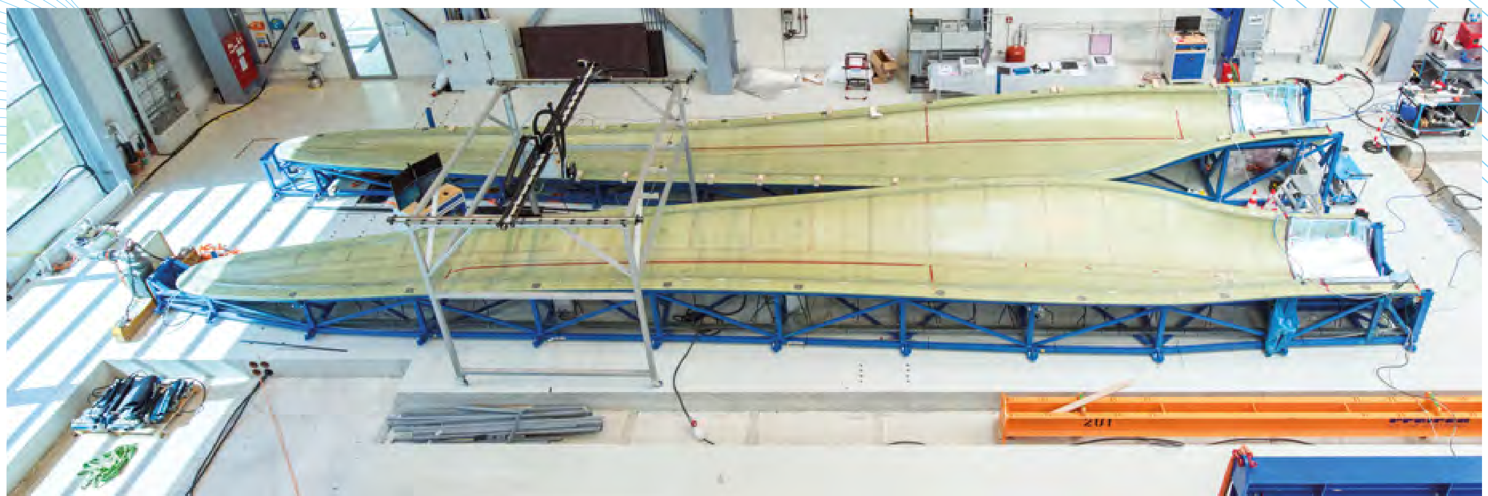
Rotor blades developed by DLR during testing at the National Renewable Energy Laboratory research campus in Denver, Colorado.

TAILWIND FOR THE ENERGY TRANSITION

DLR looks to harness the full potential of wind power with the Krummendeich Research Wind Farm

By Denise Nüssle

Something unusual is happening in fields near the small community of Krummendeich, Lower Saxony. Construction work on state-of-the-art research infrastructure has been underway here since May 2021. Right beside the River Elbe, DLR is building the Krummendeich Research Wind Farm together with partners from the Research Alliance Wind Energy (Forschungsverbund Windenergie; FVWE). The aim is to cut the cost of generating energy from wind power by 25 percent by 2035. To achieve this, wind turbines will need to be more efficient and offer the power grid greater flexibility. Improved aerodynamics and the use of lighter and more robust materials and smart control systems will also be needed to sufficiently advance wind turbine technology. At the same time, it is also important to continue to limit the impact on local people and the environment as much as possible. DLR researchers are actively developing new approaches and solutions to all of these challenges.



Intelligent rotor blades that can adapt to the current wind conditions are being developed for wind turbines at the DLR site in Stade

Wind power – a cornerstone of the future energy supply

In Germany, wind energy already accounts for the largest share of electricity produced from renewable sources. It will continue to play an important role in the future because the demand for renewable energy will grow in tandem with the adoption of new technologies for electromobility and the production of green hydrogen as a versatile source of energy, all part of the sustainable transformation of the energy and transport sectors. Current wind turbines already generate 20 times more power than their predecessors from 1990. A modern turbine with an output of approximately three megawatts can generate electricity for approximately 2000 households. Research suggests that wind turbines could have a capacity of 20 megawatts or more in future.

"Wind power has enormous potential; we just need to harness it. During the energy transition, it has reached a scale and a level of importance unimaginable in its early days. But there is still a clear technological learning curve to be addressed in many areas," says Jan Tessmer. He leads DLR's Wind Energy Experiments facility, which is responsible for setting up and running the Research Wind Farm. This is also where wind energy research at DLR is coordinated, with a large number of institutes contributing across the individual disciplines. "At the same time, in recent years, the cost of generating electricity using wind power has fallen more than we could have expected in our wildest dreams. We want to build on this development," continues Tessmer. His team found that Krummendeich, well known for its wind, offers the ideal research conditions.

A stroke of luck for science – full-scale research

Once the Research Wind Farm is complete, two highly advanced wind turbines will stand one in front of the other, aligned in the direction of the prevailing wind: west-southwest. This will allow the researchers to study in detail the effect of the two turbines on each other. Most of the electricity they produce will be fed back into the grid. A third, slightly smaller wind turbine will have a modular structure and will allow the DLR researchers to study fundamental issues such as aeroelastic phenomena in the rotors. A total of five measuring masts between the three wind turbines will hold and align an array of sensors. Among other things, these will analyse the wind speed and direction, temperature and humidity, pressure and sound. All this information will feed into the control centre located in close proximity to the turbines.

"With this set-up, we now have unique infrastructure at our disposal," says Jan Tessmer. "We can examine a range of technological issues related to harnessing wind power. We will be looking specifically at which aspects need to be further developed to make wind turbines quieter, more efficient and more cost-effective. The Krummendeich Research Wind Farm will also be made available to the scientific community as a test site." Whether studying rotor blades with a new structure, shape, material or design, the optimal control and operation of wind turbines, or noise reduction, there is a long list of exciting scientific questions to address. Once the wind farm is up and running, researchers will be able to use the extensive data generated there to verify the results of their models and computer simulations and continuously improve them to the stage at which they are ready for the next phase of experimental testing. With all this on the horizon, the team cannot wait to get started. If everything goes according to plan, trial operation will begin in the second half of 2022.

"Wind power has enormous potential; we just need to harness it. During the energy transition, it has reached a scale and a level of importance unimaginable in its early days."

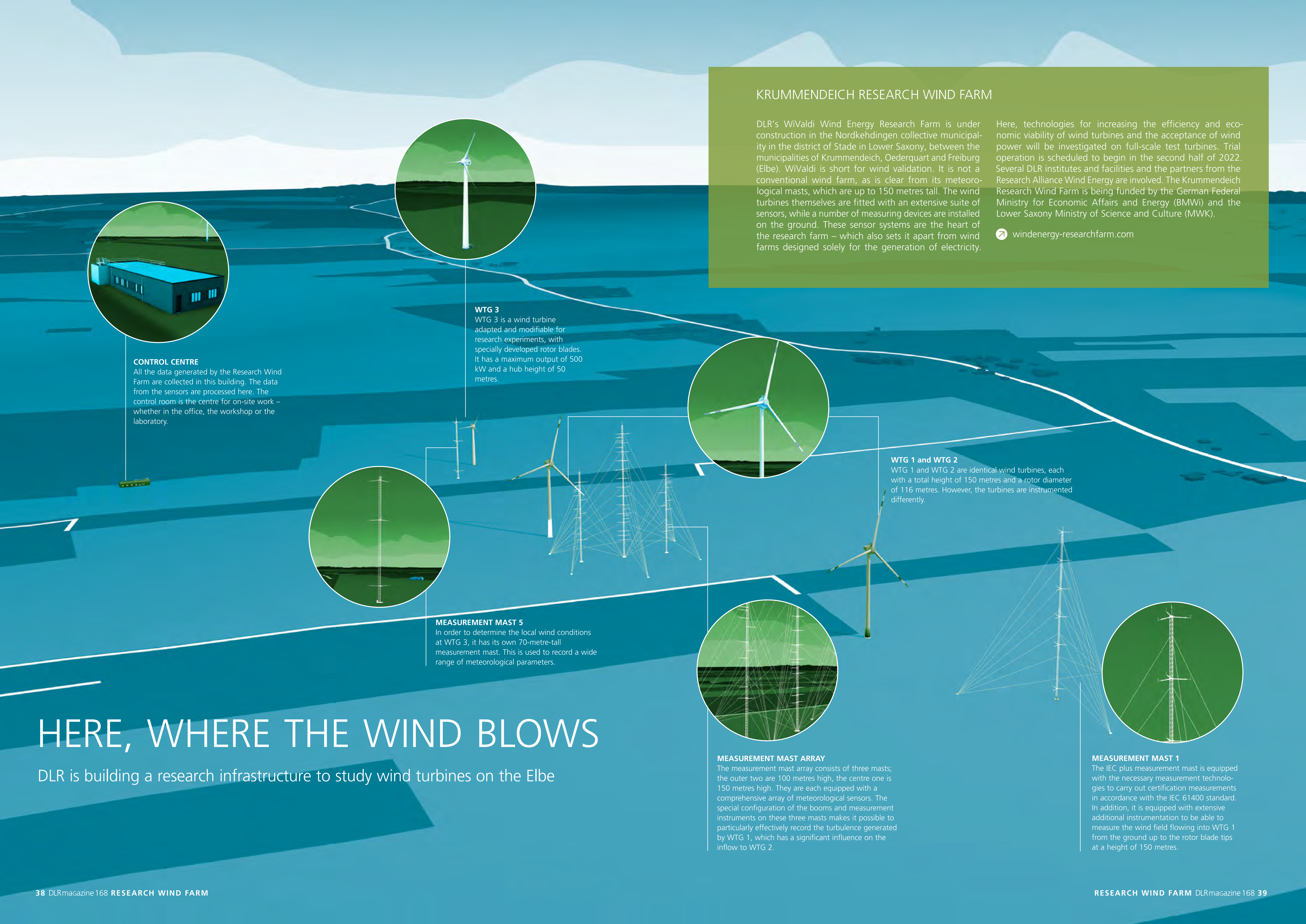
Jan Tessmer

Denise Nüssle is an editor in the Media Relations department.

