DLR magazine

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A PERFECT DUET

DLR and NASA investigate: How do biofuels affect the environment?

REAL AIRCRAFT AND THEIR VIRTUAL TWINS
VISIONS OF THE NEXT CITY CAR
CATCHING MORE SUN

DLRmagazine 157

Dear readers,

The Sun is here at last. The photographer that took the cover image was happy to finally see blue skies at the end of January. What was required for the success of the biofuel measurement flights, however, was quite different – low temperatures and humid air, both necessary for well-developed condensation trails. These conditions were necessary for the flights conducted by NASA and DLR scientists using a variety of fuel mixtures. They want to find out how biofuels affect emissions and contrails. The measurements addressed the question of whether fewer soot particles in the atmosphere also lead to fewer ice crystals and therefore reduced contrail formation. The vast amounts of data acquired during these spectacular flights in an aircraft exhaust plume will reveal ways of reducing the climate impact of aviation.

When it comes to the digital 'twins' of aircraft components, the data volumes are even larger. Modelling them is a mammoth task, especially when an aircraft's entire development and lifecycle has to be depicted. To make this possible, four aeronautics institutes have been added to the DLR portfolio. The vision – data packets for the airframe, engine and other components should move through the design and development process like a 'digital thread'. The aircraft of tomorrow will become less expensive and more environmentally friendly.

An airborne platform and sufficient sunshine are behind the success of a DLR spin-off company that was established 10 years ago. It offers solar power plant developers in-depth quality control of plant components, performed by engineers using measurement drones. Its technology is successful around the world and enables the Sun's energy to be captured more effectively.

DLR researchers look far beyond the Sun when searching for extrasolar planets. New ones are constantly being discovered and some challenge common theories. A dwarf star with a giant planet in orbit around it makes an extremely unlikely pair.

If you want to learn more about DLR's aeronautics, energy and space research, you will have the perfect opportunity to do so at the Hannover Messe (23 to 27 April 2018) and the ILA Berlin Air Show (25 to 29 April 2018).

We look forward to seeing you!

Your Magazine editorial team

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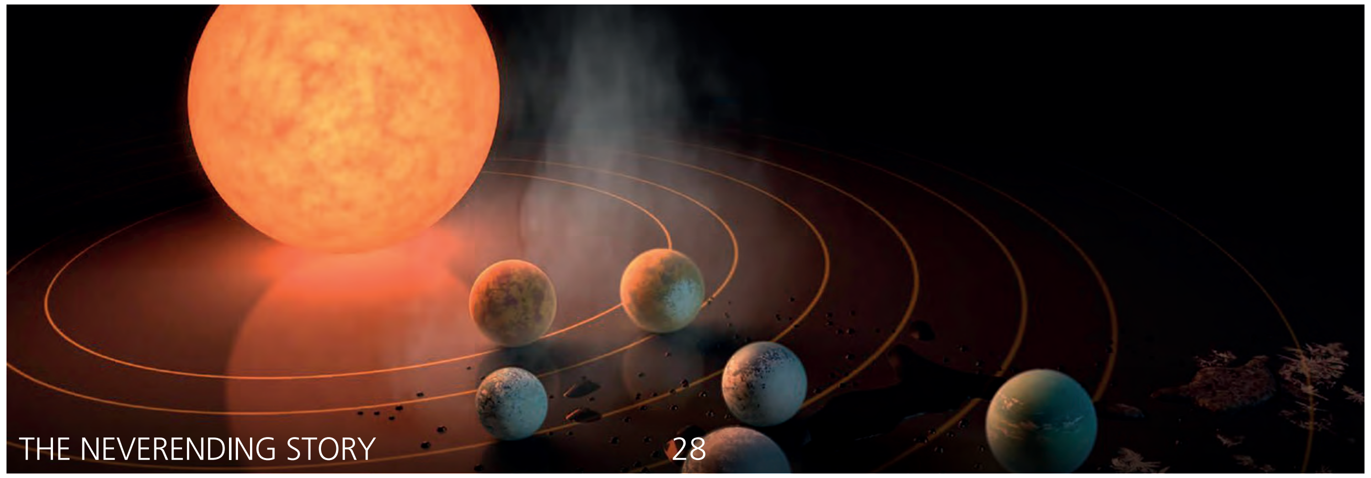

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AT THE THRESHOLD OF A NEW ERA IN AVIATION

By Rolf Henke

Rolf Henke is the DLR Executive Board Member responsible for aeronautics research

At the end of the 19th century, the work of Otto Lilienthal, including his gliding flights for humankind, opened up a new era of boundless airborne mobility. The 20th century brought about the leap from the glider to the aircraft, and then to the jet age.

Flying has long been available throughout society. The end of increasing demand for fast, point-to-point connections for passengers and freight is nowhere in sight. This dynamic is accompanied by the increasing societal need to make air transport more environmentally friendly. At the same time, a movement in technical boundaries has arisen, such as has not been seen for some time – aircraft development, production and operation are becoming increasingly digitalised. Alternative propulsion concepts for regional air transport are moving into the realm of the feasible. Air freight and logistics are at the threshold of uncrewed, highly individualised operations. Large companies and start-ups are getting involved in air taxis for urban 3D mobility. Through research and development, aviation is approaching a new leap in time.

These complex issues require deep systems knowledge. In accordance with the aviation strategy of the German Federal Government, aeronautics research at DLR addresses system-level requirements. That is, it covers the entire technological spectrum – from the fundamentals through to applications – for all significant aspects of the air transport system. With this system capability, DLR is a global instigator, driving forward developments in future aviation.

Four new DLR institutes were founded in 2017 for the digitalisation of aviation with the support of federal and state governments. These institutes will enable us to identify the potential of digital technologies for safe, environmentally friendly and cost-effective air transport and, building on this, develop new technologies. Our aim is to position DLR as a 'virtual OEM' with research contributions and stimuli in all supplier areas. In addition to conducting research in their core areas, the true impact of the four new institutes will be achieved by working in concert with all DLR institutes. This association will bring about great things through the aeronautics research programme. Together, we will drive forward the 'digitalisation of aviation', which runs along a 'digital thread' – from computer development and licensing, to the digitalised production and delivery of a 'digital twin' including all the physical characteristics, through to operations and maintenance, and finally to the simulated decommissioning of an aircraft.

Many individual aspects for this will come from industry, but only DLR can develop the digital thread, visualising the entire lifecycle from design to decommissioning – the administration of the aviation system, as it were. We have this unique selling point, at least throughout Europe.

In addition, DLR focuses on and has initiated activities in current fields of innovation: uncrewed flight and hybrid-electric flight. In the case of uncrewed flight, we are pushing ahead with research to answer the question of how – technically and operationally – even large loads can be sent optimally by air, as well as how people can be transported at a later stage using uncrewed aircraft. Research into hybrid-electric flight opens the door to establishing electric propulsion in regional aviation. In addition, there are also development opportunities for gas turbines in the hybrid segment.

DLR is working on these wide-ranging approaches to the aviation of the future, and will be showcasing them at ILA 2018 in Berlin.

PILOTLESS FREIGHT TRANSPORT

DLR IS EXAMINING SCENARIOS FOR AIR TRAFFIC CONTROL

How freight aircraft can be controlled safely from the ground is one of the questions that DLR is addressing in the UFO (Unmanned Freight Operations) project. It is looking at the integration of these aircraft into the existing air transport system. The DLR Institutes of Flight Guidance, Flight Systems, Communications and Navigation, Aerospace Medicine and DLR Air Transportation Systems are working on approaches for the airspace managed by air traffic control. This resulted in three different scenarios for which researchers then developed and validated new support systems, procedures and technologies for air traffic controllers and pilots.

Test environment of the ground control station

The three application scenarios that were developed include freight transport between two manufacturing sites, long-haul freight transport and the transport of relief goods. These three examples primarily differ in terms of the size of aircraft used and the distances covered. In addition to the technical challenges of communication, navigation and surveillance, as well as monitoring the condition of the unmanned aerial vehicle, the investigation also considered the human factor and developed ideas to help pilots and air traffic controllers.

For the transport of relief goods scenario, one surveillance possibility is to separate the airspace by means of special corridors, similar to those for manned relief missions. When transporting factory goods, both certification and authorisation for a special transport task (EASA SORA SPECIFIC) need to be considered, as well as integration into the air transport system. Long-haul freight transport, however, can only be integrated into conventional air transport. In this case, sector-less guidance would be conceivable, whereby an air traffic controller monitors unmanned aircraft over a longer stretch of the route.

PLEA FOR 75 PERCENT LESS CARBON DIOXIDE

CHANGE AT ACARE EUROPEAN COUNCIL FOR AVIATION RESEARCH

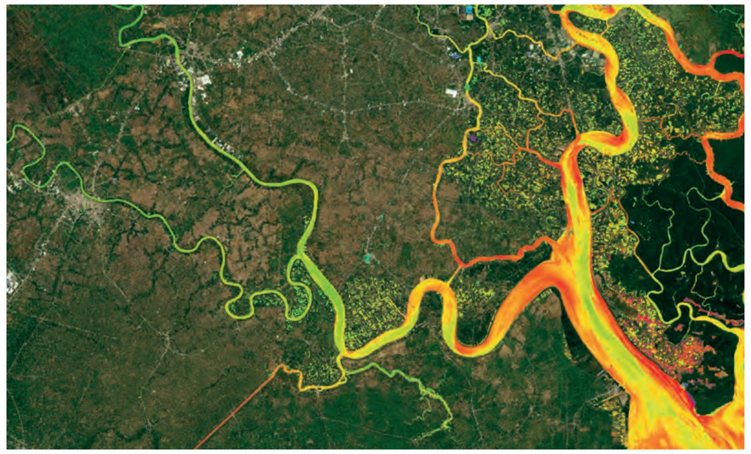
The Advisory Council for Aviation Research and Innovation in Europe (ACARE) will discuss the next steps for implementing the Strategic Research and Innovation Agenda (SRIA), updated in 2017, at the next ACARE General Assembly at the ILA Berlin Air Show 2018. Electric powered aircraft will play an important role.

Jean-Brice Dumont and Rolf Henke at the handover of the office of ACARE Chair

The SRIA research agenda updated within the scope of ACARE paves the way for ambitious European objectives in aviation. Amongst other things, by 2050 the noise and carbon dioxide emissions of air transport should be 65 and 75 percent below the figures in the year 2000 respectively. At the same time, there will be an increase in performance in European air traffic, using an air traffic management system that will provide for 25 million intra-European flights per year.

Since 2000, as a forum for all large aviation stakeholders in Europe, ACARE has drawn up guidelines for aviation research, specifying the long-term path to sustainable, clean, quiet, comfortable and safe air transport. The forum entered 2018 with a new Chair. The DLR Executive Board Member responsible for aeronautics research, Rolf Henke, as a representative of research, was succeeded by Jean-Brice Dumont of Airbus as Chair of ACARE. As vice-Chair together with René de Groot from KLM Royal Dutch Airlines, Henke will support Dumont in his work.

DLR SPIN-OFF COMPANY EOMAP LAUNCHES ONLINE WATER ATLAS



Water turbidity in the Mekong Delta in a partial view of the World Water Quality portal

The DLR spin-off company EOMAP has developed and published the portal for the International Initiative on Water Quality (IIWQ), under UNESCO's International Hydrological Programme (IHP). The portal offers map products of coastal and inland waters derived from high-resolution remote sensing data. Water experts can use it to query global measurement data, as well as generate time series and water reports. The data from satellites provides information on inland waters, rivers and lakes up to approximately one hectare in size. Parameters such as turbidity, chlorophyll content, water temperature and cyanobacteria indicators give a good idea of water quality.

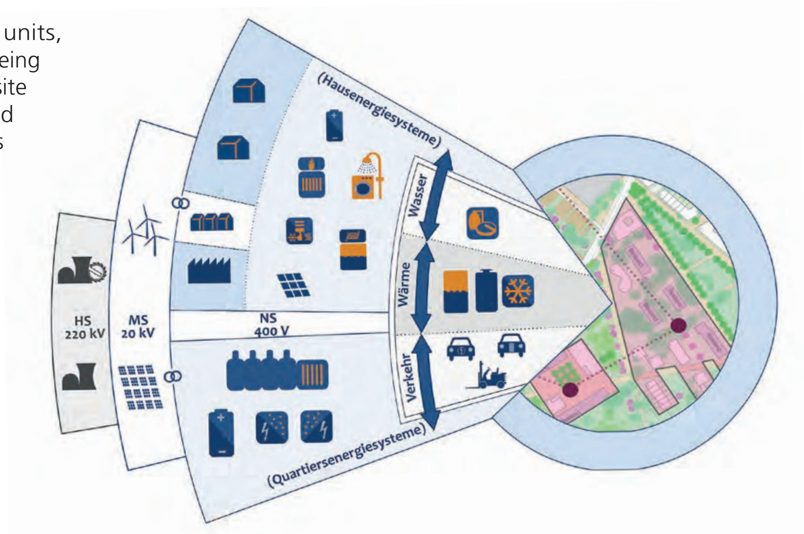
"With the new online portal, global comprehensive water quality data are now for the first time available to government institutions, environmental authorities, the water industry and universities," said Walther Pelzer, Member of the DLR Executive Board responsible for the Space Administration. Pelzer took over the management of the DLR Space Administration at the start of this year, succeeding Gerd Gruppe, who retired on 31 December 2017. According to Pelzer, the new portal will demonstrate the contribution that space technology – in this case Earth observation – can make to solving major societal challenges.

Thanks to its wide accessibility and user friendliness, the online portal will also help developing countries to build capacity and competence in their technical and administrative infrastructures. This contributes to improved management of water resources and the achievement of sustainable development goals (SDG). In view of scarce water quality information – both globally and nationally – the Portal will be a valuable tool to obtain water quality information, especially in remote areas and in developing regions (such as in Africa, Asia, Latin America, and Small Island Developing States), where there is a lack of water quality monitoring networks and laboratory capacity.

s.DLR.de/297t

CLIMATE-NEUTRAL RESIDENTIAL DISTRICT IN OLDENBURG

A climate-neutral district with around 110 residential units, consisting of existing buildings and new construction, is being built in Oldenburg, Lower Saxony, where DLR has had a site since 2017. Together with 20 partners from industry and research, the DLR Institute of Networked Energy Systems has designed the Energetic Neighbourhood Quarter (ENaQ) on part of the site of a former airbase. The project aims to clarify the best way to plan the local energy community of a neighbourhood district – both socially and economically – in order to make it attractive and economically viable in the long term for residents, energy producers and service providers. The area is being used as a 'living' participatory laboratory for smart-city technologies. The energy requirements of the EnaQ district should be satisfied primarily by locally generated power. A public supply network is being developed, which supports a combination of electricity, heating/cooling and mobility and also promotes energy exchange between neighbours.



DLR researchers are developing the overall energy concept. For this, they have simulation models and specially equipped laboratories, which can map all the components of a smart grid, such as solar installations, including photovoltaic inverters, battery systems used as home energy stores, and battery systems for electric vehicles. In this way, the district and its interactions with the higher-level supply network are recreated in a digital simulation. This model can then be transferred to the DLR energy laboratory, which digitally maps the entire networked energy infrastructure and takes into account parameters such as weather data, user behaviour, network utilisation and traffic conditions. The enterprise is one of six beacon projects on the subject of solar building/energy-efficient cities, for which the German Federal Government is providing up to 100 million euro over the next five years. The Oldenburg project is receiving 18 million euro, and industry partners are contributing another 8.4 million euro.

AUTOMATED AND NETWORKED FREIGHT TRANSPORT

The automation and networking of transport will bring changes to the logistics industry. In the ATLaS project (Automated and networked movement in Logistics – opportunities for greater added value), scientists from DLR and the Hamburg University of Technology (TUHH) are investigating how these changes will affect freight transport. DLR Project Manager Stephan Müller assumes that logistics companies will only use new technologies if these can lower their costs, increase process efficiency and generate new logistics business models using added-value services. One example of the use of new technologies is the automated and connected driving of HGVs on motorways, which can be linked to form 'freight trains', so-called platooning. Even under today's technical and legal framework conditions, the other drivers could hand over the majority of the driving tasks to the automation technology and carry out other tasks or take a break.

The effects of possible innovations on inner-city transport and on air quality will also be included in this work. Thus, the project will create a broad information base to set the correct framework conditions for the freight transport of the future.

ATLaS is funded by the German Federal Ministry of Transport and Digital Infrastructure (BMVI).

s.DLR.de/4zo5

IGNITION FOR VULCAIN 2.1 – EUROPE'S MOST POWERFUL ROCKET ENGINE

The new Vulcain 2.1 engine, which is set to carry the new European launcher Ariane 6 into space in 2020, is intended to achieve greater efficiency at lower costs. DLR engineers tested the engine, developed by ArianeGroup, for the first time on the P5 test stand in Lampoldshausen in January 2018. The test campaign included 12 firings. Before the launch, the development engines must prove that they can cope with the enormous 130-tonne thrust, temperatures of approximately 3000 degrees Celsius in the combustion chamber, the high rotational speeds of the turbo pumps and the pressure in the propellant lines. The engine features a 3D-printed gas generator, a new, simplified nozzle and a combustion chamber that can be ignited by the launcher's ground support system. Vulcain 2.1 will play a key role in carrying Ariane 6 up to an altitude of 150 kilometres within the first 10 minutes of flight. Depending on its configuration, Ariane 6 will be able to transport up to 11 tonnes of payload into space, halving the launch costs compared to Ariane 5.

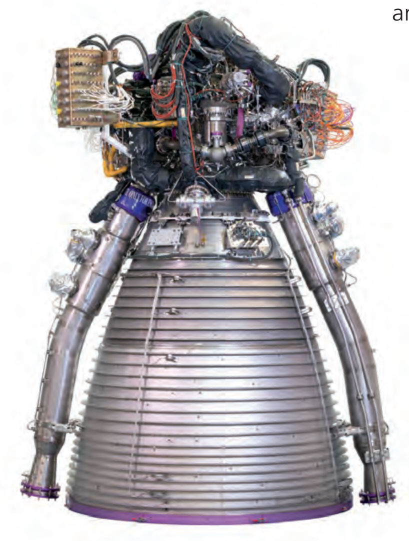


Image: ArianeGroup/DLR

s.DLR.de/x7o1

MEET DLR AT ...

ILA BERLIN AIR SHOW 2018
25 - 29 April 2018 • Berlin, Germany
The Berlin Air Show ILA is one of the focal points of aerospace worldwide. It is held at the Expo-Center Airport in Schönefeld. DLR is contributing to ILA with exhibits at its stand in Hall no. 4 showcasing its current research projects in aeronautics, space, energy, transport, security and digitalisation. In collaboration with the European Space Agency (ESA) and the German Aerospace Industries Association, the DLR Space Administration is presenting innovations made by German companies at the Space Pavilion. In addition, several aircraft of DLR's research fleet will be on display. Participating in the ILA Career Center, DLR recruiting staff will be available to answer questions on how to successfully apply for jobs at DLR.

SUMO 2018 TRAFFIC SIMULATION CONFERENCE
14 - 16 May 2018 • Berlin, Germany
The focus of this year's SUMO conference, organised by the DLR Institute of Transportation Systems in Berlin Adlershof, is the simulation of road traffic and mobility behaviour. Available since 2001, SUMO is open-source software for road traffic simulation that is able to model both individual passenger and public transport for simulation purposes. It contains a range of tools for vehicle navigation, visualising the simulation and calculating pollutant emissions. The suite of tools also contains an extensive function library and permits the addition of custom models. The conference aims to promote scientific knowledge transfer and is targeted at all those interested in traffic, mobility and simulation.

11TH INTERNATIONAL SYMPOSIUM ON SPECIAL TOPICS IN CHEMICAL PROPULSION & ENERGETIC MATERIALS
9 - 14 September 2018 • Stuttgart, Germany
This renowned scientific conference series focuses on research and technology development in the complete range of propellants and energetic materials. It is a platform for communication and networking between the participants regarding state-of-the-art approaches in the field of energetic materials, the discussion of new and improved safety techniques in the combustion and handling of energetic materials, as well as the discussion and recommendation of future directions for research in combustion, propulsion and chemical reaction systems.

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A PERFECT DUET

The scenery is quintessentially American. Fire trucks and ambulances with US licence plates and the familiar siren noise drive along the streets, which are lined with uniform yellowish-brown, low-rise buildings. Few things at Ramstein Air Base indicate that you are actually in the Rhineland-Palatinate region of Germany, except for the occasional German car or taxi, and an aircraft on the apron – DLR's Airbus A320 ATRA. Alongside is the NASA DC-8 research aircraft – a 'flying laboratory' – as NASA scientists respectfully refer to it. This is the aircraft's first mission in Germany, and the NATO base at Ramstein is just the place for this joint mission.