GROWIAN'S SUCCESSFUL HEIRS

Germany took its first steps towards harnessing wind power in the 1980s, with the Growian (Große Windenergieanlage; large wind turbine) test facility. The project was beset by technological issues and enjoyed little success. However, the tide began to turn when the Electricity Feed-in Act and Renewable Energy Sources Act were passed in the 1990s and 2000s. Wind power was then widely promoted and actively expanded. Germany is now one of the world's leading nations in the field of research, development and turbine construction.

DLR and its predecessor organisations have repeatedly made important contributions to technological progress in the field of wind power. Albert Betz, physicist and Director of the Aerodynamic Research Institute (Aerodynamischen Versuchsanstalt; AVA) in Göttingen, laid the scientific foundations for wind turbines as early as 1920. Another example was the manufacture of rotor blades from fibre composite materials in the late 1970s. These were approximately 40 percent lighter and more cost-effective than earlier rotor blades.



HERE, WHERE THE WIND BLOWS

DLR is building a research infrastructure to study wind turbines on the Elbe

KRUMMENDEICH RESEARCH WIND FARM

DLR's WiValdi Wind Energy Research Farm is under construction in the Nordkehdingen collective municipality in the district of Stade in Lower Saxony, between the municipalities of Krummendeich, Oederquart and Freiburg (Elbe). WiValdi is short for wind validation. It is not a conventional wind farm, as is clear from its meteorological masts, which are up to 150 metres tall. The wind turbines themselves are fitted with an extensive suite of sensors, while a number of measuring devices are installed on the ground. These sensor systems are the heart of the research farm – which also sets it apart from wind farms designed solely for the generation of electricity.

Here, technologies for increasing the efficiency and economic viability of wind turbines and the acceptance of wind power will be investigated on full-scale test turbines. Trial operation is scheduled to begin in the second half of 2022. Several DLR institutes and facilities and the partners from the Research Alliance Wind Energy are involved. The Krummendeich Research Wind Farm is being funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) and the Lower Saxony Ministry of Science and Culture (MWK).

windenergy-researchfarm.com

CONTROL CENTRE
All the data generated by the Research Wind Farm are collected in this building. The data from the sensors are processed here. The control room is the centre for on-site work – whether in the office, the workshop or the laboratory.

WTG 3
WTG 3 is a wind turbine adapted and modifiable for research experiments, with specially developed rotor blades. It has a maximum output of 500 kW and a hub height of 50 metres.

WTG 1 and WTG 2
WTG 1 and WTG 2 are identical wind turbines, each with a total height of 150 metres and a rotor diameter of 116 metres. However, the turbines are instrumented differently.

MEASUREMENT MAST 5
In order to determine the local wind conditions at WTG 3, it has its own 70-metre-tall measurement mast. This is used to record a wide range of meteorological parameters.

MEASUREMENT MAST ARRAY
The measurement mast array consists of three masts; the outer two are 100 metres high, the centre one is 150 metres high. They are each equipped with a comprehensive array of meteorological sensors. The special configuration of the booms and measurement instruments on these three masts makes it possible to particularly effectively record the turbulence generated by WTG 1, which has a significant influence on the inflow to WTG 2.

MEASUREMENT MAST 1
The IEC plus measurement mast is equipped with the necessary measurement technologies to carry out certification measurements in accordance with the IEC 61400 standard. In addition, it is equipped with extensive additional instrumentation to be able to measure the wind field flowing into WTG 1 from the ground up to the rotor blade tips at a height of 150 metres.

ON THE SUNNY SIDE

Ten years of the DLR Institute of Solar Research

By Michel Winand

At DLR's Jülich site, the Institute operates a solar thermal tower power plant (left). Since 2020, the site is also home to the Multifocus Tower (right), in which new solar technologies can be tested.

Image: DLR

Robert Pitz-Paal (left) and Bernhard Hoffschmidt are the joint directors of the DLR Institute of Solar Research

An abundance of energy, available almost anywhere in the world and with no climate-unfriendly emissions. It might sound too good to be true, but the Sun could help us fulfil these ambitions. However, first humankind must develop technologies that can harness this potential. Bernhard Hoffschmidt and Robert Pitz-Paal have jointly led the DLR Institute of Solar Research for 10 years. In that time, they have built up a motivated team dedicated to this task. Since the establishment of the Institute, the questions surrounding the nature of future energy supplies have gained in importance. In this interview, they discuss the past, present and future of their research.

Where did solar research at DLR begin?

Pitz-Paal: As early as the 1970s, DLR researchers at the sites in Stuttgart and Cologne were conducting research into how solar energy could be used to generate electrical power. In the late 1970s, the International Energy Agency entrusted DLR with managing the development and construction of a first experimental facility for solar thermal power generation. The Plataforma Solar de Almería (PSA) in southern Spain was established with participation of nine countries. Researchers from DLR and the Spanish research centre CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas) have been working there together since 1984.

Hoffschmidt: In 2002, DLR's solar research activities were consolidated to form a department within the Institute of Engineering Thermodynamics. The commercial spread of solar thermal technologies began to pick up speed in Europe in 2007, which provided an opportunity to turn the department into its own institute. This was followed by an exciting time in which we founded a new DLR site here in Jülich and converted a commercial demonstration power plant into a large-scale test facility.

Has the Institute's portfolio changed since its establishment?

Pitz-Paal: In the early days, we tended to focus more on parabolic trough technology. However, we realised that although tower technology was at an earlier stage of technological readiness, its potential cost-effectiveness was likely greater. As a result, the focus of our research has shifted more towards tower power plants. Just last year, we opened a new facility, the Multifocus Tower in Jülich, which has three experimental levels in which new technologies for concentrated solar radiation can be tested.

Hoffschmidt: In addition, a new institute was founded from one of our departments – Future Fuels. Everything here revolves around climate-neutral fuels.

LIGHT BECOMES ELECTRICITY

Since its establishment in 2011, the Institute of Solar Research has been researching and developing Concentrated Solar Power (CSP) systems for solar thermal power plants that convert solar energy into heat, electricity and fuels. This includes parabolic trough technology, Fresnel collectors and solar tower systems. With parabolic trough technology, a concave mirror concentrates solar radiation. At the focal point of the mirror trough is a tube through which a liquid flows, which is heated by the concentrated radiation and evaporates. The steam is then used to drive turbines. Fresnel collectors are similar to parabolic trough collectors but have a flat, sanded surface. In a solar tower power plant, several hundred steerable mirrors direct sunlight towards a receiver on the top of the tower. This can generate temperatures of up to 1000 degrees Celsius, which are used to vaporise water.

Other research topics addressed by the Institute include the development of new heat transfer mediums and the measurement and evaluation of components for solar thermal power plants. The scientists are also conducting research into related areas. The sensor technologies developed at the Institute are used, for example, to determine the energy-related renovation requirements for buildings, while the Energy Meteorology group develops systems to increase the efficiency of solar power plants and photovoltaic systems. The aim of research conducted at the Institute is to increase the efficiency of solar energy and heat generation and thus lower the costs of production. The Institute operates various large-scale facilities at its sites in Cologne, Jülich, Stuttgart and Almería (Spain), allowing it to address the entire research chain from the laboratory through to industrial applications.

How has the growing importance of the climate and sustainability in public discussion affected your work?

Hoffschmidt: Overall, it has been very positive. At the political level, for example, our topics were included in the German Federal Government's 7th Energy Research Programme and the EU's Strategic Energy Technology Plan as early as 2018.

Pitz-Paal: There has also been a marked increase in general interest. We are receiving ever more enquiries from students who want to work at our Institute. We also get media enquiries; even educational children's television programmes are showing an interest.

You work closely with the business community and have launched various spin-offs as independent companies. How do you encourage such developments?

Hoffschmidt: We are very proud that we have managed to bring many of our findings into practical application. Solar collectors or measurement processes that we helped to develop are now being used in 90 percent of the relevant systems installed worldwide. The initiative usually comes from the employees themselves, as they are keen to commercialise their research topics and ideas. Of course, the Institute has to provide fertile soil for this type of endeavour. In our experience, successful spin-offs inspire others to do the same.

Energy will be an increasingly important topic in the coming decades. How will the Institute of Solar Research respond to this?

Pitz-Paal: There are a number of major challenges in terms of addressing climate change in time and with technologies that can be implemented quickly. In addition to the expansion of solar thermal power plants for generating electricity, the provision of industrial process heat is going to become increasingly important. The combination of photovoltaics and solar thermal technology will also gain prominence. Together, these two types of technology make an essential contribution towards a reliable and cost-effective energy supply system. Finally, we will also transfer our expertise in the field of non-contact measurement technologies to other areas of application, such as building technology and photovoltaics.

This interview was conducted by **Michel Winand,** who is responsible for communications at DLR's Cologne, Bonn, Jülich, Rheinbach and Sankt Augustin sites.

Image: DLR

BREAKING NEW GROUND ON THREE FRONTS

From batteries in space to drones for disaster management – new ideas and technological advances come to life at DLR.

By Iris Werner and Silvia Oster

The unwieldy names of research institutes can often obscure the work that people actually carry out in their laboratories. 'Researcher at the Institute of Engineering Thermodynamics'? 'Scientist at the Institute of Composite Structures and Adaptive Systems'? Or 'Director of an Innovation Lab at the Institute of Optical Sensor Systems'? To many, these names mean little. But what if we talk about a mathematician who tests batteries for space, a materials engineer who uses virtual reality or a geoinformatics engineer who flies drones? These sound far more exciting and more informative – and completely different from each other.

Yet there is one thing that connects these three people. Beyond the fact that they all work at DLR, they have a common mission – to carry out responsible, pioneering work. They are researching solutions for long-lasting battery storage systems, using digitalisation to simplify and reduce the cost of production in aircraft construction and using drone reconnaissance to ensure rapid assistance in crisis situations. In short, Linda Bolay, Sven Torstrick-von der Lieth and Julia Gonschorek are using their knowledge to drive change. They present their research here under the heading 'Shaping the future'.

Nowadays, travelling from A to B requires using satellites – they control navigation and Earth observation systems. Their ability to precisely determine the position of objects on Earth is also important for land surveying and autonomous driving. Satellite monitoring also reveals the processes driving global change and facilitates targeted action.

Image: DLR/Sebastian Berger

"I'm speeding up the development of lithium-ion batteries for use in space."
Linda Bolay

Yet, as always, nothing can be achieved without energy. When flying through space, satellites need reliable batteries. These are tested extensively in the laboratory or on test stands prior to launch – often over a number of years. Satellite batteries in particular must be extremely safe and reliable as once in space, they are exposed to extreme temperatures and cannot be replaced. Linda Bolay's response to this challenge is to develop a model that accurately simulates the chemical and physical processes in the battery and should make these lengthy tests less laborious.

Linda Bolay is a mathematician and works with her team at the DLR Institute of Engineering Thermodynamics in Ulm on speeding up battery tests and experiments by using theoretical models. Her computer model is designed to determine the state of charge and condition of a battery on the basis of temperature, voltage and current measurement data alone. This could reduce the time needed to test batteries – currently several years – to just a few experiments. Ideally, it could even improve the service life of the batteries.

Image: DLR/Ingo Boelter

"My vision of the production plant of the future? One that supports a more flexible, simplified and cost-effective aircraft production process."
Sven Torstrick-von der Lieth

Those who associate virtual reality purely with video games should take a close look over **Sven Torstrick-von der Lieth**'s shoulder. With his interdisciplinary team from the fields of mechanical engineering, aerospace engineering and computer science, he is researching the manufacture of aircraft structures and is examining their production processes.

There is something special about his 'laboratory': at the Institute of Composite Structures and Adaptive Systems in Stade, DLR operates a complete production line for the aircraft manufacturing process. Entire wing shells, aircraft fuselages and other components are produced fully automatically here. Using this infrastructure, Torstrick-von der Lieth's team achieves realistic results and can detect any problems immediately. Instead of inspecting finished components for damage, they optimise the entire production process to almost entirely prevent defects in the finished product. And they go even further: they use virtual reality applications to optimise automated production processes and render them transparent. They are connecting the physical with the virtual.

How does that work? Workers receive error messages from a machine on a smartphone. Ideally, they can fix the problem immediately with the help of a tutorial played in their smart glasses. In more difficult cases, they can seek help from the manufacturer, who uses virtual reality to connect to the plant remotely. Sounds easy ...

Drones are rapidly conquering our airspace, can be deployed flexibly and are therefore now taking on a wide range of tasks. **Julia Gonschorek** uses them in civil protection and disaster management, connecting optical imaging technologies with geodata and on-board data processing. The result is reliable real-time reconnaissance that can help better coordinate emergency services on the ground.

Gonschorek and her team have a common goal: to address the needs of both users and industry when it comes to precisely clarifying a situation that is not very clear. They want to use optical imaging technologies during disasters, policing operations or major events to accurately evaluate situations and support the authorities and emergency services. The technologies for this include complex camera systems and operate on board crewed and uncrewed aircraft.

Their solution is based on a special camera for airborne image data acquisition and processing that Gonschorek and her team developed at the DLR Institute of Optical Sensor Systems. Working with the Duisburg fire service, they are currently testing the system under realistic conditions. In the event of an emergency, an airborne vehicle automatically flies to the scene of an incident and provides high-resolution aerial images and maps to the control centre in real time. This saves the emergency services valuable time that can help save lives.

Image: DLR

"In our lab we are developing new optical technologies for situational awareness."
Julia Gonschorek

Iris Werner works in the Human Resources Marketing department.
Silvia Oster works at the Project Management Agency.

Entry and career opportunities at DLR can be found at

DLR.de/jobs/en

TEAMING UP FOR SPACE

The IRAS development platform for low-cost satellites is coming to life

By Maike Busch

Satellite production today is still very much a low-volume, high-cost industry. Satellites are one-off items for which component parts are not available on the commercial market, which makes them very expensive. How can satellites be produced more cost-effectively in future? Tina Stäbler from the DLR Institute of Structures and Design in Stuttgart and her team are looking into this as part of the Integrated Digital Research Platform for Affordable Satellites (IRAS) project. To this end, they are researching technologies that can be used to streamline satellite production and developing a collaboration platform. The aim is for potentially competing companies or research facilities to use it to work collaboratively on a satellite design – all on their own computers.

The success of their project depends on the increased digitalisation of the space industry. Digitalisation is influencing the development, production and operation of satellites, and also allowing the improved use of acquired data with new software. "The availability of all this information in a consistent, digital and machine-readable format would significantly speed up every step – from design through to production," says Stäbler. When process chains are digitalised, only minimal manual inputs are required.

The digital platform on which the DLR team is working forms the basic framework of the IRAS project. It enables all parties involved in the development of a satellite to work together in the same digital space. The required programs – such as software for the design of a satellite constellation and optimisation of the spacecraft – will be incorporated using specialised interfaces. Data access will be regulated to ensure that companies remain in control of their proprietary software. This will make it easier to initiate consortia and joint projects. Although the platform is still under construction, an initial prototype is expected to be completed in 2022.

A ceramic nozzle structure straight from the 3D printer. Manufacturing methods such as this, in which the material is applied precisely, layer by layer, reduces volume.

New production methods save time and materials

Every gram of payload transported into space requires many times its mass in fuel. The smaller and lighter a satellite is, the more affordable and sustainable it becomes. For the DLR researchers, the solution lies in additive manufacturing, a process by which material is applied layer by layer to create three-dimensional objects. This method has several advantages; it allows one-off items to be made without great additional effort and facilitates the optimisation of designs in ways that would not be possible with conventional manufacturing processes. Not only does this reduce structural weight, but also volume. Cables, connectors and electronics can often be integrated directly into the component. For Stäbler, this opens up promising opportunities for DLR researchers: "The combination of the new manufacturing methods and a digital platform that brings everything together is putting the aim of affordable satellite production within reach."

The team also keeps sustainability in mind during its work. "Together with the Institute of Space Systems of the University of Stuttgart, we are researching electric and water-based propulsion systems for satellites, which do not require toxic or environmentally hazardous propellants," explains Stäbler. These will also become more efficient and flexible thanks to additive manufacturing. A tool for designing satellite constellations, also developed here, incorporates feasible end-of-life concepts that ensure satellites do not end up as space debris. A research team will also be set up at DLR to consider how individual satellite components must be designed to ensure that they burn up completely during atmospheric re-entry. Other technologies are being used to facilitate the use of commercial electronics in space with the help of radiation shielding. These additive manufacturing techniques are being developed by DLR in cooperation with the Fraunhofer Institute for Manufacturing Engineering and Automation IPA.