DLR and NASA fly together for the first time in Germany to investigate the effect of biofuels on emissions and contrails

By Falk Dambowsky

The researchers have everything they need here – a large hangar to house the DC-8, areas that can be used for performing ground emissions tests on the A320 ATRA, and space for the tanks containing the fuel blends produced especially for the mission.

The DLR and NASA team have installed themselves in a conference room right next to the hangar. Here, they will be able to prepare for the measurement flights and coordinate matters easily on site. The most important meeting on the morning of a research flight is the crew briefing – when DLR and NASA researchers go through the planning process with the crews of the DC-8 and the A320 ATRA and agree on how they will approach the joint flight. The most important element is the weather, specifically the humidity in the atmosphere at flight altitude, because the scientists are hunting for contrails. The DLR A320 ATRA flies in front, while the DC-8, which is equipped with numerous instruments for measuring and analysing ice crystals, soot and exhaust gases, follows just a few kilometres behind, 'sniffing' in the leading aircraft's exhaust plumes. In order to be able to analyse not only the exhaust gases but also the contrails that form due to the condensation of moist air on the soot particles, the temperature has to be sufficiently low, and the humidity in the atmosphere sufficiently high. When devising their plans, the scientists therefore use special forecasts to predict the formation of contrails over Germany, and then decide which region offers the best conditions for the measurement flights.

Image: DLR/NASA/Friz

On the way to the exhaust plume: NASA's DC-8 (left) behind DLR's A320 ATRA.

Image: DLR/Jörg Adam

Recognisable in the fuselage of NASA's DC-8 – air Inlets for exhaust gas measurements.

The flying laboratory is equipped for trace substance analysis

On this 19 January 2018, take-off is scheduled for 11:00, with the aircraft flying in an airspace over Mecklenburg-Vorpommern that has been especially reserved for the flight test and is closed to other air traffic. The A320 ATRA and the DC-8 stand side by side outside the hangar at daybreak, and the crews in their yellow safety vests make their way directly to the aircraft across the apron. Built in 1968, the DC-8 is one-of-a-kind and, with four engines, it is also somewhat larger than the twin-engine A320 ATRA. Its interior features wide seats with luggage compartments above. However, those are the only elements reminiscent of a conventional passenger aircraft. Cables and pipes run everywhere – small, large, thick, thin, white, red, blue. Air from the outside enters the flying laboratory via various inlets, and is guided across and throughout the aircraft to the measuring instruments, which are mounted on shoulder-high metal racks.

There is a lot of activity before the flight. The measurement stations have to be checked and started up. One might see a measuring device being purged with nitrogen, where one of the numerous tubes has been reattached or resealed. "We want to analyse the smallest concentrations of trace substances," says Hans Schlager, leader of the DLR flight campaign, as he powers up the computer at one of the measurement stations. "There should be no leaks in the feeder lines, as this would distort our data." Precision, perseverance and experience are the order of the day.

Before the DC-8 crossed the Atlantic, DLR and NASA scientists installed a total of 20 measuring instruments in the 42-metre-long cabin and on the outside of the fuselage. A gold-coloured cloud spectrometer that contains five complex instruments in one housing – laser particle spectrometers, which measure the number and size of the ice crystals in contrails – hangs from the tip of the right wing. An ion trap mass spectrometer measures gaseous emissions, among other things. A laser points out of the cabin window at the wing tip, measuring water vapour in contrails and ice clouds.

DLR's Schlager and NASA's Bruce Anderson are keen to work together with their colleagues to determine the impact of alternative fuels on aircraft emissions and contrails. For this purpose, the campaign, which goes by the not-so-catchy name of ND-MAX/ECLIF II – an abbreviation for NASA/DLR-Multidisciplinary Airborne eXperiments/ Emission and CLimate Impact of alternative Fuel – uses fuels such as the HEFA (Hydroprocessed Esters and Fatty Acids) sustainable fuel produced from camelina plant oil. Le Clercq has provided specially designed blends of HEFA with conventional kerosene. Previous campaigns have shown that a mixture with a biofuel content of 50 percent reduces soot emissions by 40 to 60 percent. Now the researchers want to demonstrate that such fuels also reduce the number of ice crystals in contrails, resulting in a decrease in the climate warming effect caused by long-lasting contrails.

A look back – waiting for the special fuel

Shortly before Christmas 2017, researchers at the DLR Institute of Combustion Technology were still working hard on the logistics for the flight tests, which were to take place from mid-January 2018. "We need a special blend of fuels for the mission, which are produced specifically for us," says project leader Le Clercq, who ordered fuel from BP Europa in Hamburg and supervised the project personally to make sure that everything with the fuel blends was exactly right. "For the ND-MAX/ECLIF II flight tests, we are using a 30 percent to 70 percent blend of biofuel and conventional kerosene for the first time," Le Clercq adds. "We designed this special fuel based on our flight tests in 2015 as part of the ECLIF I campaign, which involved the DLR A320 ATRA and the Falcon 20. The results at that time suggested that a specially designed 30 percent admixture could have significant positive effects on soot reduction, to the extent that the more expensive 50 percent blend might not be necessary." The scientists are now comparing these two blends in the flight tests.

But before this could happen, the Stuttgart-based combustion engineers were faced with a very different challenge – the fuel provider was unable to deliver it to Ramstein Air Base at short notice. This seemed to be an unfortunate consequence of the fact that the blending process and delivery could only take place just before the start of the project due to a lack of storage capacity. But Le Clercq and his team had an idea. First, they tried to hire a company specialized in fuel transport. However, their initial enquiries met with disappointment. "We are fully booked until mid-February and do not have any transport capacity." That was too late for the project. The team continued to make enquiries, but received only negative answers until just before Christmas. Tension was growing among the team – was the whole mission about to be cancelled due to the fuel delivery problem?

In the cabin of the DC-8: The hoses, where the outside air is led into the numerous instrument racks, are clearly visible. Approximately half of the instruments on board come from DLR.

At the mission control station in NASA's DC-8

Image: DLR-Jörg Adam

On the side of the 'Flying Laboratory' DC-8: air intakes and measuring instruments.

Probes for measuring the size, number and shape of ice crystals in contrails.

Image: DLR-NASA-Friz

The fuel to be analysed is pumped from one of the seven containers into the tanker

The DLR research aircraft is filled up with one of the biofuel mixtures

Le Clercq and his colleague Uwe Bauder made a last attempt with the companies Kördel and Hoyer. They succeeded – seven tank containers filled with the specially prepared fuel blends reached Ramstein on time in the first week of January. Three of them held conventional Jet A-1 kerosene as a reference fuel, two containers held a 30:70 blend, and the remaining two a 50:50 mixture. Le Clercq's careful calculations when designing the fuel and monitoring the blending process paid off, as both blends were approved as aviation fuel by a specialist laboratory. This guaranteed the safety of both the 30 percent mixture and the 50 percent blend in the tanks of the A320 ATRA today.

Take-off for a chase flight in the name of research

Before take-off, the 'Fasten Seatbelt' sign lit up for all crew members on board the DC-8. In fact, the sign was in German "… because the aircraft once flew scheduled services for the Italian airline Alitalia, which also carried German passengers," one of the old hands in the DC-8 crew reveals with a smile.

Looking out of the window, the A320 ATRA can be seen beginning to taxi. There is only a small crew on board, in addition to the special fuel blend. The DC-8 also sets off, following the ATRA. As the aircraft is set in motion, an announcement comes over the noise-reducing headphones at each seat, urging the researchers and crew members to remain seated and with their seat belts fastened, even when the aircraft flies in the contrails.

Other aircraft operations are also taking place on the runway at Ramstein Air Base. A US Air Force cargo plane is on the approach, so the research aircraft have to wait. "C 130 just landed, now we can start," comes over the headphones, and the A320 ATRA taxis onto the runway, followed by the DC-8. It is time to take off for northern Germany! The journey across Germany from Rhineland-Palatinate to Mecklenburg-Vorpommern takes approximately 40 minutes. At last, they reach the Temporary Reserved Airspace (TRA), which stretches from northern Brandenburg to the island of Rügen.

Once there, a chase in the name of research begins. It is a spectacular exercise. The A320 ATRA is suddenly in sight from the left-side cabin window of the DC-8. DLR pilot Stefan Seydel maintains his course and speed so that NASA pilot Wayne Ringelberg, sitting in the DC-8, can gradually catch up with the A320. The two jets briefly remain at the same altitude – a duet in the sky. "This manoeuvre allows the altimeters in both cockpits to be synchronised," explains Schlager as he looks out of the window. The ATRA and the DC-8 slowly pull apart until the ATRA flies ahead again and disappears from view.

The flights are easy to track from the ground using a mobile phone. The Internet platform Flightradar24.com shows users how both aircraft make their first 180-degree turn and follow one another for about six kilometres. The 'Fasten Seatbelt' sign lights up again. Over the headphones, a voice says "Let's go into the contrail!" A gentle jolting motion indicates that the DC-8 is entering the wake turbulence of the A320 ATRA ahead of it, with its contrails. The aircraft shakes over and over again, while the scientists and mission heads on board discuss the aircraft's status over their headsets and microphones.

"WE'RE STILL A LITTLE BIT TOO HIGH."

"DO YOU GET A CO_2 SIGNAL FROM THE EXHAUST?"

"WE'RE COMING INTO THE ATRA WAKE. WE DETECT ICE PARTICLES HERE."

"OH, THIS IS A LOW-SOOT FUEL."

An important part of the research campaign was the measurement of exhaust gases and particles on the ground

Control station for measurements on the apron of Ramstein Air Base

Image: DLR/Jörg Adam

The exhaust gases are directed to the measuring instruments via an air inlet and a hose system

During the ground measurements, light blue-grey exhaust air vortex can be seen, which 'falls' from the engine of the A320 ATRA.

Image: DLR/Jörg Adam

With their eyes set on the measuring equipment, the researchers observe that the emissions of a biofuel mixture contain significantly less soot, as demonstrated by the initial flights with NASA in California during 2014. Enthused, Schlager looks at the instruments in front of him: "The DLR Institute of Atmospheric Physics in Oberpfaffenhofen installed devices on board the DC-8 for simultaneously measuring the size distribution of soot and ice particles, as well as gaseous emissions in the wake of the A320 ATRA," he explains. "If you look around the cabin of the DC-8, you will see that about half the measuring devices are from DLR, alongside equipment from NASA and other partners, like the Max Planck Institute for Chemistry in Mainz," he adds rather proudly.

Fewer soot particles – fewer ice crystals – less warming?

The researchers are particularly interested in the small ice crystals that form on soot particles due to condensation in sufficiently moist air, forming visible contrails. "We want to understand the effect that lower numbers of soot particles from alternative fuels have on the size, quantity and reflective properties of ice particles in contrails," says NASA project leader Anderson as he shows his German counterpart Schlager some curves from the last set of measurement data. The researchers suspect that fewer soot particles means fewer ice crystals in contrails, which would reduce their average climate-warming effect. Condensation trails can linger for several hours in humid and cold conditions at altitudes of 8 to 12 kilometres, forming high clouds called contrail cirrus. "Depending on the position of the Sun and the nature of the ground below them, these clouds can have a warming or a cooling effect," Schlager says over his microphone, above the noise of the aircraft. "Knowledge about this is essential for assessing the impact of aviation on the climate. The research so far suggests that, globally, there is an overall warming effect."

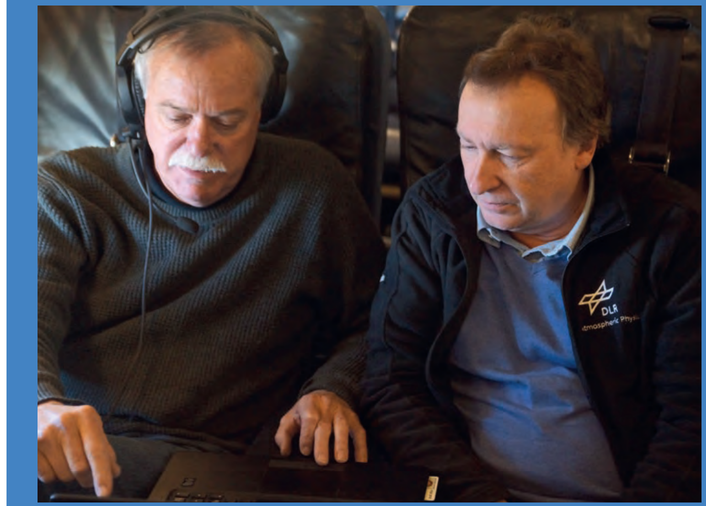
Like Schlager, the other researchers are concentrating on the measuring equipment in front of them. The A320 ATRA and the DC-8 fly laps over Mecklenburg-Vorpommern and then enter another TRA over Lower Saxony and Schleswig-Holstein, between Oldenburg and Kiel. Each lap appears on the screen as a race track shape, with a straight segment used for measurements, ending in the curve of a 180-degree turn, before commencing the next straight stretch and then the next 180-degree turn. Flightradar24.com shows that the DC-8 and the ATRA make more than 10 of these laps before NASA pilot Ringelberg and DLR pilot Seydel start on the return flight. The crewmembers on board are finally free to leave their seats. Both aircraft eventually land at Ramstein Air Base. The six-and-a-half-hour flight is followed by ground measurements on the runway, with the ATRA and the DC-8 lined up once again. A 'Follow-Me' vehicle then guides the two aircraft to their parking positions.

And again – empty tank, refill tank

Once DLR's A320 ATRA has landed, the tanker drives straight up to it. The following morning, more ground measurements have to be carried out using a permanently installed set of ground instruments before the next test flights. DLR Flight Operations Manager André Krajewski must handle the different fuels with care. "Tomorrow, the aircraft will fly with and test the 30 percent biofuel / 70 percent kerosene blend," says Krajewski as he fixes the refuelling hose to the underside of the ATRA's wing. "That means we first need to drain anything that is left of the 50/50 blend that was used today out of the tank, so that it can be filled with the new blend tomorrow morning." Having been specially produced for the flight tests, the fuel is expensive, so the leftover fuel is fed back into the appropriate storage tank.

Image: DLR/NASA/Friz

NASA Project Leader Bruce Anderson monitors the progress of measurements on board the DC-8



Bruce Anderson during a measurement flight in conversation with Hans Schlager, the leading DLR scientist from the DLR Institute of Atmospheric Physics.

Image: DLR/NASA/Friz

Project manager Patrick Le Clercq from the DLR Institute of Combustion Technology informs the press about the specifics of biofuels

REAL AIRCRAFT AND THEIR VIRTUAL TWINS

Before a single component has even been manufactured, scientists and engineers will use computer models to determine what a new aircraft will look like, what characteristics it will have, and how it can be manufactured and maintained most cost-effectively. This will soon be possible on high-performance computers using digital techniques. However, much research is still needed before this dream can become a reality. With the support of Germany's federal and state governments, DLR founded four new institutes for that very purpose in 2017. Within the framework of DLR's aeronautics research programme and in coordination with industry and the German Federal Ministry for Economic Affairs and Energy, the theoretical and practical basis for ongoing digitalisation in aviation will be developed within the institutes. In so doing, DLR will especially benefit from the synergies arising from the programmatic combination of new capabilities with those of the existing and globally renowned DLR institutes.

A look at digitalisation in aviation

By Olaf Göring

DLR researchers and engineers are not starting from scratch. Software packages were already being created 20 years ago to simulate flows on aircraft (MEGAFLOW I/II). At that time, they made a huge contribution towards computer-aided design and aircraft manufacture. More complex software solutions were added over the years. As a result, DLR has long been using simulators (for example AVES) as well as various wind tunnels and research aircraft (such as ATRA) as validation platforms that work together in a unique way. In addition, DLR has gradually installed new mainframe computers for flow simulations ($C^2A^2S^2E$ HPC Cluster). However, this is no longer adequate. The main goal of the overarching theme 'digitalisation of aviation' is to virtualise the entire system along a 'digital thread'. This involves the whole process from development and certification in the computer, to digitalised production as well as the delivery of a 'digital twin' with all recorded physical features, through to virtual operation and maintenance, right up to the simulated decommissioning of an aircraft.

Digitalisation is gaining ground

Digitalisation brings whole new perspectives to aviation in particular, with its long development times and extensive approval processes. The use of complex software models in aircraft development confirms this. Yet researchers and developers across DLR must still perform numerous tasks requiring a profound understanding of the aeronautics system before the entire lifecycle of an aircraft has been recorded.

In the meantime, the first workspaces with three-dimensional virtual representations have found their way into the industry. In particular, the use of virtual models in engine development has made especially good progress. At its location in Dahlewitz, near Berlin,

Conducting the first flight 'in the computer' is one of the primary goals of the digitalisation of aviation

On the way to digital aircraft production

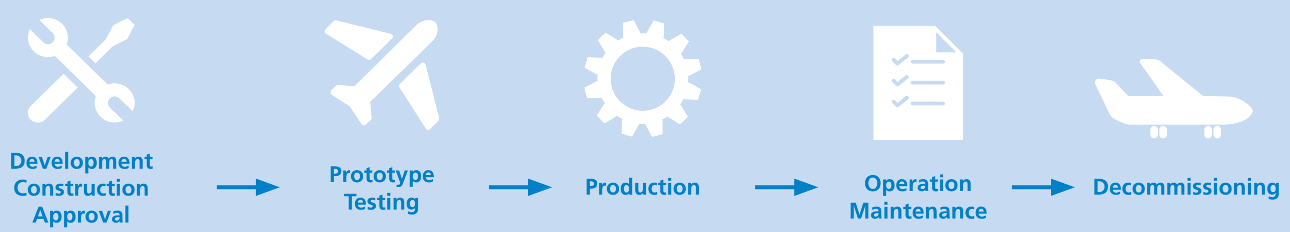
Rolls-Royce has created this type of environment for the development of its complete engines. Siemens has taken a different route that treads the line between an actual test device and virtual testing. At its Munich-Neuperlach research site, it is investigating motors for future electrically powered aircraft, together with Airbus. Here, samples of real scenarios can be tested using point-and-click flight software – like that used for computer games – in order to simulate flights and replicate the loads experienced during different flight phases with the test motor. The motor in the laboratory therefore works just as it would on a real flight. The Center of Applied Aviation Research (ZAL) in Hamburg has a virtual reality room where different areas of application – from designing the aircraft cabin to the electrification of aircraft – can be simulated. Virtual reality screenings are held in an audience area, with a capacity of up to 30 people. There is also a projection room where developers can test out and evaluate new technology and products before production, as well as identify any possible sources of error in the design.

Yet these are somewhat lonely beacons of advanced technology amid a broad field of relatively orthodox approaches to aircraft development and production. Another problem is that they are stand-alone solutions. The data from one system cannot be passed on to a subsequent system or collaborators without undergoing complex transformation processes. In many fields, there is also a lack of software and data models that would allow the necessary information to be represented in a computer model.

A virtual companion

The long-term goal of digitalisation in aviation is to overcome this state of affairs and to fashion a 'virtual twin' for each aircraft type, with sufficiently precise models and processes. This would follow the real machine from its initial design right through its entire lifecycle, all the way to its eventual decommissioning. With the help of such computer models, future generations of aircraft should be safer, more efficient and more environmentally friendly. And the challenges to be overcome are huge, as the European Union wants to maintain its global lead in aviation, according to its FlightPath 2050 agenda. Therefore, future aircraft engines will emit 75 to 90 percent less carbon dioxide, while reducing perceived aircraft noise by around 65 percent. With the help of digital models, the significant cost of certifying new aircraft is also expected to be reduced considerably, and the time between design and certification shortened.

AN AIRCRAFT'S LIFECYCLE



DLR will focus more on these challenges in future, as this issue touches upon aviation, as well as spaceflight, energy and transport. In order to keep DLR at the forefront of aviation research, four new institutes, as well as the Virtual Product House (VPH) in Bremen, were founded in 2017. They have been tasked with devising basic solutions for digitalisation in aviation. Ultimately, the virtual twins described above should become a reality for the entire lifecycle of an aircraft. DLR researchers are thinking even further ahead. They not only want to become service providers for the aviation industry with their software solutions in future, but also to continue to develop advanced designs.