Tina Stäbler completed her aerospace studies at the University of Stuttgart in 2014 and went on to obtain a doctorate with a dissertation written at DLR in the field of health monitoring of thermal protection systems in space. She has been the project manager for IRAS since 2018.

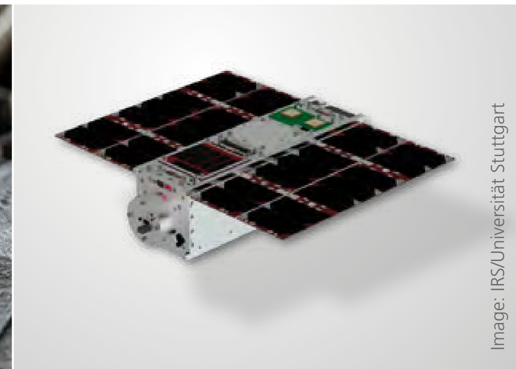
On the way to a first flight

IRAS technologies will be used for the first time in the Stuttgart Operated University Research Cubesat for Education and Evaluation (SOURCE) satellite, which is being constructed by the University of Stuttgart and its small satellite student society, KSat. Among other things, the DLR team is developing an additively manufactured multi-functional structure containing an experiment with shielded and unshielded electronics as a payload. During the flight, the researchers want to test new shielding techniques for protection against cosmic radiation on commercially available, and therefore less expensive, electronics.

SOURCE is due to launch in 2022. Stäbler is convinced that the investment in IRAS will be worthwhile: "Leading market research companies forecast that by 2040 market volume of the space sector will exceed that of today's motor industry. We are potentially on the verge of incredible growth and must remain competitive at an international level. This is where independent research is especially in demand."

Maike Busch is responsible for communications at the DLR Institute of Structures and Design.

This multifunctional satellite structure was manufactured at the DLR Institute of Structures and Design. Integrated within it are low-cost automotive electronics.



The Stuttgart Operated University Research Cubesat for Education and Evaluation (SOURCE) is being built by the Institute of Space Systems of the University of Stuttgart and the student small satellite group KSat.

VIEW FROM ABOVE

Automated condition monitoring of solar power plants with DLR technology

By Verena Müller

Electricity from solar energy is often generated in square kilometre-sized power plants. These industrial facilities are usually found in desert regions. The operating companies must constantly be informed about their condition. Are there any faulty components? Are there any parts requiring maintenance? This information is crucial, because even slight damage or partial failures can entail significant costs. The DLR spin-off Volateq GmbH develops and distributes a software tool for condition monitoring of solar fields. Drones collect the required data in just a few hours. The results allow the operators to plan operational and maintenance tasks, as well as optimise the productivity of the plant and improve safety.

"Current manual counting and measurement routines undertaken by technicians are extremely time consuming and incomplete. A drone can do this tedious job much more quickly, allowing the staff to dedicate their time to maintenance tasks," says Anne Schlierbach. She founded Volateq in 2020 with Christoph Prahl and Wolfgang Reinalter. Before that, they conducted research together for more than 10 years at the DLR Institute of Solar Research at its site in Almería, in Andalusia in Spain. For Schlierbach, this has been the key to the success of the spin-off: "We complement each other both technically and personally and have an open and respectful relationship. We are now growing together and looking forward to bringing such a wonderful technology to market."

Drones are the ideal helpers

During their time at the Institute, the team developed the QFly technology alongside their DLR colleagues. It is the heart of the Volateq software and, using drone-assisted image acquisition, can be used to generate highly accurate data on the geometry and tracking of the solar field. To evaluate the condition of the plant, the operational staff fly a drone on a predefined route over it. For a few hours, the device's cameras collect data in the visual and infrared range. The image data is uploaded and automatically evaluated using cloud computing.

The analysis tool has been designed in such a way that it is easy to incorporate into existing operating routines. Measurements are carried out continuously and analysed in a fully automated manner. For Wolfgang Reinalter, the drones are "the perfect helping hand to efficiently detect and localise weaknesses in the plant and plan improvement measures."

When plant operators began to show great interest in using QFly, the team decided to branch out on its own. With support from DLR Technology Marketing, they developed the technology to the extent that it could be launched into the market as a cloud-based service in 2020. The entry into the market started with CSP power plants. The team has already expanded the analysis technology to make it suitable for monitoring photovoltaic power plants as well. This enables it to be used for all solar power technologies, including hybrid power plants. They are also developing a 'drone in the box' concept – a fully automated system that takes off at the touch of a button and performs all the necessary measurements without requiring a pilot to monitor the flight.

At home in Andalusia and North Rhine Westphalia

In addition to Cologne, they also plan to establish a site for their new company in Almería. Long-term research cooperation with partners such as the Plataforma Solar de Almería (PSA), a research centre to study the use of solar energy, made this a natural decision. The first European solar power plants were set up in Andalusia and Spain is home to approximately one third of the world's CSP plant capacities. During their time at the Institute, the team also established good connections with Spanish partner companies. "We have received great deal of positive feedback on our technology," says a pleased Christoph Prahl. "We are passionate about sustainability and renewable energies. Through the application of our research, we are exploiting the potential of solar power and driving forward green technologies. This is very important to us. Our goal was to both make something of our own and to improve sustainability."

Verena Müller is a coordinator at DLR Technology Marketing.

Image: Volateq GmbH

From left to right: Anne Schlierbach, the 'networker', is responsible for marketing and sales and has been working on concentrating solar power projects since 2008. Christoph Prahl, the 'specialist' for technology and software, has been focusing on the optimisation of solar thermal applications since 2008. Wolfgang Reinalter, the 'balancer', is responsible for financial matters and software development and is an international solar power expert and project manager.

Image: DJI

VOLATEQ GmbH

... was founded in 2020, emerging from the DLR Institute of Solar Research site at Almería. The company provides Intelligent Image Analytics for automated drone-based Condition Monitoring of utility Scale Solar Fields. The most important condition variables of these plants are analysed using the images acquired by the drones. To this end, the QFly technology developed at DLR and licensed by Volateq is being expanded and marketed as 'Software-as-a-Service'. In doing so, Volateq is supporting solar power plant operators with the implementation of sustainable and efficient operational management.

volateq.de

THE IDEA HUNTERS

How DLR is bringing new technologies into the economy

The first digital airborne camera, a solar receiver for high-temperature applications, modular fuel cell systems for cargo bicycles and a heating method that can be used to repair fibre composites. These are just some of the technologies that have emerged in recent decades. We spoke with Professor Karsten Lemmer about the role that innovation plays for DLR today. He is member of the DLR Executive Board and has been responsible for 'Innovation, Transfer and Research Infrastructure' since March 2021.

What does technology transfer mean to you?

: At DLR, we are striving to build a successful economy through scientific research. Our expertise is concentrated in our core research topics of aeronautics, space, energy and transport, so these are the areas in which we can make the greatest impact. For example, we are developing vehicle and aircraft prototypes, such as the modular autonomous vehicle U-Shift and the Dornier 228 propeller aircraft, which is being converted into a hydrogen fuel cell aircraft in cooperation with our industrial partners. But that's not all; transfer as I understand it takes place at almost all levels. The focus is on our researchers, who take immediate or future technology transfers into account during their work. We create financial and communications mechanisms that facilitate this, reinforced by expert colleagues who provide personalised support and advice for successful transfer activities.

Why is technology transfer important for DLR?

: We transfer knowledge and technology every day, not only through spin-offs – although we have those as well, there were six in 2020, for example. We have excellent networks, prizes and formats for early-stage idea generation, as well as powerful IT tools for trend analysis. Our colleagues in the institutes are constantly attracting third-party funding from a wide range of clients, as well as implementing research projects across all programme areas using core funding. From the outset, our researchers think about the added value that their research results can bring to the economy and society.

What role does DLR infrastructure play in facilitating the practical application of scientific findings?

: Our wind tunnels, fleets of research aircraft and vehicles, test fields and simulators, as well as our new research wind farm, can all support the upscaling of technologies. They are important for our partners in scientific research and industry – particularly for smaller organisations that cannot afford to maintain and operate such infrastructure themselves. Bringing technologies from laboratory scale to market maturity requires many tests, which is just where these types of research facilities come in. Here, research and industry work hand in hand, which is key for understanding requirements and market needs.

What do you want to achieve with your new board-level responsibilities?

: It is important that we embrace the entire range of possible transfer activities: planting the seeds of innovative ideas, operating large-scale research facilities, conducting research in real-world laboratories, developing prototypes, facilitating spin-offs and start-up funding, protecting intellectual property rights, and forming an entrepreneurship culture and strong networks. All of this needs to grow together to create a vibrant culture of innovation throughout DLR – from the institutes to the administration. This is the only way to supply the 'innovation pipeline' in the long term – something we are committed to achieving.

This interview was conducted by **Julia Heil,** an editor in DLR's Communications department.