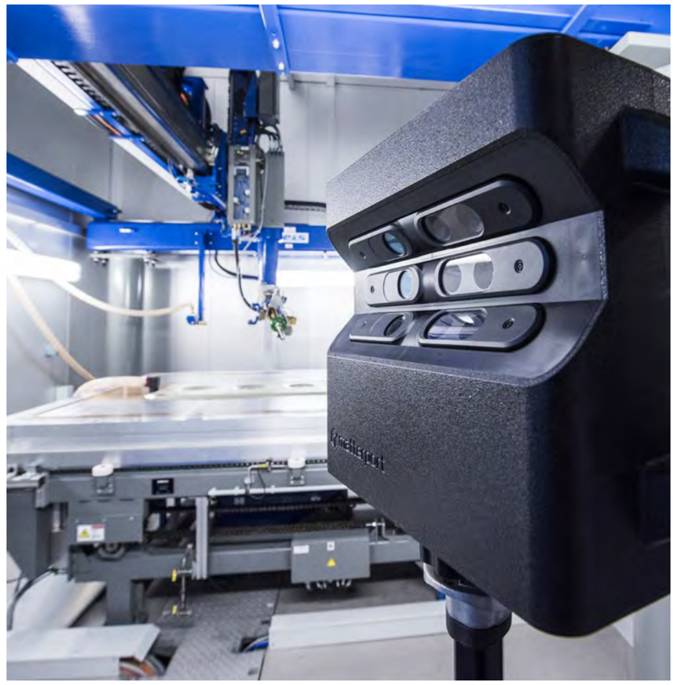
Engines via computer

Propulsion systems are the heart of an aircraft. They are designed to fulfil multiple functions: fly quietly, consume low amounts of fuel, and be environmentally friendly. Developing them is therefore a particularly complex task that takes several years. Every engine consists of more than 10,000 individual parts and can cost many millions of euros, depending on its size. They account for around 30 percent of the price of a modern airliner. To tackle this demanding task, Rolls-Royce has established a virtual reality laboratory where a complete engine can be visualised in 3D. Individual elements can be extracted and viewed from all sides using a special operating device similar to a joystick.

THE FOUR NEW DLR AERONAUTICS INSTITUTES

- Institute of Test and Simulation for Gas Turbines, Augsburg
- Institute of System Architectures in Aeronautics, Hamburg
- Institute of Maintenance, Repair and Overhaul, Hamburg
- Institute of Software Methods for Product Virtualization, Dresden

"At our Institute, we will integrate and interlink the digital and real world of measurement results much more closely for turbojet engines," says Stefan Reh, founding Director of the DLR Institute of Test and Simulation for Gas Turbines in Augsburg. Virtual engines and components, such as turbine blades or compressors, are set to play an important role in the Institute's future research work. But the Augsburg-based researchers will not just be looking at monitors and moving around in virtual spaces; they will be developing real test rigs that interact with the digital world. "It is vital for experimental projects and numerical methods to interact with one another. We are working at the limits of what is physically feasible, so we cannot rely solely on simulation techniques," Reh says. After all, the software for the virtual model has to be 'fed' with data from the real operation of an engine in order to ensure that the simulation is as close to reality as possible. Ultimately, the aim is to increase the reliability and service life of future turbines, and thus to improve aviation safety.



Street View' for indoors – a 3D scanner on the production line at DLR Stade.

Birth of a digital twin – the camera scans every corner and every angle of the component.

The 'digital thread'

Essentially, an aircraft has to be designed, constructed and maintained as a complete entity. Digital models are useful here as they provide compatible data that can be directly applied at other stages in the lifecycle. IT experts talk about a ‘digital thread’ that allows the data packets of the virtual twin (cabin, engines and other elements) to be moved from computer system to computer system, without any obstacles. The two new DLR institutes based at ZAL in Hamburg are devising solutions for this purpose. The Institute of System Architectures in Aeronautics and the Institute of Maintenance, Repair and Overhaul have both found their ideal home at ZAL, which already has a virtual reality laboratory and hosts a range of young start-up companies with fresh ideas. The DLR Institute of System Architectures in Aeronautics, for instance, focuses on the digital design of aircraft and the transfer of data to digitalised production. But that is not all – the researchers also want to link up all aircraft components with the surrounding flight operations infrastructure and present them as a system-level model in order to harness further potential for development. The emphasis is on new solutions that combine elements of the overall aviation system in a novel way. “Another focal area is the development of innovative cabin and fuselage concepts,” says Björn Nagel, founding Director of the DLR Institute for Systems Architecture in Aeronautics. The central element is a digital mock-up that can introduce different capabilities – such as cabin climate, cabin noise or lightweight construction – into the design process at an early stage, thus connecting them with the production research of industry partners.

Virtual product and Industry 4.0

The path continues from virtual design to virtual testing and virtual certification through to the virtual product. “With the Virtual Product House (VPH) in Bremen that was established in addition to the four new institutes, DLR is pursuing the goal of closely cooperating with industrial partners and the scientific community to build up an integration and testing centre for the virtual simulation and certification of components and technologies, as well as their integration into the entire aircraft,” says Kristof Risse, head of the Virtual Product House and coordinator of digitalisation in aeronautics. “In the long term, the VPH of DLR is expected to carry out the virtual certification of aircraft components for and together with the industrial partners.”

The production of aircraft and their components is the next stage in the lifecycle. This, too, will be connected to the digital thread in the future. The number of aircraft manufactured is relatively low compared with other products. At the same time, they are extremely complex and complicated products, the manufacture of which has previously required a lot of manual work by qualified staff. A batch size 1 for a component is no exception here. This is particularly true for parts made of fibre composite materials, which require real craftsmanship to produce. DLR researchers at the Institute of Composite Structures and Adaptive Systems in Stade are among those who want to change this state of affairs. Their goal is a transformable factory – a fully automated process chain for fibre composite parts is to be connected to the digital twin, thus referencing the exact dimensions and production data for each component. The machinery feeds this data into its programming, thus making even batch size 1 cost-effective. The plant in Stade is the first application of the Airbus 'Factory of the Future' project.

The path towards MRO 4.0

After production comes the operation of aircraft. Maintenance, repair and overhaul (MRO) are essential elements of this phase. These activities are highly cost- and labour-intensive, and are associated with a great deal of manual labour. In 2015, a total of 25 billion US dollars was spent globally on MRO for engines alone. There is an urgent need to streamline processes and reduce costs in this area. The DLR Institute of Maintenance, Repair and Overhaul will address this task. An MRO 4.0 Applications Centre (its name relates to Industry 4.0) is being established at the Institute for that very purpose. The aim of this centre is to demonstrate the findings of the research work and put them into practice. “Our research topics include the development of new maintenance and repair concepts, as well as their digitalisation, together with predictive maintenance,” says Hans Peter Monner, founding director of the Institute of Maintenance, Repair and Overhaul. “Another issue is product efficiency across all phases of the lifecycle.” For instance, this means taking MRO processes into account when designing a new aircraft or incorporating the recovery of components and materials from a decommissioned one. This interplay between different elements – not to mention the complicated maintenance processes and product modifications – must be tested before they are applied in ‘real life’. For this, the digital twin is simulated in parallel with the real product in order to optimise costs and operations.

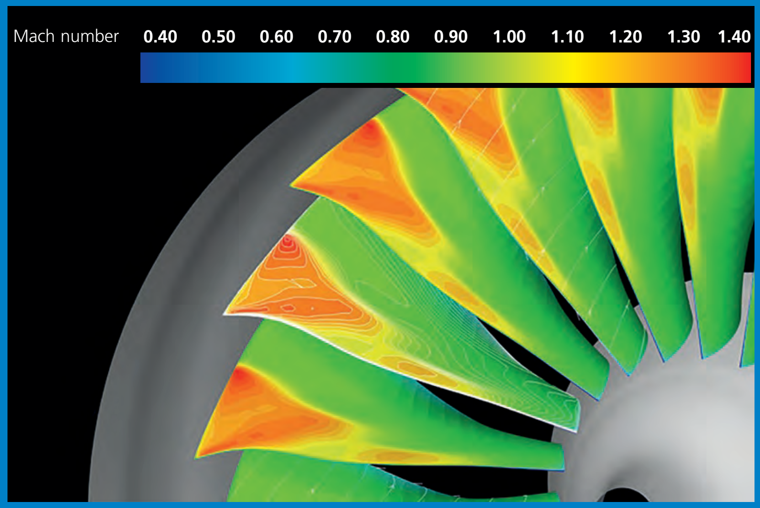
The software developers

The programming of virtual twins along the digital thread can only happen if the model remains as true to reality as possible in relation to the laws of physics and contains the fewest possible simplifying assumptions. The basic software methodologies for such models and processes are being devised at the new DLR Institute of Software Methods for Product Virtualization in Dresden. This was an area that had previously been addressed only in individual cases at DLR. In order to take into consideration all of the influences and parameters for a digital model, scientists and engineers from fields as diverse as aerodynamics, structural mechanics and manufacturing techniques, acoustics and flight mechanics have to work closely together. “Models with different levels of depth need to be brought together, correctly interlinked and executed effectively on parallel computers without user intervention,” explains Norbert Kroll, founding director of the DLR Institute of Software Methods for Product Virtualization in Dresden. In addition to the modelling algorithms, programming and data models must also be prepared for parallel high-performance computers so that the algorithms can be implemented efficiently in programs. The Dresden-based institute is therefore working in fields that will not only serve the digitalisation of aviation, but will also benefit DLR’s research as a whole.

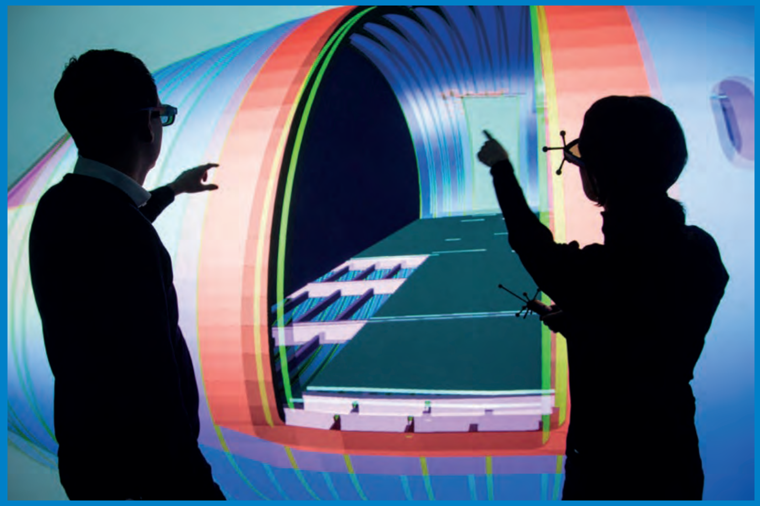
Digital models are already a reality in many places within DLR. Through the networking of individual phases and the complete virtualisation of an aircraft type throughout its entire lifecycle, DLR is harnessing new potential for innovation that will pave the way for more cost-effective and environment-friendly aircraft, while also making them more reliable and offering passengers new on-board features. The four new institutes optimally strengthen the potential of DLR's aeronautics research and ensure the exploration of this path in a timely manner.

Olaf Göring runs a press agency in Potsdam that focuses on aviation and space travel, in addition to Information Technology. His work is published in, among others, the Flug Revue.

Virtual flight tests as an alternative to real flight tests



With the TRACE simulation software, the flow conditions in engine turbines can be calculated. TRACE is now also used in industry for the design of new turbine components. MTU Aero Engines developed and optimised components for one of two possible engines for the Airbus A380 with this program.



Virtual Reality Lab – the virtual laboratory at the ZAL TechCenter in Hamburg enables up to 30 viewers to discuss virtual models simultaneously.

GLOSSARY

DIGITALISATION

is the comprehensive transformation of the economy and society at large into an intricately networked and automated society, with almost all areas of life affected in some way. This transformation process is now accelerating at a fast pace.

VIRTUAL PRODUCT

In general, virtual product describes the highly accurate mathematical-numerical representation of a new aircraft with all its features and components, such as aerodynamics, systems and engines. All phases of product realisation – from design to the prediction of performance and features, through to construction and manufacture – must be capable of simulation prior to (partial) realisation. The long-term goal is to be able to carry out the complete product lifecycle analysis virtually. An essential aspect of the virtual product is involvement in the certification process of new aircraft on the basis of numerically created data.

INDUSTRY 4.0

is a term used to describe the fourth industrial revolution, following mechanisation with water and steam power (first revolution), electrification and mass production (second revolution) and automation (third revolution). Digital computers and process controllers have been used extensively in industry for over 30 years. Now the use of such systems is to be taken to the next networking level (for example, machine-to-machine communication), with intelligent information processing.

BATCH SIZE 1

A set number of identical workpieces are called batches in industry. Accordingly, batch size 1 means a single workpiece.

VIRTUAL REALITY

is the 3D representation of a product within a surrounding space. Using virtual reality (VR) glasses, a researcher can move around the virtual product and make changes to it remotely.

AUGMENTED REALITY

Using special glasses, technicians can access extra information, work instructions or data through the glasses. This is described as ‘augmented reality’.

SEARCH AND RESCUE

Mobile Rocket Base engineers perform payload floater tests at ESA in Cologne

By Oliver Drescher and Johannes Göser

For most suborbital space flights, the successful recovery of the experimental payload is a critical point at the very end of the mission. In addition to the landing itself, the sea recovery in the Arctic Ocean is a particularly delicate task. Therefore, scientists working for DLR's Mobile Rocket Base (MORABA) have developed a variety of floating systems. In order to meet the growing scientific requirements, some of the latest development work has been dedicated to a modernised version. In cooperation with TEXCON GmbH, improved long-term floating behaviour and a considerably reduced packing volume have been achieved by using innovative materials and manufacturing technologies. In October 2017, a prototype of the newly developed floating system was put through its paces in the 10-metre-deep diving pool (Neutral Buoyancy Facility; NBF) of ESA's European Astronaut Centre (EAC) in Cologne. This was a rather unusual test scenario for the EAC colleagues, in particular to those in charge of the 'buoyancy pool', in contrast to the commonly simulated extra-vehicular activities of the ESA astronauts' training programme.

www.dlr-gsoc/moraba2015/

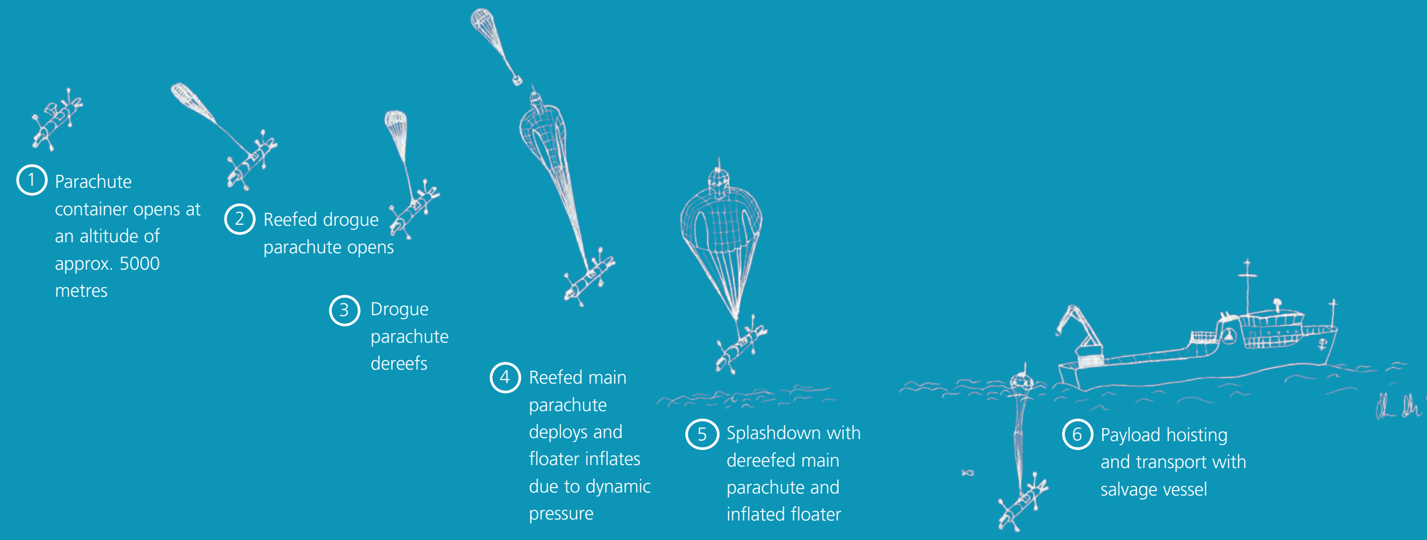


Illustration: DLR/Oliver Drescher

Illustration of a typical recovery of sounding rocket payloads at sea

The combination of a 10-metre-deep diving pool with an overhead crane was decisive for selecting the NBF as the suitable testing facility. The accompanying spaceflight atmosphere made it almost perfect.

The partly submerged payload floater carrying a test mass of 200 kilograms equipped with draught marks and pressure sensor

DINOFLAGELLATES WITH SENSOR POTENTIAL

Things could have turned out quite differently. Jens Hauslage could have been either a taxi driver or a pharmaceutical representative. Those, he says, were the typical job prospects for people studying biology. But this did not prevent him from choosing biology as his field of study at the University of Bonn. He had always found biology easy to grasp at school, without much need to study, whereas mathematics was a very different story. He might well have gone into a technical profession; after all, he did his first soldering at the age of five. Electronics has been a hobby ever since then. Today, the 40-year-old has a foot in both fields at the DLR Institute of Aerospace Medicine – a mechatronics engineer and biologist at the same time. As a biologist, he has sent the flowering plant *Arabidopsis thaliana* – thale cress – into microgravity conditions on sounding rockets. As a mechatronics engineer, he builds his own experimental equipment, with the aim of recording data or transmitting it back to Earth during these flights.

Jens Hauslage brings biology and technology together in his work on life in space

A portrait by Manuela Braun

Just recently, Jens Hauslage moved from an office in one area of the DLR premises in Porz-Wahn, on the outskirts of Cologne, to another. Catching a glimpse of the biologist behind his desk in his previous small office had been rather difficult. There, an enormous ficus tree stood in front of him, a model of DLR's C.R.O.P. biofilter, which he developed – complete with water, tomato plants and lava rocks – stood in one corner, and the window ledge was crowded with young plants, tiny mussel shrimps in a preserving jar and a microbacterial fuel cell. On the bookshelf, mementos of missions and test tubes containing praying mantises were squeezed in against the book spines. Disused or modified computer parts lay on the scarce unused square metres of floor. Nowadays, his much larger empire lies at the end of a long corridor, right beside the computer room. It almost seems a little out of the way. "It is fantastic – I have much more space now," he says

Biologist Jens Hauslage has been working at the DLR Institute of Aerospace Medicine since 2005

Thinking outside the box

Hauslage needs space, because both his thoughts and his practical efforts are generally divided between several areas of work – he is constantly switching between tasks for current missions and upcoming projects while tinkering with gadgets for work or simply as a hobby. "I am a real idea factory. My mind is always on the go, moving between different things," he says. A 3D printer that he has constructed himself sits on a table against the wall. He built it from purchased parts and 3D-printed components. On his desk, a small wooden box containing a microcontroller sits alongside his computer. The black needle on the display points to 50. "The box is connected to Google Maps and informs me of how many minutes it would take me to drive home if I were to leave DLR now." He loves building these little boxes. He might make them from old-fashioned light bulbs or obsolete parts that once had a function, but he always injects a lot of creativity. The things that he creates can shine, take measurements or react to their surroundings. He sometimes uploads details of his inventions – and instructions for building them – to websites where hobbyists, electronics aficionados and inventors can exchange ideas and enthuse over these unusual items.

Timers, turntables and 3D printing

Hauslage's first experiment was for a DLR parabolic flight. At the time, he was still a student at the Institute of Gravitational Biology at the University of Bonn. He crafted a used – but still functional – record player into a centrifuge to be included on the flight. Hauslage describes himself as a 'dumpster diver' – someone who rifles through discarded, rejected items to find something of use. Finished products that were once employed within the field, or things that can be repurposed for a different function after their initial use, are combined with self-built items to become experimental scientific equipment. "Can you still use that?" the DLR medical officer once asked, an old timer in his hand. The quartz crystal in that precise timer went on to become part of the real-time clock to fly on board the MAPHEUS-6 sounding rocket. MAPHEUS-7 also includes components made using the self-assembled 3D printer in Hauslage's first-floor office. "Made from biodegradable plastic, of course," says Hauslage, ever the biologist.

Hauslage's fascination with space travel first came from the Space Shuttle, whose flights he followed avidly as a child. But it was the Biosphere 2 project, built by the billionaire Edward Bass in Arizona in 1991, that really captured his imagination. This habitat, comprising savannah, ocean, tropical rainforest, mangrove swamp, desert and agricultural land, was intended to allow humans to live within an enclosed ecosystem. For two years, an eight-person crew lived in this artificial biosphere, which was supposed to function like a second, self-sufficient Earth. Something went awry, with the result that the biosphere community did not remain as isolated and autonomous as planned. Since 1996, universities have used Biosphere 2 to research ecological issues. "Back then, I saw a television special on Biosphere 2, and it was like my own personal version of the Moon landings," recalls Hauslage. "In my case, I was not hooked by the human story, but by the natural world elements, the cells and plants."

Sensitivity to gravity

As far as Hauslage is concerned, plants are the true heroes. "Plants have an infinite ability to adapt. It is quite simple – without plants, there can be no humans." He has been working as a scientist in the field of gravitational biology since 2001, having started out as a

Engineer Jens Hauslage assembles components for experimental systems that must be absolutely reliable

Below: As a biologist, he investigates the effects of gravity on plants. They are exposed to microgravity on parabolic flights and sounding rockets.

Plants are the real heroes for Hauslage. They can adapt to adverse conditions remarkably well.

Replacing his soldering iron with a pipette, Jens Hauslage prepares his 'test subjects' for the experiments in the laboratory.

student assistant, examining the perception of gravity by higher plants in his doctoral thesis and carrying out research on parabolic flights and sounding rockets. Gravity is the only parameter that never changed, he says. "So my question is – how has gravity shaped life?" In March 2003, one of his experiments flew on a sounding rocket for the first time. Maxus 5 took off from the Swedish Esrange Space Center, with Hauslage present as a student about to graduate. "I have been a fan of rockets ever since," he says. He has experienced microgravity conditions himself on more than two dozen parabolic flights and has also had his 'test subjects' experience microgravity on many occasions. The 22 seconds of microgravity experienced during a parabolic flight is enough for plant cells to react to the change in gravity.

Tomatoes make it into space

This year, another apparatus will join the parabolic flights and rockets that are already carrying Hauslage's biological experiments into microgravity conditions. In 2018, two greenhouses are set to be launched into space on the Eu:CROPIS satellite, having been built and tested by the DLR Institute of Space Systems in Bremen. Tomato seeds are then supposed to germinate and grow into plants that, in turn, provide seeds for the next generation of tomato plants. They obtain their nutrients from artificial urine, which will trickle through a lava stone biofilter. Living microorganisms will convert it from harmful ammonia into nitrite and then nitrate, which is digestible by and useful for plants. Euglena – single-celled organisms provided by the University of Erlangen-Nuremberg – support the process and generate oxygen. Meanwhile, the satellite will rotate about its own axis at different speeds, replicating the gravity of Mars and the Moon for six months each. Numerous cameras inside will observe how the tomatoes are coping in space. Hauslage is one of the principal investigators of the mission, alongside Michael Lebert of the University of Erlangen-Nuremberg. "In future, this kind of closed life-support system could make it possible to supply the crews on long flights or in habitats on the Moon or Mars with fresh produce," he explains.

Charophyte green algae and thale cress

Hauslage is convinced that biology helps us to understand all sorts of relationships between things. His brain is certainly always connecting things, with one topic leading to the next. He can recall complex facts at the drop of a hat. "Have you ever heard of dinoflagellates? They are plankton that create marine phosphorescence." Hauslage has already subjected them to split-second microgravity through free fall in the Drop Tower in Bremen. "They light up when they are mechanically stimulated by being subjected to shearing forces." If a dinoflagellate illuminates during a microgravity experiment, it can indicate that complete microgravity has not been achieved. In this case, Hauslage is interested in the changes to biological membranes when subjected to microgravity. "They are a superb bioindicator for how good or poor the microgravity conditions really are." From there, it is a short jump to his next topic of conversation: "This behaviour is a clever alert system, like a burglar alarm." If a dinoflagellate is in danger of being eaten by a crab, it lights up, thus attracting octopuses, which then eat the crabs. Hauslage is enthused. Dinoflagellates, charophyte green algae and thale cress – even their names get him excited.

Alongside his work as a scientist and researcher, he is a member of the Chaos Computer Club Cologne, where he gives talks on electronics in space and exchanges ideas about tinkering with gadgets and technology. He attended the 'Still Hacking Anyway' meeting for electronics enthusiasts in the Netherlands in 2017, where data cables, computers and tents were set up to give the thousands of attendees the chance to pool their creativity and technical skills over the course of several days. Wikipedia provides an apt definition: "Any skilled computer expert that uses their technical knowledge to overcome a problem." In Hauslage's case, it is his 'little boxes'. Most of them do not have far-reaching applications, but they are equipped with niche capabilities and have been lovingly soldered and screwed together.

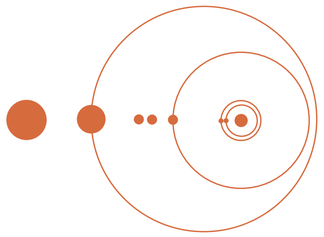
Schematics as light reading

"Wood, brass, tubes, old computers. That is how I balance out the dryness that sometimes comes with science." Novels that dispense with technical detail are not his 'thing'. "I can lose myself completely in circuit diagrams." And information about flora or fauna has the same effect. He took some home-pickled peppers to the meeting in the Netherlands. "Rocoto peppers," he stresses: "Otherwise known as the Gringo Killer." This variety is native to South America, and genetically depleted, he explains. They are incredibly spicy. Even science-fiction films that deal heavily with space travel do not tend to be of much interest to this scientist. That said, he has heard a fair bit about 'The Martian'. The protagonist is supposed to ensure his survival on Mars by growing potatoes, thus creating his own source of food. "A person needs around 2000 kilocalories a day. Boiled potatoes have just 70 kilocalories per 100 grams. That means that each astronaut would have to dig up, cook and eat 2.8 kilograms of potatoes per day. That would never work." For Hauslage, biology is most exciting when it remains rooted in real life – just as it is all the more thrilling when it is combined with technology.

Right: The DLR researcher developed the biofilter system C.R.O.P. The closed life-support system will launch into space in the summer of 2018 on board the Eu:CROPIS satellite.

THE NEVERENDING STORY

The first extrasolar planet around a Sun-like star was discovered nearly 25 years ago; today, approximately 4000 new planets have been found. It is not only the sheer number that is remarkable – their incredible diversity is raising new questions regarding the origin and evolution of planetary systems. Exoplanet research also helps scientists to better understand the Solar System. The PLATO and CHEOPS missions currently under preparation are intended to address currently unanswered questions. This article looks back at what has been happening during recent years in the exploration of these distant worlds.



Discovery of remote worlds challenges current theories

By Ruth Titz-Weider

CoRoT and the super-Earth

The DLR Institute of Planetary Research in Berlin-Adlershof has been involved in the search for and characterisation of extrasolar planets for many years. The CoRoT (**Co**nvection, **Ro**tation and planetary **T**ransits) telescope, launched in 2006, was the first space mission for the detection of exoplanets. DLR researchers were part of the project's science team and developed the evaluation software for the instrument on board the spacecraft.

CoRoT's most remarkable discovery is CoRoT-7b – it is what is known as a super-Earth. Planets of this type are somewhat heavier and larger than our home planet, with no more than 10 times the mass of Earth and a radius of between one and two Earth radii. Today, CoRoT-7b is one of the most closely studied exoplanets, and was the first rocky planet for which the radius and mass could be accurately determined. CoRoT-7b has five times the mass of Earth and has a density similar to that of our planet. This super-Earth has an orbital period of 20.4 hours and is tidally locked, which means that its day side permanently faces its star.

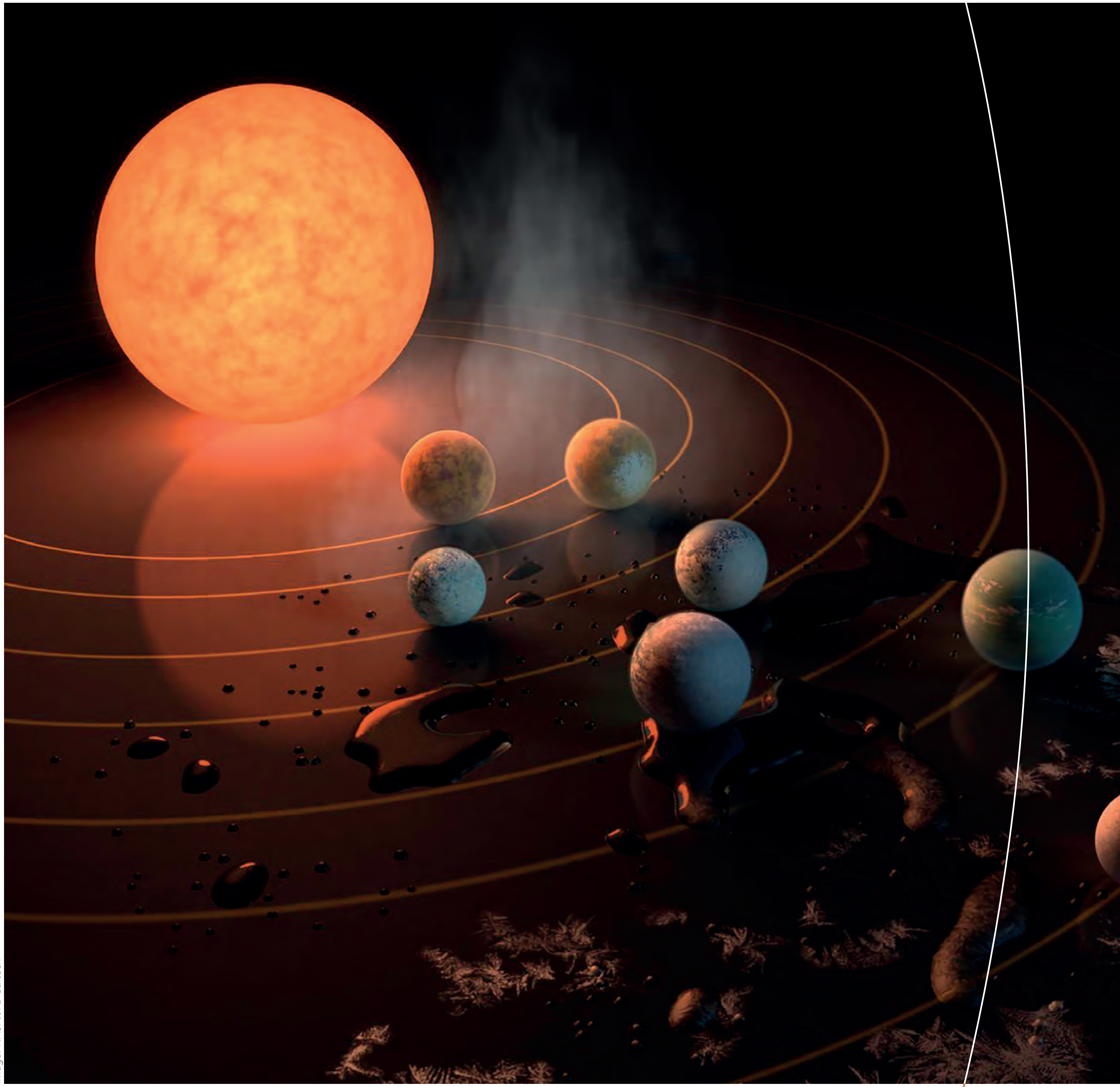
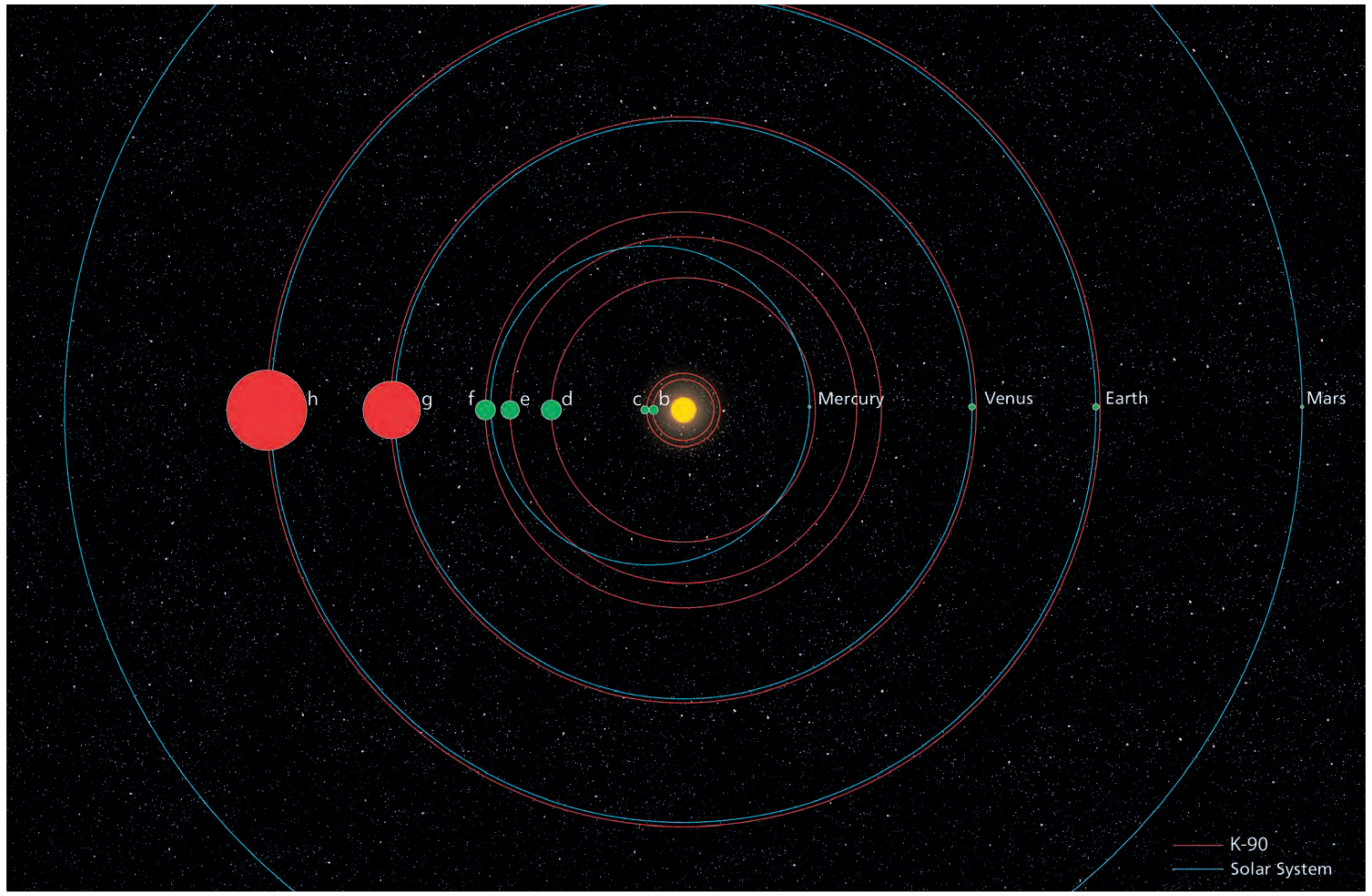


Image: NASA/JPL-Caltech

Artist's impression of the planetary system around the dwarf star TRAPPIST-1, which has seven rocky planets. The radius of these planets is approximately the same as Earth's. Three of the planets orbit the star in the habitable zone.



Comparison of the Solar System with the seven-planet system around Kepler-90. In both systems, the small planets orbit closer to the star, with the gas giants farther out.

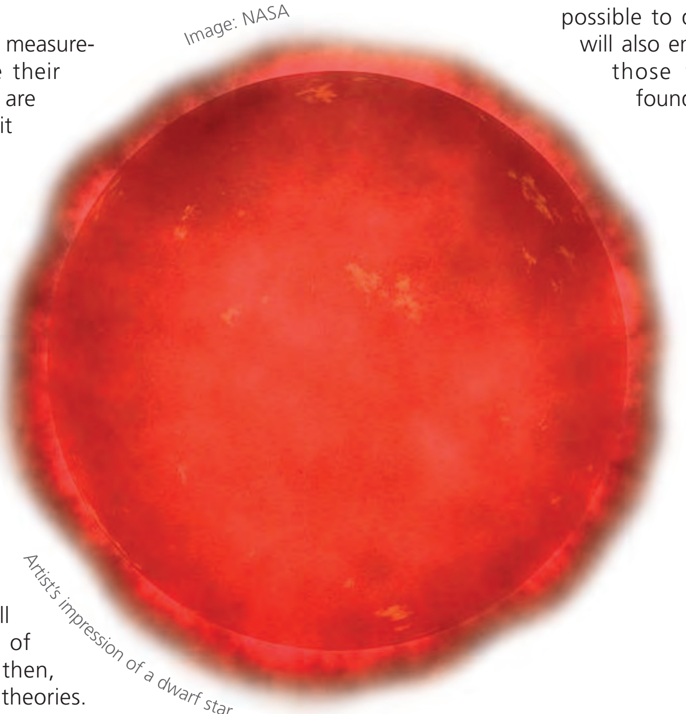
The number of discoveries is growing steadily

NASA's Kepler mission, launched in 2009, significantly increased the number of detected planets – numerous exoplanets with interesting properties were discovered in the data of the primary mission from 2009 to 2013, and in its continuation as K2. It was Juan Cabrera from the DLR Institute of Planetary Research and his colleagues who discovered the first seven-planet system around the star Kepler-90. This has a similar configuration to the Solar System, with small planets close to their star, and larger planets farther away. One could say that it is like a miniature Solar System, as none of the planets found thus far are more than one Astronomical Unit – the distance between Sun and Earth – from their host star. If the discovery of an eighth planet is confirmed, Kepler-90 will continue to be the largest exoplanet system discovered thus far.

Another record-breaking discovery made at DLR is the planet K2-137b. With one of the shortest orbital periods registered so far – just 4 hours and 18 minutes – it is an ultra-short period (USP) planet. Its radius is only 0.9 times that of Earth's. Although its mass cannot be determined from measurements, its short orbital period gives an indication of its mean density and composition – the planet's mean density must be at least 6.4 grams per cubic centimetre; otherwise, it would have been torn apart by tidal forces long ago. This constraint suggests that it must consist of at least 50 percent iron – a proportion higher than that of Earth, Mars and Venus, but possibly lower than that of Mercury, the planet closest to the Sun.

Although planets are discovered on a daily basis, a complete set of planetary characteristics cannot be generated for every discovery. For many detected planets, there is no information about the mass because successive measurements are not possible in the case of faint stars. Without knowing the planet's mass, its mean density cannot be directly determined and it cannot be further characterised. It can therefore be the case that, with new measurements, some detected objects lose their planetary status. Two main methods are used to detect exoplanets. The transit method measures the dimming of a star's light when a planet passes between its disc and the observer. The radial velocity method examines shifts of the stellar spectrum that arise when a star and a planet move around a common centre of gravity. Whilst satellite missions generally use the transit method, the radial velocity method is only used with ground-based telescopes.

Image: NASA



Artist's impression of a dwarf star

Exoplanets of different ages provide a unique opportunity to look into both the past and the future. Their incredible diversity gives scientists the chance to investigate all kinds of planets in different stages of development – and every now and then, new discoveries challenge prevalent theories. For example, a giant planet should, in principle, not form around a dwarf star. This is because both the star and planet originate from the same cloud of gas and dust, and most of the mass is collected by the star. But this is exactly what Alexis Smith (DLR Berlin) and his colleagues discovered. The dwarf star NGTS-1 – with an abbreviated name derived from the name of the telescope array Next-Generation Transit Survey – is orbited by a Jupiter-sized planet (NGTS-1b). This unlikely pair was the first discovery made by the NGTS in Chile, in which DLR is also involved.

Exoplanets also help researchers address the question of whether life could have originated on other planets. In 2017, researchers surprised the world with the announcement of a system of seven rocky planets orbiting the dwarf star TRAPPIST-1. Three of them had been discovered during the previous year using the Belgian telescope – a reference to the famous Trappist beer – at the La Silla observatory in Chile. The discovery of the remaining four planets was announced in February 2017. All seven planets are about the size of Earth; three could lie in the star's 'habitable zone' – also known as Goldilocks zone. The star is an M dwarf star. Stars of this kind emit much less energy and have a much longer life expectancy than the Sun. This could mean that the origin and evolution of life could take place on a different time scale.

In the future, two European missions will be in the limelight. CHEOPS will be launched this year, and the European Space Agency's M-class PLATO mission is planned for 2026. Both missions will search for exoplanets. From Earth, they will be supported by the NGTS telescope array.

The search for extrasolar planets will continue for years to come. Increasingly sensitive techniques and new, more subtle detection methods will make it possible to discover more planets and will also enable to better characterise those that have already been found.

Ruth Titz-Weider works at the Department 'Extrasolar Planets and Atmospheres' of the DLR Institute of Planetary Research. She is involved in, among other things, evaluating transit measurements.

The new planetary detectives

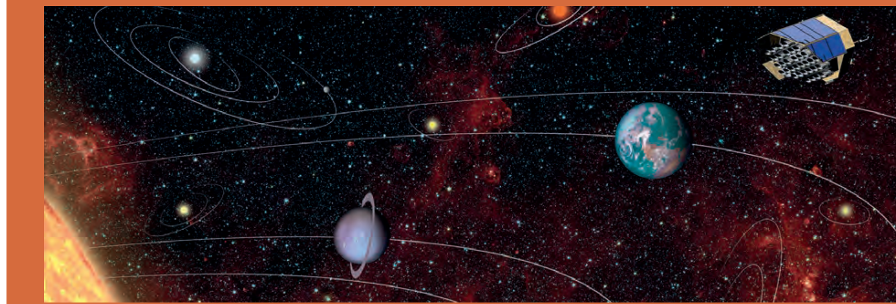


Image: DLR

PLATO

The promising ESA '**PLA**netary **T**ransits and **O**scillations of stars' – PLATO mission is scheduled for launch in 2026. Like all other exoplanetary space missions, it will search for planets using the transit method. PLATO will focus on very bright stars and determine the mass, radius and age of the planets and their stars with unprecedented accuracy. The aim is to produce a catalogue of extrasolar planetary systems, with emphasis on the properties of terrestrial planets in the habitable zone around Sun-like stars. It will then be possible to further examine these planets using follow-up atmospheric measurements.