Karsten Lemmer
is the DLR Executive Board Member for the new division 'Innovation, Transfer and Research Infrastructure'.

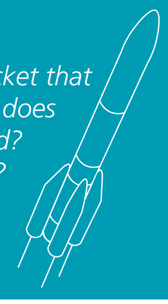
YOUR QUESTIONS ANSWERED

Our researchers answer questions from the community

Asking questions is key to improving your understanding of how and why things work as they do. Particularly in science, an inquiring approach is indispensable for addressing and better understanding complex topics. We regularly receive questions about a wide range of scientific subjects on our social media channels, by letter or by email. If you too have a question you would like to ask, please contact us at magazin@dlr.de.

Question from Stefan via Facebook:

Assuming you are flying in a rocket that travels forever in a straight line, does space eventually come to an end? Or will you eventually hit a wall?



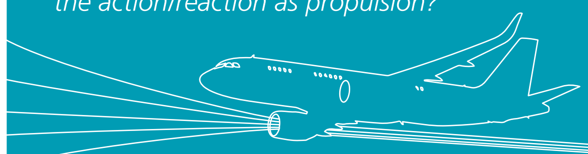
The existence of an 'edge' of the Universe is one of the oldest questions in philosophy. What we currently know is that the Universe has existed for a finite time and is constantly expanding. All the galaxies are constantly moving away from one another and, the further away they are, the faster they are moving apart. Einstein's General Theory of Relativity states that this motion causes time dilation. The effect is measurable in the way the wavelengths of visible light are stretched (moved towards the infrared) on their journey to Earth. Then there is the Big Bang. Since the creation of the Universe, light has had approximately 14 billion years to propagate. No matter where an observer is located in the Universe, they can only see things up to approximately 14 billion light-years away. But that does not mean that the Universe is only this size, because no observer is at its centre.

Then it becomes more complicated because there are competing theories about whether the Universe is 'open' or 'closed'. If the total mass of the Universe is large enough, it has a boundary that cannot be crossed – similar to a black hole. However, the boundary is not a 'wall', but a curvature of space – and 'straight ahead' no longer means what one thinks of in everyday life. In the General Theory of Relativity, this is described by the curvature of four-dimensional spacetime. In some horror films, there are scenes where characters escape from a city heading west, only to end up where they started, arriving from the east. This city is like a closed universe but it has no walls. Simply put, you can keep your rocket engine running without any fear of hitting an outer wall. You should just be careful not to collide with stars, planets or the spaceships of other inquisitive travellers!

Martin Knapmeyer, DLR Institute of Planetary Research, Berlin

Question from Admir via Instagram:

"Would it be possible to compress air in front of an aircraft and expel it again at the rear to use the action/reaction as propulsion?"



The principle of action and reaction is, in fact, the mechanism that has been used for the propulsion of motorised aircraft since the beginning of aviation. First, propellers were mounted on the aircraft nose, then on the wings. The propeller blades compress and accelerate the air, generating propulsion. In combination with the special shape of the wings, this creates lift. Over the course of aircraft development, propellers were replaced by higher-performance jet engines which now have large fan stages at their intake. Today, these provide the necessary thrust for large passenger aircraft. The airflow exiting from the rear of the engine generates the necessary propulsion by exploiting the principle of action and reaction. In military aircraft, the jet engine is fully integrated within the aircraft fuselage, in order to achieve higher flight speeds by making the shape of the aircraft more aerodynamic. However, in none of these types of engines would it be of any benefit to move the compression of the air for propulsion further towards the front of the aircraft.

Melanie Voges, DLR Institute of Propulsion Technology, Cologne

HAND IN HAND

The DLR Project Management Agency for Aeronautics Research and Technology supports the German Federal Government in shaping the aviation of tomorrow

By Anne Lohoff

Humanity has been captivated by the idea of flight for thousands of years. The dream finally became reality a little over a century ago. Much has happened since. In recent decades, we have become acquainted with the concept of uncrewed flight, safe flying machines and low-emission flying. These ideas have been brought to fruition by businesses and research facilities that continue to be bold enough to launch research projects and missions. All these pioneers are supported by the Project Management Agency for Aeronautics Research and Technology. It assists and advises experts, researchers, and federal and state ministries in the field of aeronautics.

Very few would dispute the need for the transformation of air transport, no matter their interest group, age or sector. Yet the implementation of such a transition is the subject of fierce debate. Opinions on this subject are so multifaceted, the technologies so complex and the circumstances so unique that making the right decisions is no easy feat. The Project Management Agency for Aeronautics Research and Technology was set up back in 1994 to support the Federal Government with this decision-making. The agency brings together administrative and technical expertise on aviation topics in order to provide government ministries with neutral advice.

Federal and state ministries regularly put funding programmes for the aviation sector out to tender. The invitations to tender are intended to encourage companies, universities and research facilities to support the Federal Government's aviation strategy. The Project Management Agency for Aeronautics Research and Technology acts as an administrative assistant in this regard, bringing together and coordinating the tenders.

The big picture

Researchers who have worked in aviation consistently say how idiosyncratic the sector is, particularly in aspects such as the enormous number of regulations involved in approval procedures, the lengthy development times, and the structure of the supply chains. At the same time, the sector faces major challenges, for example in ensuring safety and reducing its carbon footprint.

The requirements of the employees of the Project Management Agency for Aeronautics Research and Technology are correspondingly high because staff must keep track of the jungle of rules and regulations and raise awareness of the Federal Government's funding programmes throughout the sector. The team's engineers evaluate the project descriptions submitted for the areas for which they are responsible, assessing them in terms of technology and Germany's aviation objectives.

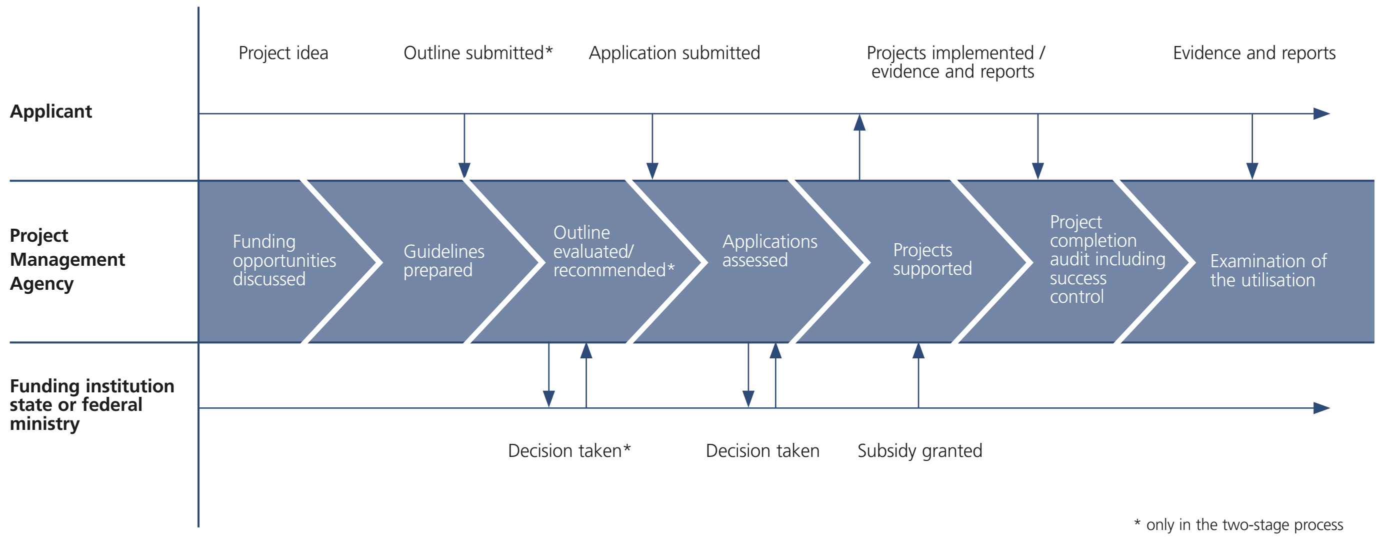
Transparency and independence

In order to advise the federal and state governments independently and make the funding process transparent, the Project Management Agency for Aeronautics Research and Technology has built up a pool of external consultants who determine and make funding recommendations through a standardised evaluation process. These consultants are aeronautics experts from higher education institutes or industry, although they are not necessarily actively involved in the research activities of the funding programmes. Applications for consultant candidacies are accepted at any time. The peer review process is supervised by an additional independent consultant whose test report is published.

United in Europe

International cooperation – whether with the European Commission, ministries or national counterparts of the Project Management Agency for Aeronautics Research and Technology – plays an important role. One example is international cooperation through the Group for Aeronautical Research and Technology in Europe (GARTEUR). Through GARTEUR, the Project Management Agency for Aeronautics Research and Technology supports the Federal Ministry for Economic Affairs and Energy and the Federal Ministry of Defence with a view to intensifying cooperation in Europe and coordinating national aeronautics research strategies in Europe.