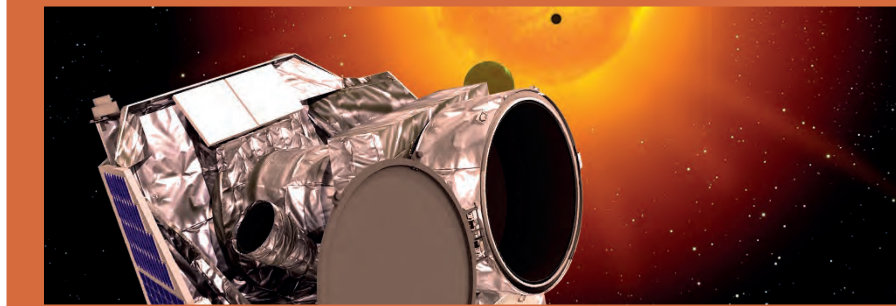


Image: ESA – C. Carreau

CHEOPS

The European '**CH**aracterising **E**x**OP**lanet **S**atellite' – CHEOPS – spacecraft will be launched in 2018. CHEOPS is an ESA small satellite mission. The University of Bern is leading the development of the scientific instrument, supported by DLR Berlin, among others. CHEOPS will carry out highly accurate transit measurements on bright stars already known to host planets. The aim is to achieve a more accurate characterisation of known planets and to discover and characterise new ones, particularly in order to determine their mean density.

Image: ESO/G. Lambert

NGTS

The Next-Generation Transit Survey (NGTS) telescope array has been searching for distant worlds since 2015. It is operated by scientists from the DLR Institute of Planetary Research, together with an international team at the European Southern Observatory (ESO) Paranal Observatory in northern Chile. The array has been designed for large-scale observations and consists of 12 comparatively small robotic telescopes, each with an aperture of 20 centimetres. Eight of the 12 cameras have been financed by DLR.

A TON OF ENERGY

The plumes of smoke that once heralded the presence of a coal-fired power station from afar are now a thing of the past, and gigantic opencast excavators are now a mere technology monument. In 2030, solar and wind power are long established members of the array of energy sources – at least, that is the vision. Only small amounts of coal and oil are still being burned to generate electricity, while the Sun and wind satisfy an ever-increasing proportion of the world's energy needs. For this vision to become a reality, energy storage solutions that deliver reliable power – even when the wind is not blowing and the Sun is not shining – will be required. With this in mind, spring 2018 will mark the start of a European project for power-to-heat-to-power storage. Magazine editor Cordula Tegen spoke with engineer Dan Bauer of the DLR Institute of Engineering Thermodynamics in Stuttgart about new storage concepts.

Power-to-heat-to-power storage for stable energy supply

The road from the use of fossil fuels to renewable sources of energy is rocky. One thing standing in the way is the fluctuating availability of sunlight and wind. Energy storage systems are expected to overcome these hurdles. How would you rate their levels of availability?

: Existing storage technologies will not be able to meet the growing demands of the future, as the potential for pumped hydroelectric storage systems is largely exhausted in Germany due to their specific requirements in terms of geographical location and available space. Battery-based energy storage is not sufficiently resistant to cycle-related performance degradation and is also too costly for this application.

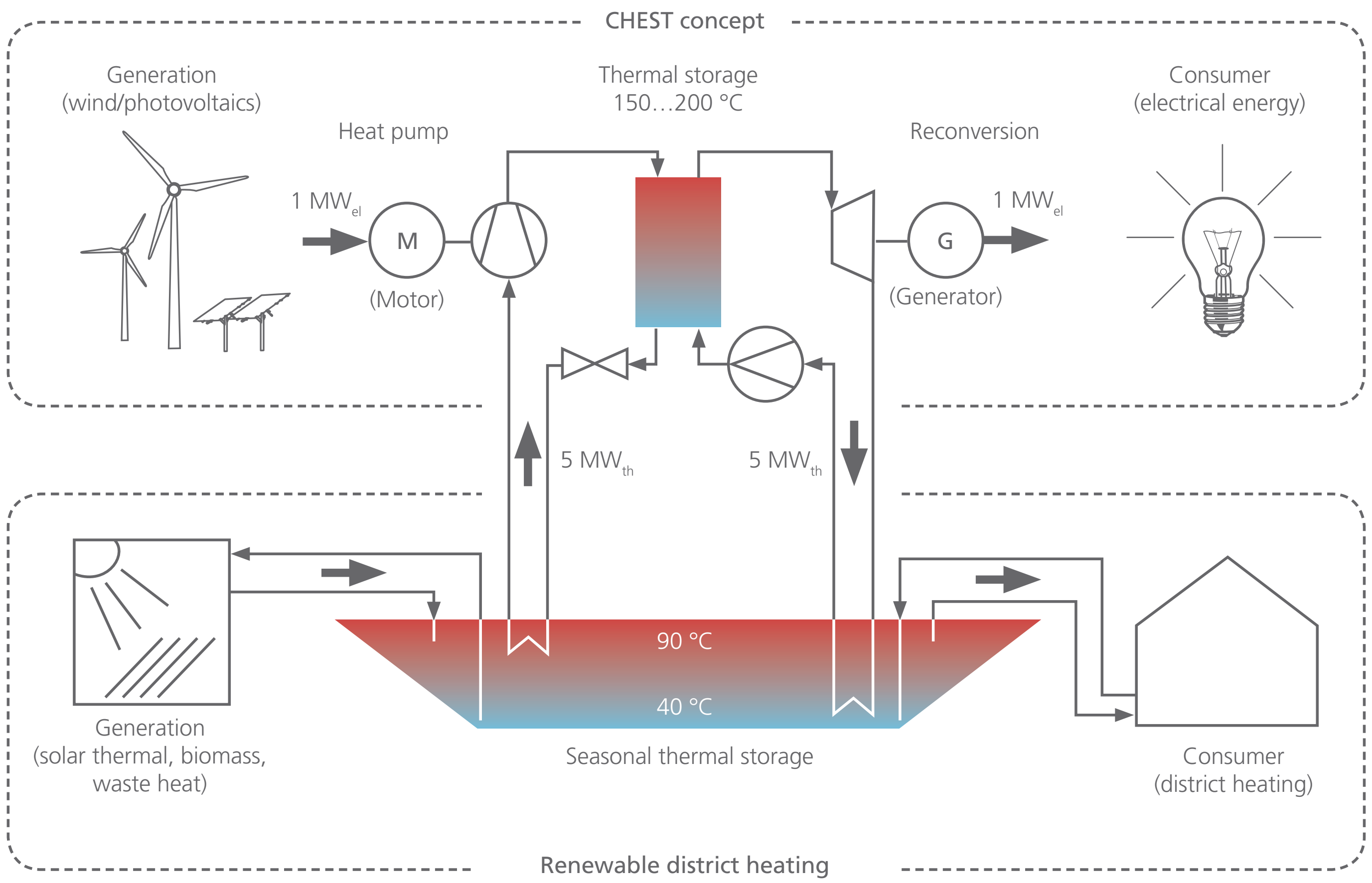
What do you suggest?

: One proposed solution is large-scale energy storage that converts incoming electrical power into another form of energy, and then converts it back after some time has elapsed. At DLR, our research work is focused on three basic principles – power-to-heat-to-power storage, compressed-air energy storage and power-to-gas-to-power storage. I believe sector-coupling concepts to be particularly crucial for the energy system – in other words, flexible storage that can supply both electricity and heat as needed, for example. If such a system were to be implemented using the best available techniques, the losses that occur when electrical power is converted into another type of energy and then reconverted into electricity could be kept to a minimum. In order to achieve this, however, power-to-heat-to-power storage needs to be supplemented by a heat pump, while compressed-air energy storage systems and power-to-gas-to-power storage needs to be implemented in tandem with heat storage.

How far have you progressed with that?

: For power-to-heat-to-power storage with high energy density, we have developed a process that we call CHEST, which stands for Compressed Heat Energy Storage. In this process, we convert electrical energy and low-temperature heat into high-temperature heat using a heat pump. A phase-change storage system absorbs the heat and can return it – as needed – for power generation. We want to design and build a pilot plant by 2020.

Dan Bauer is in charge of the interdisciplinary work on Power-to-X-to-Power storage at DLR in Stuttgart, as well as in the field of thermal systems with phase-change.



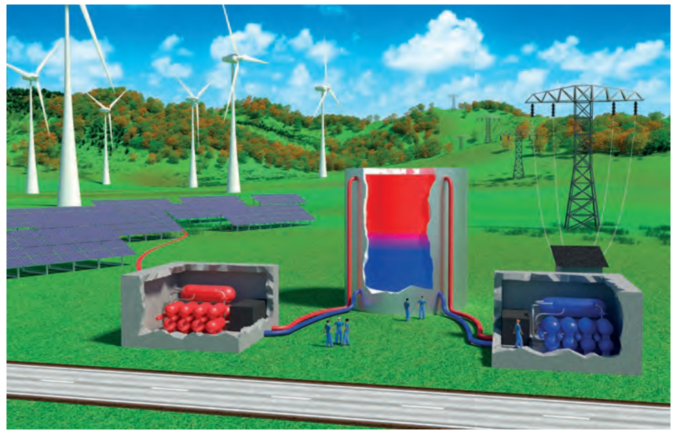
DLR is researching how district heating using renewable energy sources can be combined with the CHEST concept to provide a flexible energy management and storage system. The plan is to store sufficient energy for several hours of electricity generation and provide seasonal balancing for the heat supply. This will be demonstrated for the first time in the world with a pilot plant.

What is the advantage of this concept?

: The combination is what makes it special. Unlike pumped hydroelectric storage systems, it does not depend on being in a particular location, and it only requires a small amount of space. At the same time, it differs from battery-based energy storage by being resistant to cycle-related performance degradation, which enables it to be operated for many years without signs of ageing. All in all, the concept should gain a high level of acceptance in society and industry. As a result, CHEST has been included as a key technology in the EU CHESTER project, which is aimed at developing power-to-heat-to-power electricity storage. The objective is to identify possible flexibility options for the electricity and thermal energy markets, and to offer a technical demonstration of the concept by building a pilot plant at DLR.

What do you see as potential obstacles to the success of such a development?

: Other research institutions are also working on these types of storage systems. So far, however, their efforts have mainly consisted of conceptual thermodynamic designs. We are already one step ahead with our system designs, but nothing has actually been built yet. Turning theory into practice and tackling the numerous technical challenges are the next crucial steps. High-temperature heat pumps and thermal energy storage are of particular importance as key components in these plans.



This is what a power-to-heat-to-power storage system might look like

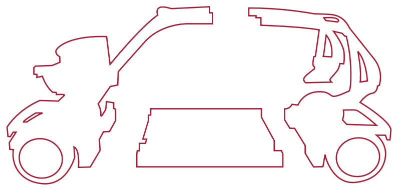
ENERGY STORAGE

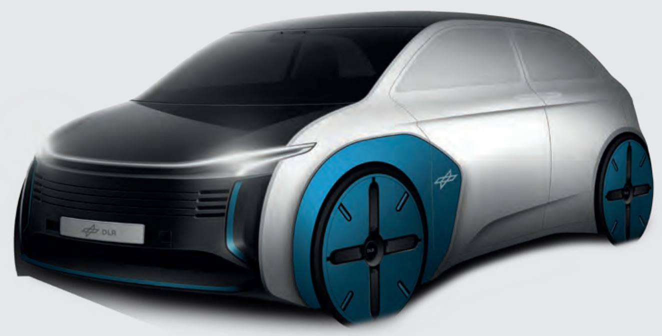
DLR experts in the areas of process engineering, electrochemical energy technology and thermal process technology at the institutes of Engineering Thermodynamics, Propulsion Technology, Solar Research, and Flight Systems are pooling their expertise to develop energy storage systems for the future, known as PXP storage, or Power-to-X-to-Power.

They are investigating three concepts:
· Power-to-heat-to-power energy storage
· Adiabatic compressed-air energy storage
· Power-to-gas-to-power energy storage

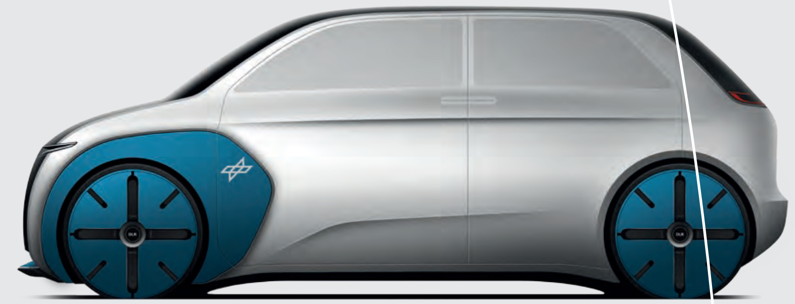
VISIONS OF A NEW CITY CAR

In the future, vehicles will be automated and electrically powered. In addition to new materials and production methods, many aspects of vehicle construction are being rethought. DLR researchers are working on such concepts for the car of tomorrow in the Next Generation Car (NGC) project and have developed a concept for a modular electric city car – the Urban Modular Vehicle (UMV). Thanks to its various modules, particularly for the body in white, the vehicle can be constructed to meet different requirements: as a small city utility vehicle or even as a large, fully-automated 'cargo mover' able to transport its load from point A to B without a driver.

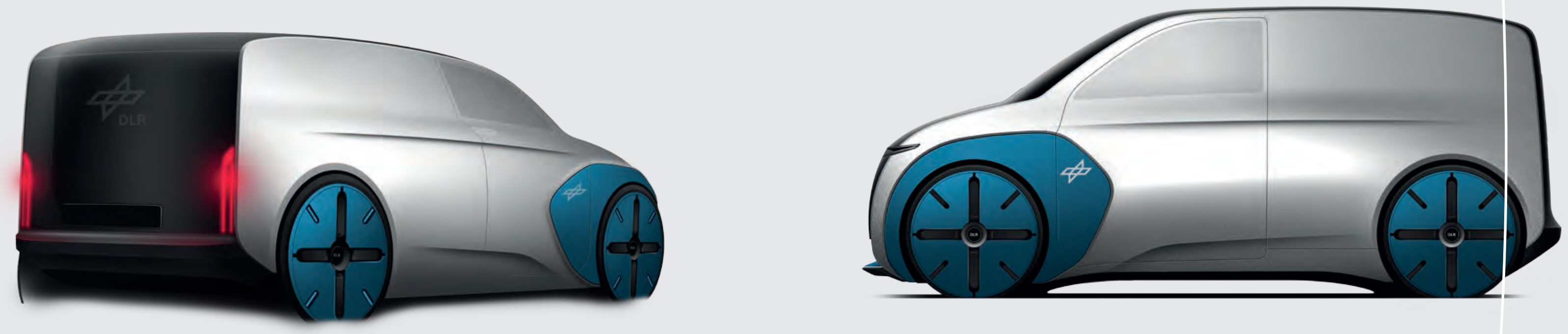




UMV Basic with 2 + 2 seats and a length of 3.7 metres as well as a battery that offers a range of 400 kilometres



UMV Long – more luggage space and range.



UMV Cargo with a length of 3.7 to 4.1 metres and a load capacity of up to 2800 litres

UMV 'Peoplemover' and 'Cargomover' for fully autonomous driving

A modular concept increases flexibility and efficiency for the automotive industry

By Dorothee Bürkle

The very first car looked like a carriage, but without horses. Today, vehicle body in white is designed to provide the highest levels of safety and comfort, and the engine (generally an internal combustion one) is located optimally inside it. Although interfaces for hybrid or even battery-electric powertrains are – in most cases – available, they have had little influence on vehicle design so far. But what will the car of the future look like? During the course of the NGC project, researchers from the DLR Institute of Vehicle Concepts have re-imagined the car 'from the ground up', and developed a vehicle and bodywork concept for electric, assisted and even autonomous cars for cities and large conurbations.

In the beginning, the question was what requirements a city car of tomorrow will have to satisfy. How many people should it accommodate? Who needs what amount of space for luggage or cargo? What range should it have? "This resulted in a number of variants with different sizes, referred to as packages," says Marco Münster, project coordinator for the UMV, describing the procedure. The keyword here is modularisation, which goes beyond today's platform boundaries and must also have an intelligent safety structure. One of the concepts is the Basic variant of the UMV. It is 3.7 metres long and can comfortably accommodate two passengers in the front seats and two more passengers in the rear seats. The two electric motors are powered by a battery in the floor module that should provide a range of 400 kilometres.

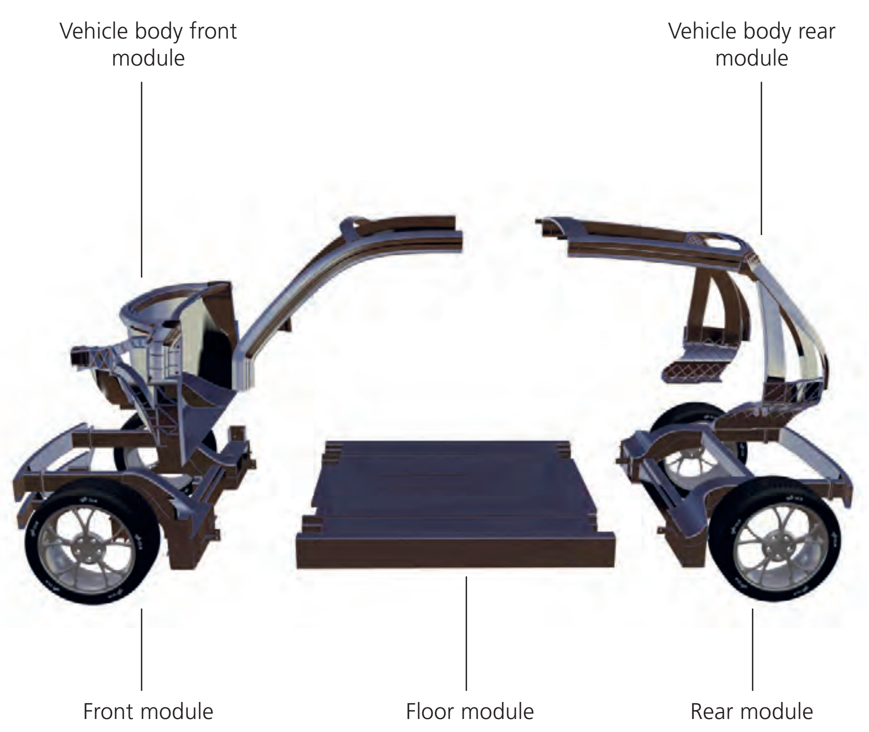
The Urban Modular Vehicle (UMV)

UMV Basic
Length: 3.7 metres, 2+2 seats
Purpose: city vehicle for private use or car sharing
Variants: long, short

UMV Cargo
Length: 3.7 metres, 2 seats
Purpose: tradesperson's vehicle with up to 2800 litres of cargo space
Variants: long

UMV Peoplemover
Length: 3.7 to 4.1 metres, 2+2XXX seats
Purpose: fully autonomous vehicle

UMV Cargomover
Length: 3.7 to 4.1 metres, 0 seats
Purpose: fully automated vehicle for cargo transport



It depends on the intended use – variable vehicle lengths and bodywork types

In order to address the numerous and varied requirements for future city cars, the researchers have developed concepts for an entire family of vehicles. They consider a total of eight variants to be sensible – ranging from the UMV Basic already described to the tradesperson's or delivery vehicle, the UMV Cargo, and to the autonomous 'people' and 'cargo' movers. One innovation of the UMV is the rigorously thought-out modular body architecture – from the classic small car to the autonomous 'Peoplemover' vehicle. Starting from a floor module, which can vary in length, the vehicle is assembled from building blocks of bodywork parts. To get from the UMV Basic to the UMV Long variant, for example, a longer floor module and three different structural components are all that is required. For the UMV Cargo, the rear greenhouse structure of the vehicle is specially produced, but the other body parts can be the standard units. The fully automated vehicles for cargo and people can also be assembled with the modular body kit. The modular body kit for the UMV is designed so that just a few different modules are sufficient for all applications. It already offers the opportunity to use highly modular bodywork platforms for the market launch of fully autonomous vehicle derivatives. And it also offers great potential savings for vehicle production.

NGC

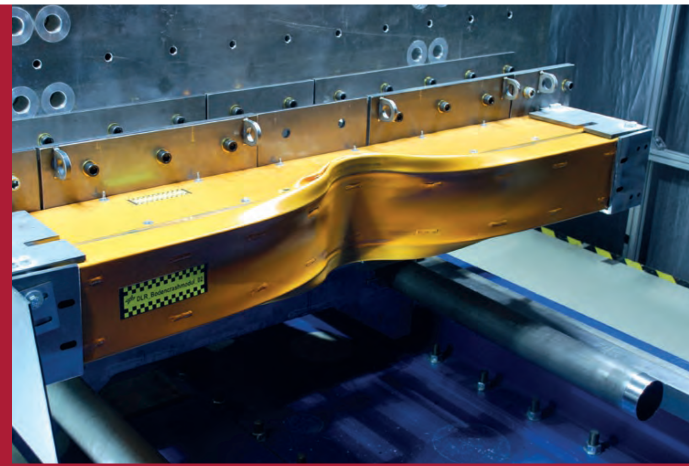
In the Next Generation Car project, DLR transport researchers are developing a family of vehicles that covers the widest possible range of uses. Their work can be divided into the following research subjects:

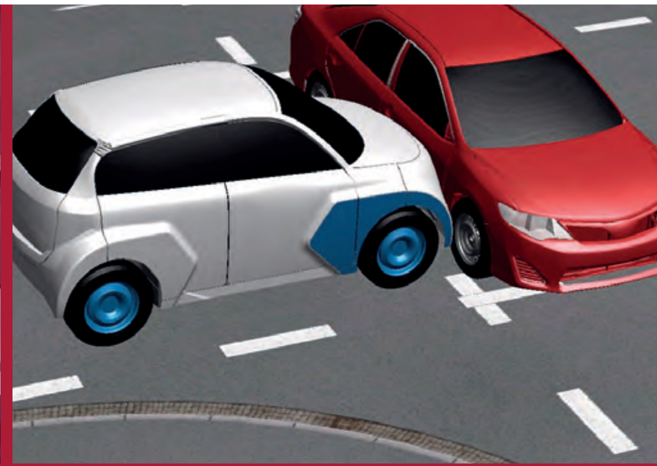
· Vehicle intelligence
· Vehicle concept
· Vehicle structure
· Chassis mechatronics
· Powertrain
· Energy management

Thinking beyond the series

"Car manufacturers thinking about the next generation of models often have to adapt their designs to an existing vehicle series for production reasons," says Gundolf Kopp, head of the research field at the Institute of Vehicle Concepts. "With our vehicle concepts, we can look systematically further into the future in a user-oriented way." In addition, the engineers are already able to implement developments in their concept vehicle that vehicle manufacturers or their suppliers do not yet want, or are unable to bring into mass production. "Our goal is to support and give impetus to the industry, but also suppliers or start-ups, both for specific technologies and for vehicle design methods," says Münster.

In particular, the systematic and integrated methodology with which vehicle variants are created, depending on requirements, accelerates and simplifies vehicle design. As a result, engineers can immediately work out the optimal vehicle structure – down to the smallest detail – depending on the requirements. "In the case of a commercial vehicle that has to provide enough space for an entire pallet, it is not sensible to have the battery and powertrain positioned beneath the cargo space," Kopp says. "Or, variable-use passenger vehicles should not have a centre console, so that there is more freedom in how the interior can be used." In addition, using their methods, the researchers are not only able to work out the ideal shape of a car, but also to calculate the loads that individual vehicle components will have to withstand. These details are then evaluated in simulations and also verified in real crash tests – for example, in the highly integrated floor module that can withstand a crash.


DLR engineers use crash tests to investigate how the energy of an impact is absorbed by vehicle components


DLR's work also includes the analysis of innovative adaptable safety systems for 'unavoidable accident situations'

Crash test to protect the battery

In all new concepts, vehicle safety is taken into consideration right from the start and verified in impact tests – both in simulations and in real crash tests. In the UMV, it is necessary to protect not just the vehicle occupants, but also the battery in the floor module, one of the most important and expensive vehicle components. The researchers tested the stability of the floor module and the crash absorption structure by using what is referred to as a pole crash test. This test involves a vehicle colliding laterally with a column or pole at a speed of 29 kilometres per hour. The high energy generated is cleverly absorbed in the newly developed floor module within a short distance (approximately 160 millimetres) through deformation of the relevant component.

HARD KNOCKS IN THE LABORATORY

Large-scale equipment at DLR – the dynamic component testing facility at DLR Stuttgart

When it comes to novel components for vehicles, not only the lightweight construction, but also the safety of large assemblies and components play a role. Crash tests with entire vehicles are complex and expensive. With their unique test system, DLR researchers can stress entire subsystems in such a way that their deformation behaviour is very close to that in real life situations. DLR transport and energy editor Dorothee Bürkle interviewed Gundolf Kopp from the Institute of Vehicle Concepts.

Mr Kopp, how would you describe the Stuttgart crash facility in action?
: In order to depict the largest possible number of test configurations, the facility consists of two sleds. For a crash test, one of the two test sleds is accelerated along a track and hits the second sled. This sled can either be fixed – for example to reproduce a frontal crash against a stationary obstacle – or set up on the track to move freely in a longitudinal direction. The latter case is used for reproducing a side crash, for example. The sled is accelerated using a cylinder operated with compressed air, and the acceleration is controlled using a hydraulic brake. The impact velocity can be accurately determined in this way.

What is special about the research facility?
: With a total mass of 1300 kilograms, the test sled can accelerate to a maximum of 64 kilometres per hour. This allows large bodywork structures for light- to medium-weight vehicle concepts to be tested under realistic conditions. The sleds are guided both vertically and laterally to achieve a high level of test reproducibility.

How important is it to your research?
: The crash facility allows large components and substructures to be tested, so that it is not necessary to construct a complete body. Such automotive-specific module tests can confirm structural calculation results, even in early development phases. Thanks to the flexible structure of the dynamic component testing facility, we can carry out a large number of different crash tests. This goes as far as the verification of novel adaptive vehicle structures in the digitalised development chain. Particularly relevant here are structures that, despite their innovative modularisation, can actively and passively address all the requirements for integral safety.

LICENSED FOR SPACE

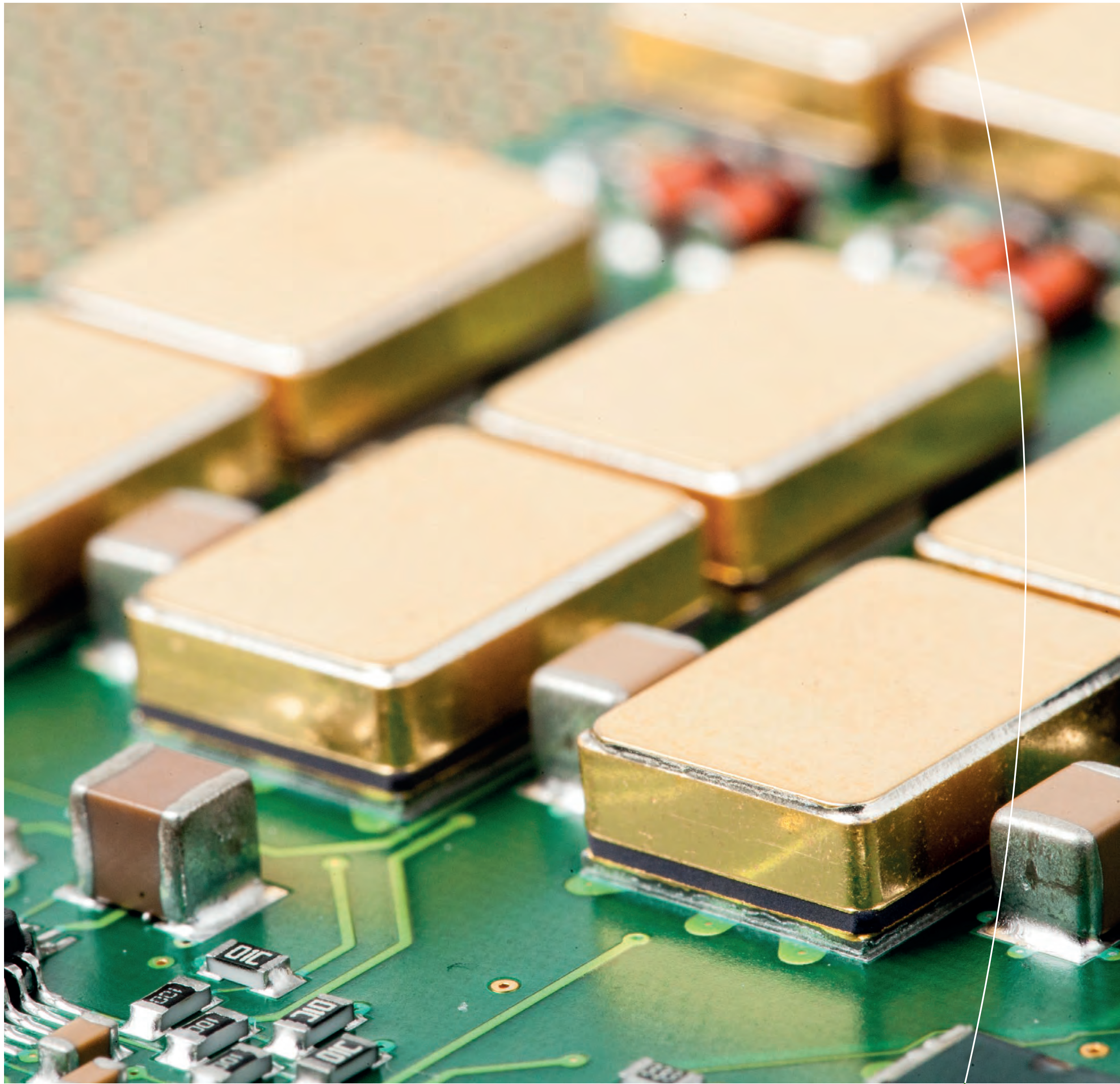
Space flight is hard work – not only for the astronauts and scientists who develop, construct and send the instruments on their way, or the engineers who build the space probes and the teams who operate the missions from their control rooms on Earth. The herculean task is the flight through space, especially for each and every cable and diode carried on board the probe. When a rocket is launched, these components are given a rough shaking and must withstand enormous accelerations. As they fly through space, they are struck by cosmic particles. And the continuous alternation between the Sun and shadow phase makes them subject to extreme temperature fluctuations. With the success of the entire mission depending on these components, their suitability for space use must be guaranteed in advance. This is demonstrated via a space qualification process. The only certification body providing this in Germany is DLR in its role as a space agency.

DLR engineers ensure that components work under the extreme conditions encountered in space

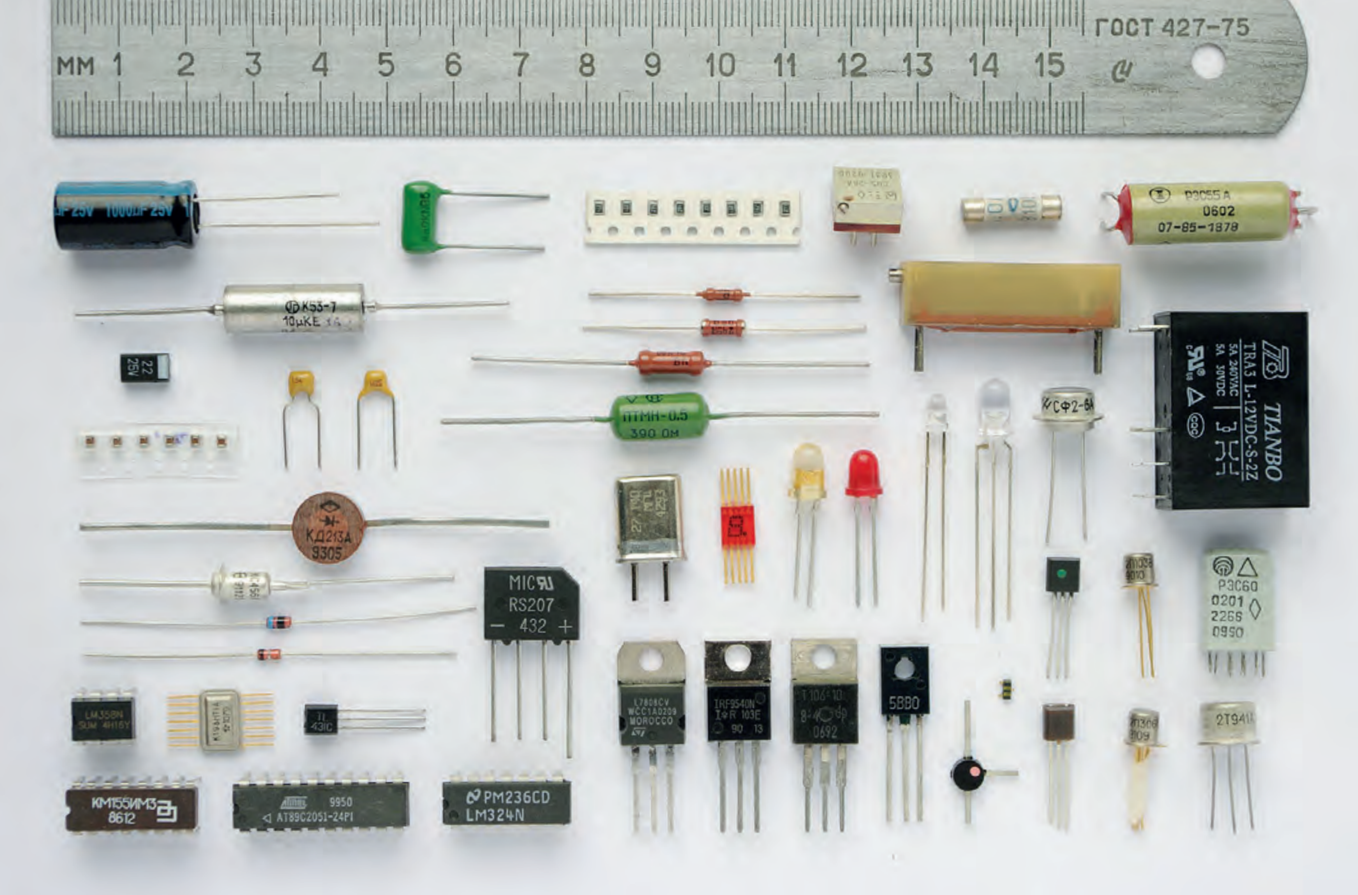
By Manuela Braun

With a filigree appearance and hardly longer than a matchstick, they are arranged in gold-plated encapsulations on a printed circuit board. They look inconspicuous – but in October 2018, current will flow through the PowerMOSFETs (Metal Oxide Semiconductor Field-Effect Transistors), be amplified and drive the motor, which will set a small swing arm in motion. Then, this arm will make the DLR MASCOT (Mobile Asteroid Surface Scout) lander 'hop' several metres to its next measuring location on the asteroid Ryugu, 325 million kilometres from Earth. By that time, the PowerMOSFETs will already have endured a rocket launch, a 47-month journey through space and a landing on an unexplored celestial body. If the power transistors survive the mission undamaged, it is thanks to DLR engineer Guido Joormann. This electrical engineer helps conduct the crucial work of testing and optimising transistors until they belong to a very specific and rare type of component: one that is qualified for space.

However, Joormann seldom knows where his PowerMOSFET will be headed. "Most of the time we do not know which missions our qualified components will be used on," the engineer says. The components are not selected and tested individually for each mission. Instead, an extensive, standardised range should gradually emerge, which many satellite, probe and instrument design engineers in Germany can make use of when planning and implementing their missions. "The component is then specified for application in numerous possible projects – this



Small but crucial, the 'PowerMOSFETs': What is hidden under this gold-plated encapsulation ensures that the asteroid lander MASCOT receives exactly the power required to 'hop' from location to location.



Components that should in no way fail during a mission must be specially qualified for space conditions

requires a lot more effort at the start, but it pays for itself in good availability, larger lot sizes and greater reliability. This reduces procurement costs for individual projects." For special missions with even more rigorous requirements – such as the radiation resistance of components for the Jupiter mission JUICE – only a few additional tests have to be carried out on the space-qualified components.

Independent of monopolies and customs regulations

Transistors, which control electrical voltages and currents, are found in every television, mobile phone and radio today. But none of these devices would reliably endure the conditions under which components have to function on space missions. "Earth's atmosphere protects us from space radiation; but in space, radiation particles can shoot unobstructed through components at high speed and energy and destroy them." The loss or malfunction of a strategically important component could mean failure for the mission. The launch itself already subjects the fine wires of a transistor to forces not generally encountered during conventional use on Earth.

The extensive preliminary investigations, development and tests for MASCOT's transistors began back in 2004 and ended in the autumn of 2012 with successful qualification by DLR. "Previously, only one manufacturer in the world offered these qualified, radiation-resistant components," Joormann explains. This was an undesirable situation because, in addition to the monopolistic market, there were also very strict, and thus costly, export regulations. With the successful qualification of the PowerMOSFETs from Infineon Technologies, components developed by a German manufacturer are now available to the national, European and international space industry as well as to space research.

Tiny but crucial

Cables, resistors, capacitors, integrated circuits, diodes and transistors must all be qualified; so do the entire processes required for the construction of components – such as a soldering process for multi-pole components with more than 1000 connector pins. In order to guarantee a continuous uniform standard, European space agencies, users of components within the European space industry, and manufacturers of electrical, electronic and electro-mechanical components joined forces to establish the European Space Components Coordination (ESCC). As an ESCC member, DLR represents the German space agency as well as the national interests of the space industry, and is responsible for the necessary qualifications for space flight. In the process, DLR engineers define and check the essential threshold values and specify minimum requirements.

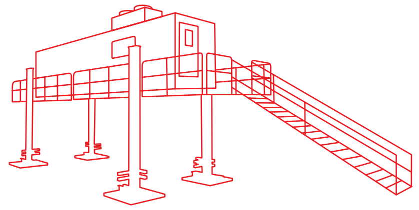
The PowerMOSFETs that are tucked away in the MASCOT lander and are currently on their way to the asteroid Ryugu are little survival artists: They can endure temperatures from minus 55 degrees Celsius to 150 degrees Celsius and are resistant to a radiation dose up to 3000 gray. In addition, they can withstand shocks of 1500 giganewtons, vibrations in the frequency range of 10 to 2000 hertz and acceleration forces of 20,000 giganewtons, which is 20,000 times their own weight. Anyone wanting to use such a component for future missions can now be certain that it meets the requirements of space flight. "But to reach that point,, we have had a lot of red tape and had to review numerous test reports," department head Joormann says.

The qualification of components is very intricate and complex – manufacturers and test companies must be surveyed, many samples viewed under the microscope, and measurement results analysed and evaluated. Every certificate for the ESCC has to be renewed every two years. It takes approximately two to three years for a 'normal' marketable commercial component to become a 'special' space-qualified component. Each and every step of this process has to be documented carefully and in detail. "If there is a malfunction, we have to be able to understand exactly when and under what conditions it occurred."

Errors can only rarely be corrected in space – once components are launched, they can no longer be accessed for repairs, and items cannot be replaced quickly in a subsequent mission. For the industry, an order to qualify components not only brings a financial benefit, "it is also a type of quality seal for industry partners," Joormann stresses. "If you are able to produce components for ambitious space flight applications, it means you have the knowledge, the commitment and skilled workers."

FRESH FOOD 'MADE IN ANTARCTICA'

EDEN ISS greenhouse in the Antarctic demonstrates that fruit and vegetables can also thrive under 'otherworldly' conditions



The overwintering for the crew at the Alfred Wegener Institute (AWI) Neumayer III Antarctic station has begun – no fresh produce will be delivered until November. The menu will only be enriched with fresh greenery thanks to the fruits and vegetables that DLR scientist Paul Zabel will be harvesting in the EDEN ISS greenhouse, 400 metres from the Station. DLR set up this greenhouse designed for extreme environments. The Antarctic is the ideal test site for this special type of vegetable growing – without soil and using artificial light in a closed-loop system.

The tests in the Antarctic are not only meant to demonstrate the possibility of growing crop plants in desert or in low-temperature regions on Earth, but also during future crewed missions to the Moon and Mars. But before the harvesting could begin, the greenhouse had to be set up – and it was entirely housed in containers. Once the two container sections were towed from the edge of the ice shelf to the Station, they were assembled on the pre-installed framework. The shelves were set up, the pumps for the nutrient solution installed, and the special LEDs for optimal illumination calibrated. Most of the team left in February upon completion of this preparatory work. Since then, Paul Zabel from the DLR Institute of Space Systems has been 'a lone gardener'. He will look after the harvest during the polar winter.

The specific technique for harvesting used in the EDEN ISS project in the Antarctic is called aeroponics – plants are cultivated without soil in a sterile environment, their roots are sprayed with a computer-controlled water/nutrient mixture, and their leaves receive the right amount of light using special LEDs. "We are also adapting the air in the greenhouse to meet the needs of the plants as much as possible. The carbon dioxide content is increased, and we clean the air of moulds and bacteria using special filters and sterilise the air with ultraviolet radiation, which means that purely biological growth is possible without insecticides or pesticides," explains DLR Project Manager Daniel Schubert. "Just as in a space station, the greenhouse has a completely closed air recycling system, including an air-lock, through which Zabel will enter the greenhouse every day. The enclosed system additionally allows all the water to be collected and reused."