The Project Management Agency experts are also key contacts in the area of aviation within the European framework programme 'Horizon Europe'. Here they constitute the National Contact Point for Climate, Energy and Mobility, Aviation Sector, which is responsible for providing information about the framework programme and supporting applicants in all phases of an application – from the classification of an idea to the submission of an application and the execution of the project. The Project Management Agency for Aeronautics Research and



* only in the two-stage process

FOR THE TRANSFORMATION OF THE AIR TRANSPORT SYSTEM

Interview with Jan E. Bode, Director of the Project Management Agency for Aeronautics Research and Technology

Jan E. Bode has been in charge of the Project Management Agency for Aeronautics Research and Technology since 2019.

What role will German aviation research have in the future?

: Aviation is in unprecedented turmoil. The effects of the COVID-19 pandemic and the consequences of climate change have combined to present the industry with enormous challenges. At the same time, aviation processes are changing and accelerating, partly due to the numerous start-ups emerging in the sector.

The task now is therefore to maintain and expand public acceptance of air transport by researching and developing forward-looking technologies and by incorporating new business models. The unique opportunities afforded by air travel should remain available to future generations without restriction. For example, consider the benefits of cultural exchange, not just personally for each one of us but also for global cohesion. This form of travel must therefore be sustainable in the future, which is why, like other transport sectors, we are accelerating the electrification of drive trains.

What must we not lose sight of in the process?

: On the one hand, the integrated added value chain. We must consider the entire product life cycle, from engineering through to production, operation and recycling. It is also important to pay as much attention to the impact on people and cost-effectiveness as we do to the engineering. By 'people', I mean the passengers – how can they feel at ease on the plane after the pandemic? But also the people in the flight deck – how best can we process all the information on weather conditions, radio traffic and airspace monitoring? And the people on the ground – how are they affected by aircraft noise? We take a technology-neutral approach to the evaluation of such issues.

What role does the Project Management Agency for Aeronautics Research and Technology play in this?

: Our role as a mandated support agency of the German Federal Government's national aviation research programme is to implement the aforementioned transformation by supporting the development of technologies that have the potential to achieve this.

Our 50 employees are in direct dialogue with beneficiaries from industry and research. Seen in this light Germany is well placed with its science infrastructure in terms of industry, research facilities and universities. To maintain this and ensure we remain competitive in the future, we promote the expansion of small and medium-sized enterprises. Here we take on an advisory role and support the networking of different actors. In addition to the conventional business of project management, we are therefore the central point of contact for the federal and state ministries with regard to aviation. We mainly work for the Ministry for Economic Affairs and Energy but are also in dialogue with other departments such as the ministries for transport, the environment and defence; we also advise the European Commission. In summary, everyone at the Project Management Agency for Aeronautics Research and Technology is working to support the transformation of air transport.

This interview was conducted by **Julia Heil,** editor in the DLR Communications department.

Technology also supports the Federal Ministries of Transport and Digital Infrastructure and the Federal Ministry for Economic Affairs and Energy in the area of the 'Single European Sky' and 'Clean Aviation' institutionalised partnerships.

In a state of constant change

Since its launch, staff at the Project Management Agency for Aeronautics Research and Technology have supervised more than 3000 research projects, each lasting an average of three years and three months. Currently, there are more than 1000 projects running in parallel. The research disciplines and programme lines have been adapted to the latest developments in industry and research and they continue to evolve. For example, in recent years new branches of technology have been added such as digitalisation, Industry 4.0, artificial intelligence and low-emission propulsion concepts. Standalone programme lines have also been established for higher education and small and medium-sized enterprises in order to promote junior scientist training and guide students into the industry long term. A protected area within the research programme has been created for small and medium-sized enterprises where they can develop their innovative ideas independently of big industry.

In addition to these programme lines, the funding system of the Project Management Agency for Aeronautics Research consists of the six main specialist aviation disciplines, which are guided by the economic fields of activity within the sector: cabins; propulsion systems; structures and design; systems; flight physics; and aviation processes such as flight guidance and flight safety. A matrix of the different proposals can be derived from these disciplines but this is not set in stone: each new call is also guided by and adjusted to reflect current trends and funding policy goals.

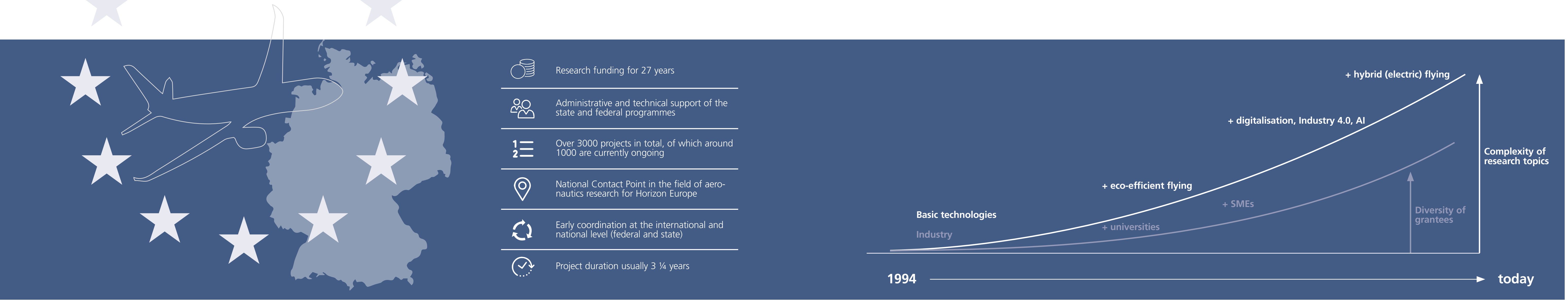
Anne Lohoff heads the Communication/Public Relations and European Programmes department of the Project Management Agency for Aeronautics Research and Technology.

Further information and contact details (in German) can be found at

www.luftfahrtforschungsprogramm.de

Staff provide support from initial idea through to implementation of an aviation research project


The Project Management Agency for Aeronautics Research and Technology is located in Bonn-Oberkassel



FROM THE ARCHIVE

The DLR Central Archive stores more than 50,000 documents. Buried among them are some real treasures. Dive with us into the sea of photographs, documents, official records and texts as we search for clues to find them. This first article in the series features the young women who kept research running smoothly in a time before computers.

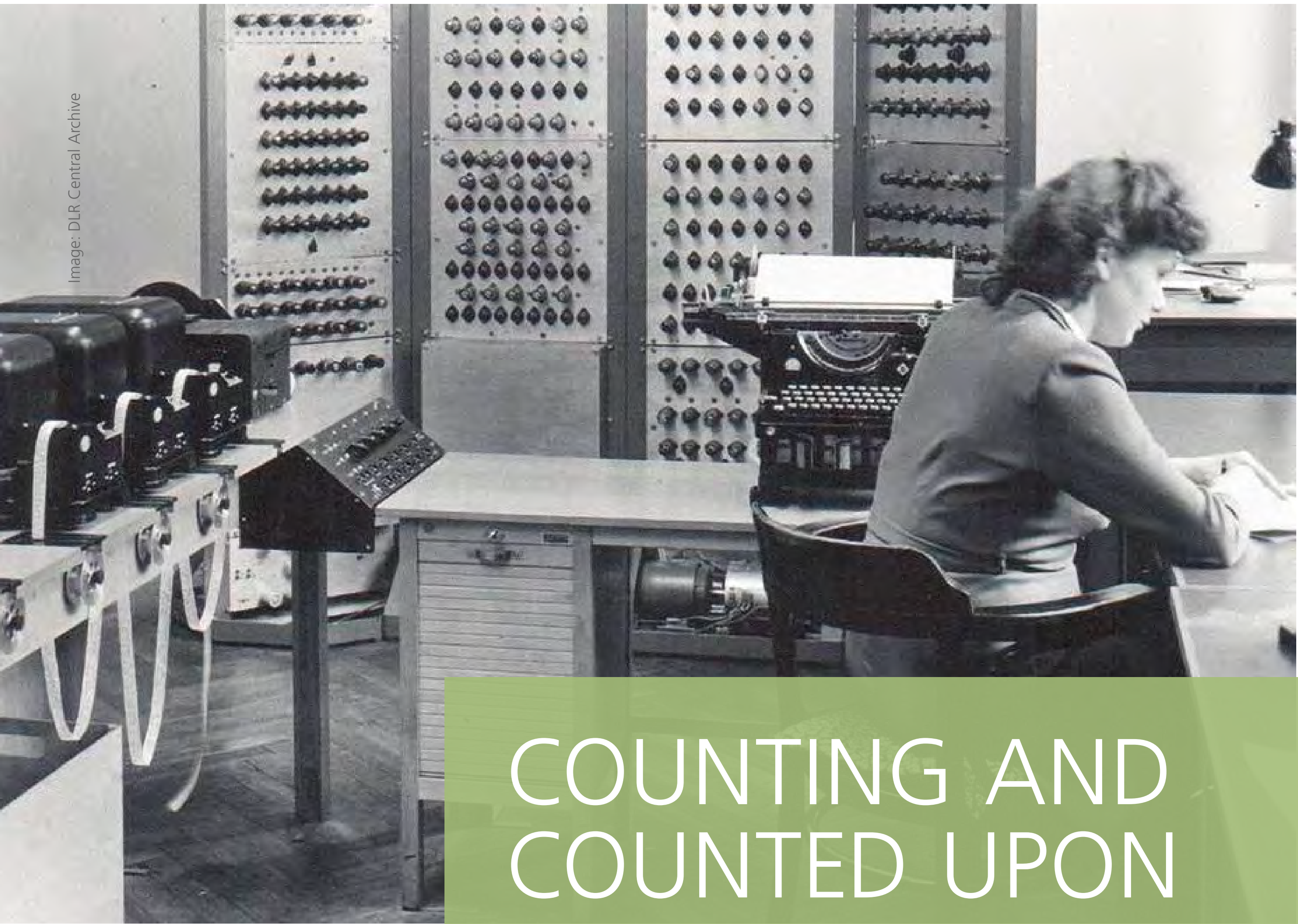


Image: DLR Central Archive

Large calculating machines such as Heinz Billing's G2 arrived at the research facility in the early 1950s. They were operated by human computers.