From 21 May to 22 July, the Sun will not rise above the horizon in the area of Neumayer Station III, where temperatures can fall to below minus 40 degrees Celsius. "Our menu will certainly be enriched when Paul adds fresh vegetables straight from the greenhouse to our food supplies," said Bernhard Gropp from AWI, who, from February 2018, will take over as station leader for the coming winter season. During this time, a 10-person crew – consisting of scientists, engineers, a cook and a doctor – will live on Neumayer Station III. "We are interested in seeing whether the fresh food will produce a positive psychological effect," said Gropp. Paul Zabel's mission is clear: he will sow and harvest again and again in the coming months, continuing a project that started with cucumbers, tomatoes and peppers.

Tegen/Braun


The AWI Neumayer Station III in Antarctica will be DLR scientist Paul Zabel's home for one year

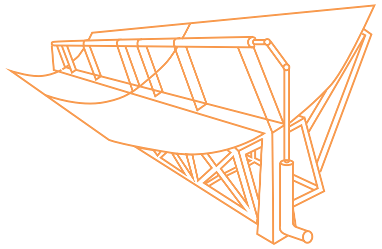
INTERNATIONAL PARTNERS

The EDEN ISS project is carried out in collaboration with the Alfred Wegener Institute (AWI) Helmholtz Center for Polar and Marine Research in Bremerhaven, Germany. The research consortium also includes representatives of partner organisations from several other countries: The Netherlands (Wageningen University & Research), Austria (LIQUIFER Systems Group), Italy (National Research Council, Thales Alenia Space Italia, EnginSoft, Arescosmo and Telespazio), Canada (University of Guelph), Sweden (Heliospectra), Ireland (Limerick Institute of Technology) and the USA (University of Florida), as well as Airbus Defence and Space, again from Germany. The project is financed by the European research programme Horizon 2020.

The mission can be followed on Twitter, Facebook and Instagram via the hashtag #MadeInAntarctica.

CATCHING MORE SUN

A drone flies steadily over the parabolic troughs of the Spanish Andasol solar power plant. Using a measuring camera, it captures every square centimetre of the mirrors from different angles. The mirrored parabolic troughs of the solar power plant have a total length of 90 kilometres, so it takes the drone two hours to complete its flight over the solar field, which has an area equivalent to 450 football pitches. The images are later assessed in detail by a computer program. Employees at the DLR spin-off CSP Services GmbH use such measurements on behalf of their customers to assess how efficiently the collectors in a solar field concentrate light, and how their operation can be optimised.



DLR spin-off company CSP Services has been optimising solar power plants for over 10 years

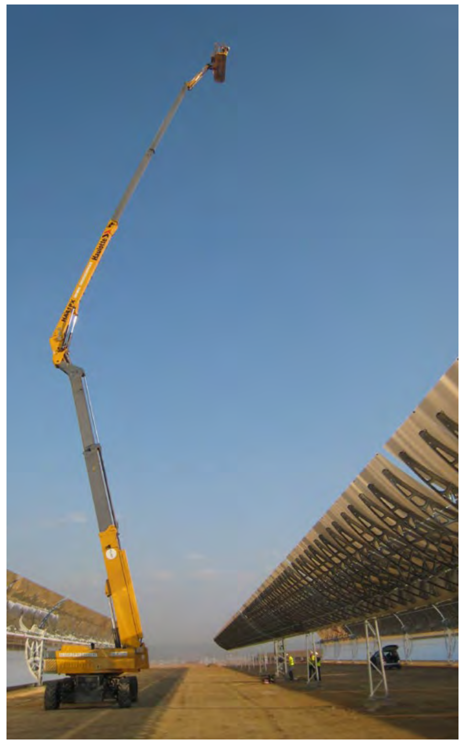
By Dorothee Bürkle

The Sun supplies the raw material for a solar power plant. The more precisely the mirrors concentrate its radiation, the more electricity the plant can feed into the grid. Based on these checks and the subsequent optimisation – for instance through the precise alignment of the collectors – CSP Services can increase a plant's yield by several percent. For the plant operators, this means important additional revenue in a highly competitive market. The measurement procedure and associated software QFly come from a DLR development project and has recently been licensed to CSP Services. "What would once have taken months can now be achieved in just a few days. That is an advantage that we now want to offer our customers all over the world," says Klaus Pottler, one of the two managing directors.

Expertise in the development of solar power plants

CSP Services was spun out of DLR in 2007 as a global service provider aimed at optimising solar power plants and increasing revenue. Since then, the company advises manufacturers, plant operators and investors on concentrating solar power plants and offers measurement techniques to inspect plants. The spin-off is based on licences, expert knowledge and results from the energy research conducted at DLR. As early as the 1980s, DLR began research on what are known as concentrating solar power (CSP) systems.

Fast data acquisition from the air. The parabolic mirrors of a solar power plant are measured using the flying camera system QFly. With the data, operations can be optimised and the yield can be increased.



The methods for the optimisation of solar power plants were developed within DLR's energy research programme. CSP Services is offering plant operators the licensed procedures.

In parabolic trough systems, curved mirrors reflect the Sun's rays onto a line in the focus of the trough. Located at this line is the solar receiver, which converts sunlight into heat. In solar tower power plants – which are used as an alternative – the Sun's rays are concentrated onto the top of a tower by a field of dual-axis tracking mirrors (heliostats). From this point onwards, a solar power plant functions in a similar way to a conventional gas- or coal-fired power plant, using heat energy for electricity generation. In this area of technology, DLR scientists have helped industrial partners to develop key components, such as mirrors and receivers.

Expert knowledge in demand by power plant operators

With their many years of expertise, DLR researchers have become increasingly important points of contact for plant manufacturers, operators and investors. "In 2005, when Spain started to promote solar power plants with high feed-in tariffs, there was great demand for DLR's expertise, and enquiries became more frequent," recalls Steffen Ulmer, founder and joint Managing Director of CSP Services and formerly a DLR researcher. It soon became clear to his former working group that these requests from industry could be better served by a spin-off company dedicated to that purpose. It was a great success that renewable power generation technology co-developed by DLR entered the market. The demand for their measurement technology grew. However, offering consulting services and optimising commercial power plants do not fit with the tasks of a research institution in the long term. At this point, three DLR energy researchers – Eckhard Lüpfert, Steffen Ulmer and Klaus Pottler – took the plunge and, together with two other partners, founded a company of their own. They received support from the Helmholtz Enterprise Funds (HEF) and DLR's Technology Marketing department and were awarded for their business plan with two major prizes by the start-up initiative Neues Unternehmertum Rheinland e.V. (NUK).

Despite this vote of confidence, the founders had their doubts: "We started out as researchers and wanted to tackle the subject in depth. Becoming entrepreneurs was not actually part of the plan," Ulmer recalls. Yet there was a lot to be said for taking this step: "We already had our first customers, the industry was in an optimistic mood, we had good support from the DLR Technology Marketing department and an important safeguard: last but not least, a measure of security – we were able to reduce our work load at DLR, but initially retain our positions there."

This was followed by a period of intense work. In 2008, the founders opened two offices – one at DLR's headquarters in Cologne and the other near the Plataforma Solar de Almería (PSA) – the 'Silicon Valley' of solar energy research in southern Spain. The photogrammetric 'QFoto' 3D-measuring technology, which the founders had developed at DLR, was licensed to CSP Services by DLR and used commercially for the first time in an order for the Spanish power plant builder Abengoa. "Many things were new to us," Ulmer says in retrospect. "We had to focus on quite mundane things like offices and operational infrastructure, while also negotiating international contracts and familiarising ourselves with tax and insurance laws. Our systems were only available as prototypes, so we had to make them failure-proof and viable for industrial use. And on top of all that, we were also looking for new staff members."

Pottler remembers one of their first orders, which involved installing a measurement system for the quality assurance of the series production of collectors at the Kuraymat solar power plant, near Cairo in Egypt. The system was set up and ready to go, and their return flight for the following day had been booked. But when the backup copy was being created, the measurement computer malfunctioned and had to be restarted overnight. "We worked throughout the night under emergency lighting to fix the fault. The system was rebuilt by dawn. At one point during the night, the watchmen – hired Egyptian farmers from the area – invited us to sit at their campfire. We had a cup of tea together under the vast, starry Egyptian sky." Pottler is keen not to miss out on such experiences: "Contact with other cultures, religions and languages in far-flung rural areas of the world is at least as interesting as our work with solar technology."

In addition to handling their first orders, the entrepreneurs developed new measurement techniques during this phase. In 2009, CSP expanded its range of services and launched the first automatic weather stations and the 'QDec' system – also licensed by DLR – onto the market. With their order books full, the founders and some other DLR employees also won the SolarPACES Technology Innovation Award in 2009, as well as the DLR Innovation Prize from the Gesellschaft von Freunden des DLR. In 2012, the company was nominated for the German Entrepreneur Award.

Sudden change – collapse of the Spanish market

At first, the start-up only experienced growth, and two and a half years after the foundation, it had 20 employees and was continuing to expand. But 2012 marked a turning point, when the Spanish government cut subsidies for solar power plants, even retroactively, in the wake of the economic crisis. Solar power plants were no longer lucrative, and the Spanish market largely disappeared. The economic crisis in Spain hit at a time when the market in North African countries was not developing as well as had been hoped as a result of the Arab Spring. In addition, investors preferred photovoltaic systems, which were rapidly becoming less expensive. "This was a pretty tough time of consolidation," Ulmer says. "Luckily, our customers were able to expand their business in countries like the United States, South Africa and Chile, so while order intake dropped, our company was able to keep on running." CSP Services shrank from about 30 staff members back to 20. At the same time, the company was also gaining new customers, particularly in China, where a programme for CSP power plants was launched. "Our strong position within the market saw us through this crisis in the end. If a power plant builder or investor is looking for sound quality assurance, then there really is no alternative to our offering," Ulmer says confidently.

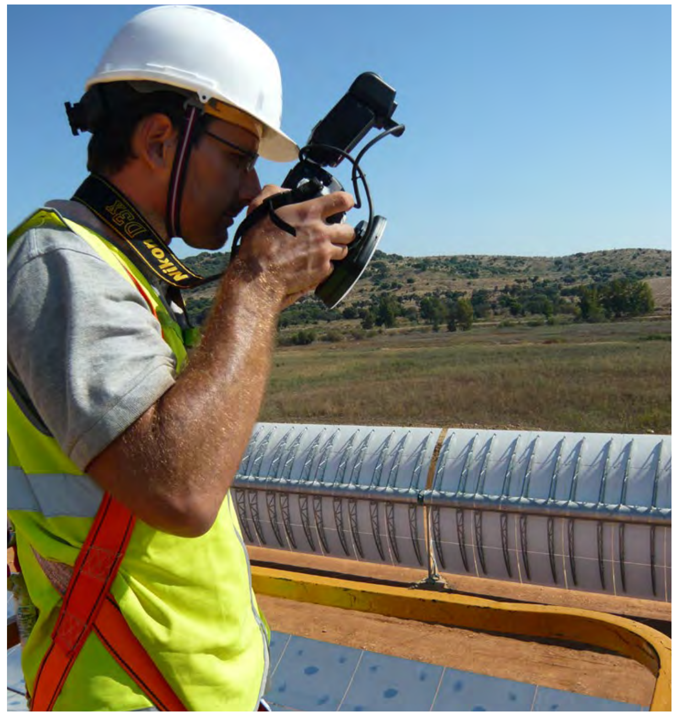
An optimistic outlook

Currently, CSP Services – like the whole sector – is again more optimistic about the future. In Dubai, large CSP plants can now generate electricity for base loads at lower prices than gas-fired plants. Investors are increasingly appreciating the benefits of thermal solar power plants, which can produce round-the-clock electricity thanks to low-cost thermal storage, even though the technology still entails higher generation costs than photovoltaic systems. "There is growing recognition that we need controllable solar power plants to provide a higher proportion of energy from renewable sources," Pottler says. "In addition, a number of well-performing power plants have been constructed in the meantime. This means that investors see the risk as being far lower, so financing conditions have improved."

Global player with sleepless nights

The company's founders do not regret taking the step into self-employment one decade ago. "We established ourselves in the market, made a name for ourselves in the industry, and have gained confidence as a result," Pottler says. Today, the founders are working in an international environment and have come to know and understand different cultures and business practices. "In China, everything appears different at first and the language barrier is difficult to overcome, but when you look closer, you see that there are many parallels. Even there, company employees cannot fill up the fuel tank without getting a receipt for expenses," Pottler adds with a smile. Their wealth of experience makes up for the fact that they sometimes have to work around the clock and also on weekends: "Our customers often come from different time zones, and their public holidays do not coincide with those in Germany or Spain." But this is outweighed by the positives, Pottler explains: "We are free to decide how CSP Services will proceed in the future and what our priorities will be. As entrepreneurs, we have learned how to make decisions and we do not want to give up that kind of freedom."

Working where the Sun shines – CSP Services also opened an office in Almería, southern Spain.

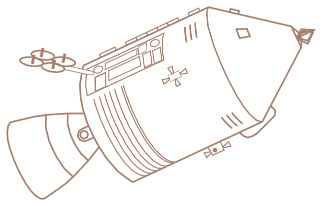


Quality assurance from a height of 10 metres – the camera is always there to measure with sub-millimetre precision.

CSP Services Managing Directors Steffen Ulmer and Klaus Pottler: "We have learned to make decisions as entrepreneurs."

“SOMEHOW WE JUST BELONGED THERE, ON THE MOON”

On 16 April 1972, he became the tenth human to set foot on the Moon during the Apollo 16 mission. Only two more astronauts would do the same on the Apollo 17 mission. After this there was a gap – a big gap that has lasted up to this day. How does Charles Duke remember his mission? And what are his thoughts on a possible return to the Moon? DLR editor for space, Manuela Braun, spoke with this ‘Moonwalker’.



Charles Duke talks about his Apollo mission and shares his views on future space travel

Forty-six years after his ‘Moonwalk’, Charles Duke talks about the past and future of human spaceflight.

Your astronaut career began with a milestone – a trip to the Moon. In your opinion, how do spaceflight missions today compare with your own mission?
: It is hard to compare, I think. You know, I only experienced zero gravity during our flight to the Moon and in lunar orbit. So it was not like weeks on end – like on the Space Station – where you also have to carry out experiments and all. Most of our time in zero gravity, especially when travelling to the Moon, was spent on basic housekeeping. Three of us in a cramped space, smaller than this table here. You tend to lose things. Where did the towel go? Where is my spoon? Things just kept getting lost. And then there was no privacy at all. We were extremely focused all of the time, you know, we were going to the Moon for only three days! And then you are there, and the first day goes so quickly. Then you are on the Moon for just two more days, and then only one more day… I am not sure I would do so well on the International Space Station for one whole year. But everybody I have talked to who has been there for a prolonged period has told me that it was fascinating to be in space for such a long time.

During your time on the Moon, did you still feel connected to Earth somehow?
: I never felt isolated. Out on the surface especially, John and I had a direct communication channel and almost instantaneous communication with Earth. But for most of the time, John and I were talking. We had what we called a ‘hot mike (live microphones)’, so we just started talking when we heard one another. I never felt isolated, even from Earth. And on the whole there was a true feeling of belonging. I never felt like I was a stranger in a foreign land. It was like we belonged on the Moon, at least during those three days.

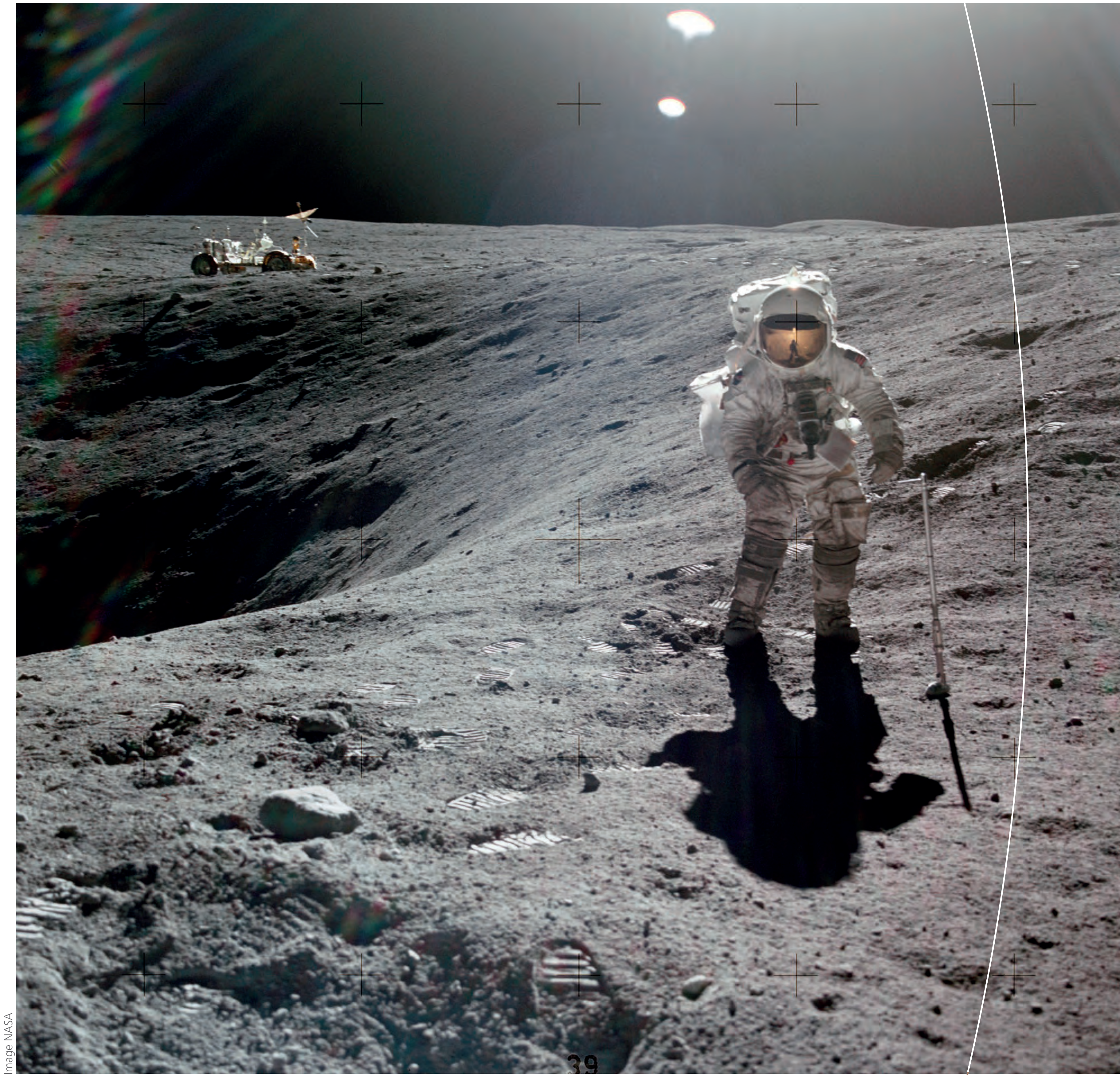


Image NASA

Charles Moss ‘Charlie’ Duke flew to the Moon on 16 April 1972 on the Apollo 16 mission. He was the tenth human to set foot on Earth’s satellite.

During the Apollo 11 mission, Charles Duke sat in the control room and kept in touch with Neil Armstrong as he made his historic 'giant leap for mankind' on the Moon.

Duke is certain that "we will see humans return to the Moon and then go on to explore Mars." It is the human drive to explore that will make this possible.

What did you think about before going to sleep, when things had calmed down? Was it the day's events, or did you think about Earth, your wife, or your family?

: During the first rest period on the Moon we got our hammocks out and went to 'bed'. Most of all I thought about all the things I had seen outside of the window, and I could not wait to get out there and look at them. I did not think about Houston, no thoughts about home. It was mostly operational stuff I was thinking about. I was so excited that I could not get to sleep easily. So that is why I took a sleeping pill the first night. But after that – eight hours in a space suit is a lot of hard work – so I was out like a light as soon as I laid down.

Was there ever a question of you going on another space mission?

: Not really. After I got back, we were put on as back-up crew for the next Apollo mission, which was to be the last mission to the Moon. But the Apollo 17 mission crew stayed healthy, so we did not get the chance to go again. John Young and T.K. Mattingly – who I flew with – stayed in the astronaut corps and flew on the Space Shuttle in the early days. But I got frustrated, I guess. The dynamic pace of Apollo ground to a halt. In 1973, the first Space Shuttle flight was still eight years away, and there were meetings and more meetings and not many dynamic training activities. So I decided to leave NASA. Occasionally I look back and wish I had stayed and flown on one of the early Space Shuttles.