COUNTING AND COUNTED UPON

Before the emergence of the digital age, female 'computers' kept research alive.

By Jessika Wichner

Today, computers perform most of our calculations. But how did research facilities carry out their calculations when the computer was in its infancy? At that time, human computers were employed to prepare and evaluate measurement data with painstaking attention to detail. A few years ago, the book Hidden Figures was published in the USA, followed shortly by the film of the same name. The story features the mathematicians of the National Advisory Committee for Aeronautics (NACA), which later became the US National Aeronautics and Space Administration (NASA). But similar female computers were also employed at DLR's predecessor organisations.

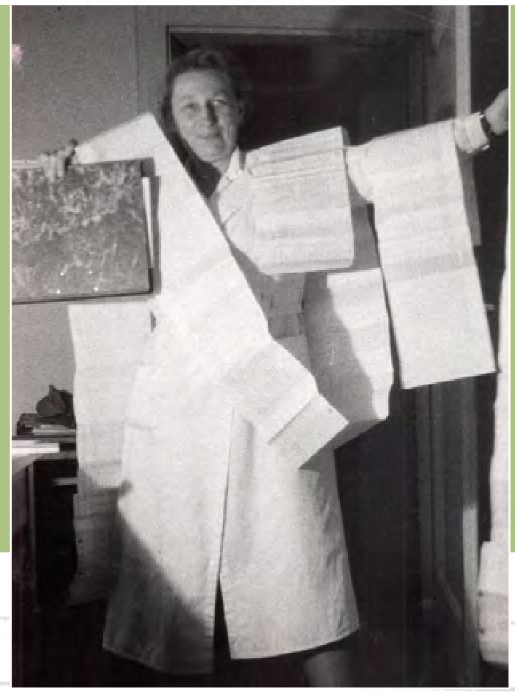


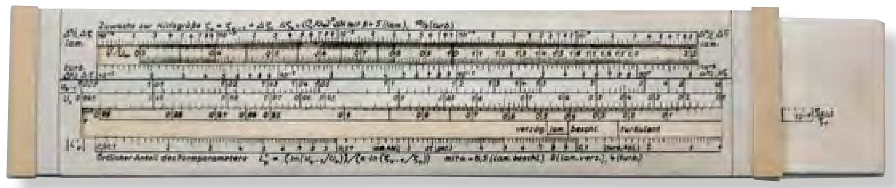
Image: DLR Central Archive

Maria Otto worked at the Aerodynamics Research Institute in Göttingen, a predecessor organisation of DLR, from 1927 to 1961.

Genuine handiwork

In 1907, DLR's first predecessor organisation, the Model Research Institute of the Motorised Airship Research Association (Modellversuchsanstalt der Motorluftschiff-Studiengesellschaft; MVA), was founded in Göttingen. Under the direction of Ludwig Prandtl, the first Göttingen-type wind tunnel was built here with a closed circuit. While the MVA only had one wind tunnel at its disposal, the measurement results could still be evaluated by the scientists themselves. The research facility was renamed the Aerodynamics Research Institute (Aerodynamische Versuchsanstalt; AVA) in 1918. As it grew, the quantity of measurement data that had to be processed and evaluated grew with it. The AVA employed a host of human computers for this work. They were mostly young women, who came straight from school and carried out the evaluations of wind tunnel measurements. The human computers worked in pairs, performed their calculations in parallel and compared their results after each step to ensure no errors crept into their work. They were equipped with slide rules and early calculating machines, which made the work easier. As conventional slide rules were not suitable for every kind of evaluation, they also designed new types of slide rules, which they used to solve complicated equations quickly and easily.

In addition to the female computers, there was also a small number of male mathematicians at the AVA. They were mostly mathematics students who worked at the research facility during university holidays. The number of female computers at the AVA increased sharply during the Second World War. The reasons for this were complex. Several new high-speed wind tunnels were installed in Göttingen during this time, and the operation of the plants switched from two-shift to three-shift operation so that the wind tunnels could be operated around the clock. The AVA also took on the management of several outposts in occupied areas, to some of which workers from Göttingen were seconded. Altogether, more than 90 female computers were employed at the AVA in 1944. It is impossible to say how many were employed at DLR's other predecessor organisations at the same time due to a lack of sources, as no personnel files from this time from the other predecessor organisations were preserved. The female computers were paid at similar rates to technical draughtsmen or technical assistants, who helped place models in wind tunnels and recorded the measurement results.



The female computers also designed slide rules for the aerodynamic calculations with scales that could not be sourced from specialist retailers.

Tuition in mathematics, physics and flight mechanics

To induct the newly employed female computers as fast as possible a special training course was provided at the AVA. The participants were trained both in mathematics and physical principles, and specifically in the field of flight mechanics, to ensure a comprehensive understanding of their future work.

In the late 1940s and early 1950s in particular, electronic calculating machines developed rapidly, and the computing power of the electronic machines developed by Konrad Zuse and Heinz Billing soon far surpassed the computing capacity of the female computers. Their job description also changed as a consequence. They no longer carried out the actual calculations but wrote the 'software' for the electronic calculating machines and ensured their smooth operation.

Unlike their colleagues at NACA and later NASA, the female computers from DLR's predecessor organisations did not pave the way for human spaceflight. Nor has a Hollywood film been made about them. Yet they were an essential part of everyday research and our scientists would have been at a loss without them. Through their perseverance and accuracy in the evaluation of measurement data, they formed the backbone of research. And so, this shows that the oft-quoted prejudice that women are distinctly inferior to men in mathematics has very little to do with reality.

Jessika Wichner heads the DLR Central Archive in Göttingen.

IN THE PILOT'S SEAT

The National Museum of the United States Air Force

By Joshua Tapley

Image: U.S. Air Force, Ken LaRock

Near Dayton, Ohio, the hometown of the Wright brothers, is the National Museum of the U.S. Air Force. Located at Wright-Patterson Air Force Base, it is the largest military aviation museum in the world, with over 300 aircraft and vehicles and thousands of unique artefacts. The museum traces the history of flight in the United States, specifically military aviation, from biplanes to orbit, but perhaps even more impressively, not a single aircraft is needed to visit it from anywhere in the world.

Starting the virtual tour sees you land in front of the museum as if by parachute. Before you stand the museum's four vast hangars. The first hangar leads us through the period of flight from the earliest endeavours of the Wright Brothers up to World War II. It contains the greatest variety of aircraft shapes from the early days of flight before the most efficient designs were identified and increasingly optimised. It is here we find balloons and airships, biplanes of fabric and wood, open cabins and colourful paintjobs – all visible in great detail and with the ability to zoom in to the finest details. There is even an early helicopter design in the Kellett K-2/K-3 Autogiro. Before the Second World War, aeronautical engineers sought to build an aircraft that could make short take-offs and landings, and the United States Army needed an aircraft capable of flying very slowly to monitor battlefields.

SAM 26000 (Air Force One) at the Air Force Museum. The Boeing 707 was specially built to transport the President of the United States.

The National Museum of the United States Air Force is located on the edge of the Wright-Patterson Air Force Base in Dayton, Ohio.

Images: U.S. Air Force, Ken LaRock

Eventually, these efforts produced the helicopter, but the autogiro was a real contender at the time. The museums 'Cockpit360' images offer a complete view from the pilot's seat of most of its aircraft. The drastic increase in the number and variety of dials, lights, gauges and levers make it clear just how challenging it would have been to keep up as an Air Force pilot in the 1900s.

The last flight of the Valkyrie

Dominating the Research and Development Gallery, the futuristic XB-70A Valkyrie is the signature aircraft of the museum. At almost 60 metres in length, the aircraft is almost twice as long as the legendary first flight made by the Wright Brothers at Kitty Hawk – a flight that took place less than 60 years before the Valkyrie was constructed. Originally proposed as a way to deliver nuclear strikes at supersonic speeds, by the early 1960s, it had become clear that long-range missiles were a more reliable and less costly solution, and the expensive B-70 bomber programme was cancelled.

Seeing the potential of supersonic aircraft, however, the U.S. Air Force purchased two XB-70A Valkyries for research and development. The first is now on display at the museum. It was used for testing the aerodynamics, propulsion and other characteristics of large supersonic aircraft. It first flew in September 1964 and achieved Mach 3 (three times the speed of sound) flight in October 1965. The second Valkyrie was destroyed in 1965 following a deadly mid-air collision. The lone remaining Valkyrie was flown to the museum on 4 February 1969 after providing four years of valuable scientific test data. It has been on display in the museum's fourth and newest hangar since October 2015.

SAM 26000

In the next hangar, we find the Boeing VC-137C known as SAM 26000 (SAM two-six-thousand). You may recognise it better from the callsign it bore when transporting its unique cargo, Air Force One. Any Air Force aircraft with the President of the United States on board is assigned the callsign Air Force One to ensure the president's whereabouts in the sky is never in doubt, but SAM 26000 was the first jet aircraft built specifically for use by the US head of state. During its 36-year flying career, it carried eight presidents and countless world leaders, diplomats and officials from across the globe on historic journeys known as Special Air Missions (SAM). The aircraft on display at the museum is the very one that flew President Kennedy to West Berlin in June 1963, where he delivered his famous "Ich bin ein Berliner" address to assert America's continued support for West Berlin following the construction of the Berlin Wall. After more than 13,000 hours in the sky, SAM 26000 began its new role as an educator for the million yearly visitors to the museum on the history of presidential transport and the importance of the global reach of U.S. political power during the Cold War.

Alone in the museum

Without any visitors walking around this or any other exhibit, however, the hangars are eerily quiet. Museums are inherently social spaces. They offer educational services, tours and often rely on donations or the revenue generated by shops and cafes on site. While the audio guide and the videos interspersed throughout the exhibition galleries break the silence, they cannot capture the atmosphere of a space usually buzzing with human activity. Overall, however, the virtual museum experience far exceeds expectation. The National Museum of the U.S. Air Force and many others have gone to great lengths to keep the spirit of the museum alive during hard times and expand their educational services to new audiences. Their efforts offer a surprisingly engaging way to visit museums around the world from the comfort of your own home. Where will it take us next?

Joshua Tapley is an editor for the English DLRmagazine at EJR-Quartz.

National Museum of the United States Air Force
Adress:
1100 Spaatz Street
Wright-Patterson AFB OH 45433
Dayton, Ohio, USA

Admission: Free, on site and virtually

www.nationalmuseum.af.mil

nmusafvirtualtour.com

Keep an eye on your windows, pilot! Navigating the virtual museum can feel like facing the dials and levers of a fighter jet. The tour offers more than immediately meets the eye, but the different features are not well integrated. To best enjoy your visit, keep multiple web browser windows open: one for the museum itself, one for the 360-degree views and one to access the audio tour files.

REVIEWS

CHAMPAGNE? CHECK!

Alongside expected items such as provisions, a sextant, a radio receiver, harpoons, and a ship's pharmacy, the inventory from Thor Heyerdahl's expedition from Peru to Polynesia on a replica of an Inca raft includes a guitar and a parrot. The journalist and world traveller Nellie Bly took only a leather bag on her circumnavigation of the globe. It contained a jar of cold cream and a bottle of Mumm champagne in addition to very little but extra-durable travel clothing. Amelia Earhart not only carried a parachute and lifeboat on her Atlantic crossing, but also Dr. C.H. Berry's Freckle Ointment. Sir Robin Knox-Johnston thought of everything necessary for survival and communication for the first solo non-stop circumnavigation of the globe. He even took stationery with him on his teak boat, which, when he lost radio contact, allowed him to send mail to his loved ones at home by delivering it to a passing ship. He did, however, forget to pack a shaving kit, the pump for the compressed air harpoon and solder to repair the electronics...

'What the Great Explorers Took into the Unknown' was often the difference between life and death and is the subtitle of the illustrated book **Expeditions Unpacked (White Lion Publishing)**. British adventurer and author Ed Stafford compiled equipment, photographs, and a wealth of astonishing information. He also quite confidently and rightfully included his Amazon trek from 2008 to 2010 and his wife Laura Bingham's canoe trip along the Essequibo in the book. He tells the tales of daring women and men with a special focus on what they took with them on their journeys into the unknown. This book is simply well written, compiled in an intriguing manner and beautifully illustrated by Christine Berrie. Berrie's lovingly drawn equipment, clothing and accessories can be found throughout, in muted colours and with a light sepia tint. Her many detailed drawings of equipment, in the style of hidden object games, add a charming touch to the book.

The stories are so incredibly exciting, and the photographs so fascinating, that once you have opened the 240-page book, you won't be able to put it down. One thing becomes clearer and clearer with each chapter: no matter how good the equipment or how sophisticated the logistics, no expedition into the unknown can succeed without tremendous enthusiasm, trust, and material and moral supporters. Above all, it requires a great deal of courage.

Cordula Tegen

BIG BROTHER

George Orwell wrote his pessimistic, futuristic novel '1984' shortly after the end of the Second World War. When the book was published in 1949, the events surrounding Winston Smith, a low-level employee of the Ministry of Truth, were set 35 years in the future. Orwell's story about an individual who begins to rebel against a totalitarian surveillance state has since become a modern classic.

Orwell's gloomy vision seems ideally suited for a portrayal using atmospheric, predominantly black-and-white images. Couple these with the compact, reduced text, and **1984: The Graphic Novel** (Mariner Books) develops a magnetism. Now in 2021, the story is set 37 years in the past. But it has not lost any of its relevance. Motifs such as 'Big Brother is watching you' or the idea of 'Newspeak' – using language to influence people's thought processes – are recognisable today, almost 72 years after the novel was published.

Philipp Burtscheidt

OFF TO SPACE!

Do you enjoy building things, especially spacecraft, and want to explore the Solar System? In the game **Space Agency** by Nooleus you are responsible for designing and building rockets, launching satellites and space telescopes, as well as constructing your own space station. Once you manage to reach orbit the possibilities are endless. You can stay close to Earth or travel out into space to explore the Moon, other planets or the Sun. Another option is to upgrade and expand your space station. As you progress, you make new scientific discoveries that could even allow you to land on and discover Mars. While the game itself is comparatively simple, this doesn't mean it lacks obstacles. Overcome them and you will be rewarded with a sea of possibilities that delights any player who is an explorer at heart. Player tip: Keep an eye on your budget!

Space Agency is available on the App Store and Google Play free of charge.

Sara Kehrer

RECOMMENDED LINKS

TIME TRAVEL THROUGH THE WORLD
earthengine.google.com/timelapse
With Google Earth, not only can you virtually stroll through streets and marvel at elevation maps of the sea, but, as of the latest update, you can now even see how Earth is changing. Twenty-four million satellite images from the last 37 years have been embedded in the software. Users can now go on a journey through time and see how places on our planet have changed – whether the entertaining and informative construction of Berlin Airport, or the terrifying decrease in Arctic sea ice.

CHECK YOUR BUDGET
showyourbudgets.org
A website for all those who want to know how quickly their country has to act to be climate neutral and comply with the Paris Climate Agreement. In addition to an overview graph for the whole world, you can also view the graph for your own or any other country. A detailed FAQ section also reveals the background and scientific basis of the website.

OLYMPICS FROM SPACE
instagram.com/p/CRwdiEqjSH8/
"Many countries are competing for gold but from our perspective 250 miles up, we are all one team." NASA astronaut Shane Kimbrough captured this view of Tokyo, the host city for this year's Olympic games, from the International Space Station on 25 July. The astronaut's Instagram account contains many other views from across our planet taken from low-Earth orbit.

THE ART OF REMOTE SENSING
s.dlr.de/WiSsV
Images produced using remote sensing data can often feel 'flat', even when they contain three-dimensional data. In this DLR blog, former DLR researcher Manfred Gottwald describes the way researchers are using techniques involving light and shadow developed by artists centuries ago to trick the human eye and breathe life into topographic maps.

MINUTEEARTH
youtu.be/MbHIxbbyOi8
MinuteEarth has a regularly updated collection of short, free science videos all about Earth. These short, animated videos give fun insights into the world of science – from animals, to the human body, our planet, and through to the Solar System and beyond. If you're curious about science, this is a great resource.

Cover image

A chip can be the heart of a quantum computer. Atoms or ions can be separately trapped on it. These can serve as information carriers, so-called qubits or quantum bits. Quantum computers have the potential to solve problems that would push today's computers beyond their limits. Within the next four years, DLR, together with partners from industry, small and medium-sized enterprises, start-ups and science, will establish two consortia to create the framework for a German quantum computer as well as develop the corresponding software and identify quantum-specific applications.

DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center