What do you think of plans or talk of going to the Moon or to Mars? And what do you think we need to do for this?

: Whatever we do – we need commitment. Governments have to make a decision: "This is what we are going to do." As long as this decision is not made, nobody is ever going to pay for it. I think the human spirit is going to take us to Mars. We have that drive to explore within us. From my point of view, I think the most logical step would be to return to the Moon and build a Moon base or a Moon village, to gain experience in building these types of systems. And then – when we finally make it to Mars – we can take that experience with us and know how these systems work and how to repair them if need be. It is crucial to build this level of confidence in near Earth orbit or on the Moon. Because once you are on Mars, you are on your own. "Houston, we have a problem" – "Sorry, buddy, you are 12 radio minutes away, you better be able to solve it on your own." The Moon is close to Earth – with almost instantaneous communication – and you can fly crews back and forth. You can develop procedures to repair the necessary systems and all of that stuff. So I would be pushing for a Moon base. But when you talk to some of the other astronauts of my generation, they will say: "We have been to the Moon, let's go to Mars!"

When you look back at the last decades of spaceflight, which would you say have been the most important developments?

: Space technology has brought great steps forward for the global economy as a whole. Just take a look at Information Technology, computers, medical electronics, manufacturing techniques, new materials, and so on. I think that when we start preparing for these long duration missions to the Moon or Mars, the type of technologies and the materials that we will be developing for this will also spread into the global economy eventually. The Harvard Business School has carried out a study on the benefits of the Apollo missions – the return was 10 times as high as the investment. The Apollo missions were good for 400,000 jobs. These jobs fed numerous families who, in turn, supported the people that sold them the food. If you think about it, we are not spending money on the Moon – we are spending money on Earth to develop the technologies. I stress the commitment needed for this on the part of the governments: "This is something we have to do." I see this commitment at the verge of being developed, but we are not quite there yet. But I am optimistic; I think we will live to see a return to the Moon, and then a mission to explore Mars.

As a 'Moonwalker' you are part of a very exclusive group. Is it a blessing or sometimes also a curse to be an Apollo astronaut and be reduced to only that at times?

: I consider it more of a blessing, I think, because I have the opportunity to inspire a lot of people. I hold motivational talks, keynote speeches at conferences, and speak with companies. I talk about teamwork, thorough planning, and I use the Apollo missions as examples. Half of the world's population was not even born when we went to the Moon. So every time I talk I have a new audience of sorts. I do not keep track of how many talks I give a year, but they are many. Every time I do give a talk, I get enthusiastic again because I can see the effect that the portrayal of my experiences is having on the audience.

When you return to Earth after setting foot on the Moon, isn't everything a bit too mundane, too much routine? Did life after you came back not seem a little 'boring'?

: I would not exactly say that life was boring, but I did ponder after I came back: I was 36 years old when I went to the Moon and I turned 37 as I was training for Apollo 17. When the Apollo era was over, the thought occurred to me: What am I going to do now? A lot of Apollo astronauts actually said that. The drive that took us to the Moon was still there, and when climbing the ladder of success most people think: If I can just get to this level in my career, I will have 'peace, joy and satisfaction'. But it does not work like that – at least not for me. I started having trouble in my marriage, but what really did change my life came about six years later. I became a believer in Jesus. Now when I look back at the whole Apollo mission I see the beauty of God's creation – in all parts of our mission. "The heavens declare the glory of God and the skies proclaim the work of his hands." It is one of my favourite Psalms.

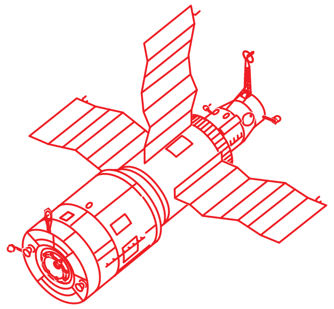
Did you stay in touch with any of the other Apollo astronauts? Everybody's lives were probably touched by such a mission ...

: That is true. We do not see much of each other, but on occasion our paths do cross – those moments are a good opportunity to reminisce and share our thoughts about what is going on in the world and what is going on in our lives. We remain connected. And that feels really good.

Apollo 16 was astronaut Charles Duke's only mission in space. He left NASA in 1973. He is still in touch with his fellow Apollo crew members.

SIGMUND JÄHN – GERMANY'S GAGARIN

On 26 August 1978, when Sigmund Jähn became the first German to fly into space – accompanied by his Soviet commander, Valery Bykovsky – East German propaganda celebrated it as a sign of the superiority of the socialist German state over 'imperialist West Germany'. Yet this alleged superiority was short-lived; 12 years later, East Germany was no more. Jähn's achievements, however, endure.



40th anniversary of the first German space flight

By Gerhard Kowalski

Image: Gerhard Kowalski

Veterans of the cosmos – Soyuz commander Valery Bykovsky (right) and Sigmund Jähn 30 years after their flight together.

For more than twice as many years now, we have been celebrating this momentous date in a unified Germany. For the Vogtland-born Jähn, who turned 81 this February, his lifelong dream was destroyed with the demise of East Germany. Yet the former National People's Army major general soon settled in the West. Ulf Merbold, once a 'refugee from the Republic', helped him greatly in the process – a highly noble gesture and a peculiar irony of Germany's divided history. Indeed, Merbold was born just a mere 35 kilometres from Jähn's native village in Vogtland, Thuringia, and became the second German to fly into space, with the United States, five years after Jähn.

With Jähn's achievement, the small republic of East Germany became the fifth country in the world to have its own astronaut – after the USSR, the United States, Czechoslovakia and Poland. He was the 90th person in space.

The German cosmic pioneer did not join the reunified Germany empty-handed; from then on, the country's space programme saw the merging of two different approaches to innovation – albeit with a very similar scientific and technological profile. As an advisor to the German Aerospace Center (DLR) and later the European Space Agency (ESA), Jähn was able to contribute much more than just his skills and experience. After all, together with Bykovsky, he conducted 22 scientific experiments during their weeklong mission on the Salyut 6 space station, in the fields of Earth observation (2), atmospheric physics (2), materials science (6), biology (4), medicine and physiology (7) and space technology (1). His organisational experience and close personal contacts with Russian partners in 'Star City', where potential astronauts from across Germany would soon carry out their training, proved just as valuable.

In 1983, Jähn distilled his special insights into the evaluation and application of remote sensing data – acquired using the multispectral camera MKF 6 and commercially available handheld cameras – in a doctoral thesis, earning him a PhD summa cum laude. For some reason, however, this remained under the radar until German reunification.

This year, on the 40th anniversary of Jähn's pioneering space flight, a small survey on the results of his research and what has become of it have revealed something of a surprise. Frank De Winne, Head of the European Astronaut Centre in Cologne, mentioned Jähn's 'time' experiment from all those years ago, which investigated the dynamics of the subjective sense of time among the members of international crews. According to De Winne, it was "one of the best examples" of the connection between the research of yesteryear and that of today. Under the title 'Time Perception', it is being continued as an ESA experiment on the International Space Station (ISS). In addition, Jähn's medical observations – even though his mission lasted only a week – helped to gain a greater insight into the effects of weightlessness on cardiovascular function, oxygenation of the human body and cell physiology, according to the Belgian ESA astronaut.

Since then, Jähn has not only helped his five compatriots Klaus-Dietrich Flade, Ulf Merbold, Thomas Reiter, Reinhold Ewald and Alexander Gerst prepare for missions on the Russian space station (Mir) and the ISS; he has also assisted several ESA astronauts from other countries on their journey into space. The highly regarded doyen of the 11 German astronauts has now been retired for several years, but he is still overwhelmed with invitations to give lectures and attend other events. He also looks after the German Space Exhibition in his birthplace of Morgenröthe-Rautenkranz, which has become a true visitor attraction.

The 40th anniversary of Jähn's feat is being celebrated in numerous ways across Germany, and each of the event organisers invariably expects the man himself to attend, something that the modest and reserved Jähn is keen to avoid. The round of celebrations began at Easter in Morgenröthe-Rautenkranz with the special exhibition 'Germans in space – it began in 1978'. The exhibition management is still trying to have Jähn's Soyuz landing capsule relocated from the Armed Forces Military History Museum in Dresden, at least temporarily. This event will be followed by the ILA Berlin Air Show in late April. The Leibniz-Sozietät der Wissenschaften zu Berlin e.V. – of which Jähn is an honorary member – will then hold a scientific colloquium on the topic 'Humans in Space' in mid-May, looking at how a space travel programme as restricted as that of East Germany was integrated into the overall programme of the USSR, a global superpower. The festivities in Morgenröthe-Rautenkranz will reach their peak on the last weekend in August, and if everything goes according to plan, Alexander Gerst will send a greeting all the way from Earth orbit …

Gerhard Kowalski is a freelance journalist and Gagarin biographer

Image: Kowa Scan

Jähn and Bykovsky give their first interview after the landing of the Soyuz capsule on the Kazakh steppe on 3 September 1978

RENDEZVOUS WITH 'THUMBELINA'

Dreaming of a summer in Sweden? Then, having a plan B for cooler days is a must. For those interested in aviation, the Swedish Air Force Museum (or Flygvapenmuseum) in Linköping, located some 180 kilometres south-west of Stockholm, is commendable. With its many bicycles in a lively centre, this university town is similar to Münster in Westphalia, but significantly smaller with some 150,000 inhabitants. If you do not fancy a swim in the giant Lake Vättern nearby, an excursion into the history of mainly Scandinavian aviation is a worthwhile alternative.

At the Swedish Air Force Museum in Linköping

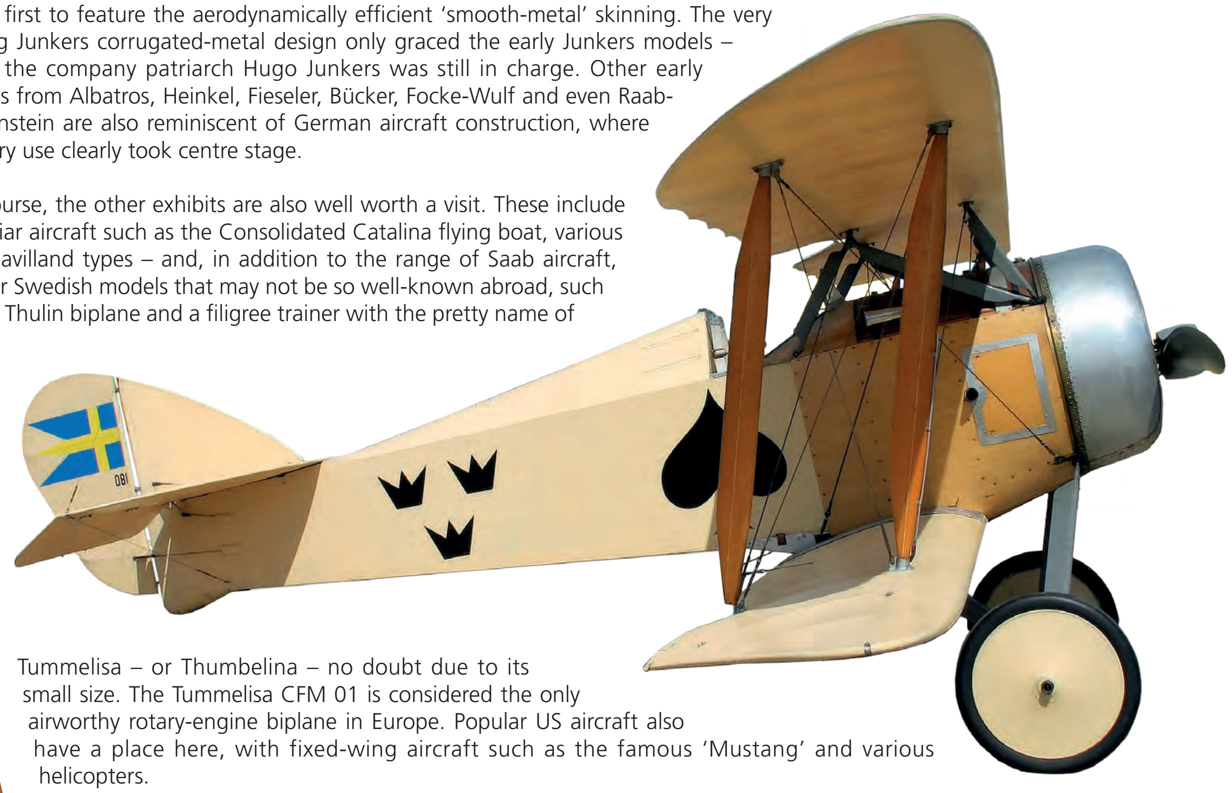
By Hans-Leo Richter

The museum is located about six kilometres outside the town, right next to the Malmen Airbase, and – as one might expect – focuses primarily on military history. In existence since 1984, its main sponsor is the defence and security group – and aircraft manufacturer – Saab. Unlike the private aircraft collection housed in Stockholm Arlanda (presented in Magazine 154/155 in September 2017), here the visitor encounters an ultra-modern museum building. With its large, well-lit halls, the entire setup is impressive at first sight – and no wonder, as some renowned companies have invested in this project, with the help of Saab. Naturally, the museum presents an almost complete type series of Saab aircraft, from the first B 17 of 1938 to the cutting-edge types S 35 Draken, S 37 Viggen and JAS 39 Gripen.

Aerodynamically efficient skinning

Numerous exhibits from the early years of aircraft development will be of particular interest to those interested in German aircraft – above all a fantastically restored twin-engine Junkers Ju 86 K, a Swedish licence-built version of the mid-range bomber, originally designed and used as a small passenger aircraft. This type was one of the first to feature the aerodynamically efficient 'smooth-metal' skinning. The very striking Junkers corrugated-metal design only graced the early Junkers models – when the company patriarch Hugo Junkers was still in charge. Other early models from Albatros, Heinkel, Fieseler, Bücker, Focke-Wulf and even Raab-Katzenstein are also reminiscent of German aircraft construction, where military use clearly took centre stage.

Of course, the other exhibits are also well worth a visit. These include familiar aircraft such as the Consolidated Catalina flying boat, various de Havilland types – and, in addition to the range of Saab aircraft, other Swedish models that may not be so well-known abroad, such as a Thulin biplane and a filigree trainer with the pretty name of Tummelisa – or Thumbelina – no doubt due to its small size. The Tummelisa CFM 01 is considered the only airworthy rotary-engine biplane in Europe. Popular US aircraft also have a place here, with fixed-wing aircraft such as the famous 'Mustang' and various helicopters.



In the large hall, visitors can immerse themselves in a century of aviation history. Right next to the balloon basket is a rescue helicopter HKP 1– Vertol 44a from the late fifties.

Final highlight: a Gripen flight simulator

One spectacular exhibit awaits the visitor in the basement, which has a somewhat enigmatic feel to it thanks to the sparse illumination in dark shades of blue. At first sight, it appears to be a nondescript ruinous heap of distorted metal sheet. But with some imagination, one is able to visualise the contours and details of a former twin-engine Douglas DC-3. This commercial aircraft was shot down in 1952 by a Soviet fighter plane over the Baltic Sea, where it remained for about 50 years before finally being salvaged in 2003 – its ultimate destination would come six years later at the aircraft museum as a permanent memorial.

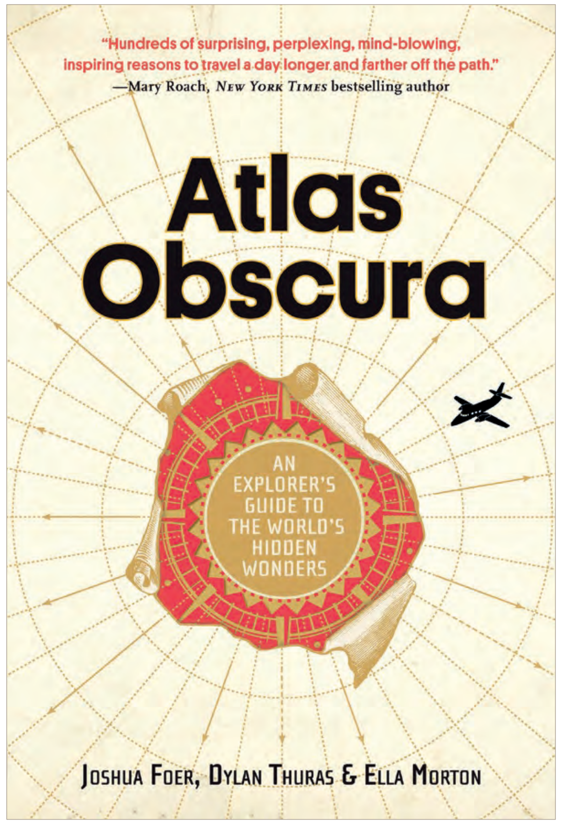
Last but not least, this commendable museum is also aimed at young people through its impressive informative presentation, including its flight laboratory with various experimentation options and a simulator. The cockpit of the large simulator of an authentic JAS 39 Gripen is just one of the many attractions the Swedish Air Force Museum – which is free to visit – has to offer in Malmslätt, just a few kilometres west of Linköping.

www.flygvapenmuseum.se

The Museum presents itself in a modern hall on the edge of the Malmen Airbase. In the background on the left a Sud Aviation Caravelle, equipped for special electronic tasks.


With this medium-range bomber, Junkers left the traditional corrugated iron construction in favour of an aerodynamically improved smooth skin planking. The exhibited specimen is the world's only remaining Junkers Ju 86.

The lightweight 'de Havilland 60 Moth' trainer was one of the most popular training aircraft of the Swedish Air Force. Significant long-haul record flights were made with this type in the thirties.



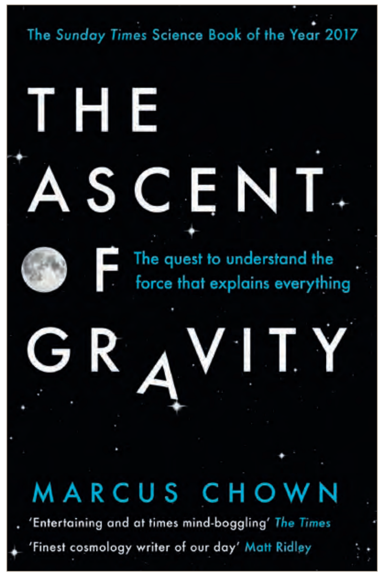
ODD, OFF THE BEATEN TRACK AND VERY SPECIAL

Right away, the 'important information' on the imprint page sets the tone: "Readers are cautioned to travel at their own risk and to obey all local laws." And neither the authors nor the publisher may be held liable or responsible for any loss, injury or damage allegedly arising from information in the book. This sounds worse than it is – not all of the more than 700 tips in **Atlas Obscura: An Explorer's Guide to the World's Hidden Wonders** are so adventurous. And even if they were, the weighty tome is no traditional guidebook in any case – it is also bags of fun if you forget about travelling anywhere and just read it sitting comfortably on the sofa. Besides, the choice of destination would be difficult. Would you rather go to the most remote inhabited island in the world, Tristan da Cunha, which can only be reached after a seven-day sea voyage from Cape Town? Or would you opt for the annual escaped-animal drill in Ueno Zoo in Tokyo, where zookeepers dressed as monkeys, zebras or rhinos plan to abscond while colleagues train to prevent them from doing so? Or why not go to Livermore in the USA to see the light bulb that has been burning in a fire station since 1901 and still generates four watts even after more than one million operating hours (Fire Station 6, 4550 East Avenue, Livermore). "Ring the bell at the rear of the station and see if anyone answers," the unusual guidebook says.

Two of the authors of Atlas Obscura – Joshua Foer and Dylan Thuras – began to collect curious travel tips on a website in 2009. Other users were allowed to add to the suggestions. The 480-page paper atlas now provides a topic selection to be perused at one's leisure. With short texts and photographs, one discovers the world and becomes familiar not only with new facts, but also with masses of stories and anecdotes. The reader learns about the Danish lighthouse Rubjerg Knude Fyr, which is increasingly engulfed by dunes; and about the Hawaiian island of Molokai, which for over 100 years (until 1969) was used as a natural prison for lepers and can be reached after a half-hour flight from Honolulu. Or about the libraries of Chinguetti, a desert village in Mauritania, which houses medieval manuscripts on science, mathematics, law and Islam. This is also the first atlas that contains information on Arctic spaceship architecture, decommissioned nuclear power plants or deadly creatures in Australia.

However, some of the destinations listed in this page-turner are neither unknown nor particularly dangerous. They are also to be found in 'normal' guidebooks, which direct tourists to the tanneries in the medina of the Moroccan town of Fez. The Nazca Lines, etched into the ground in Peru, are also on the tourist bus trail. But this does not lessen the enjoyment of reading the book. At least it means you can tick off some destinations if you have already visited them. However, few people will have seen the shrines in the ice tunnels of the Amundsen-Scott South Pole Station, the gopher museum in Torrington in Western Canada or the constructed but never operated 3000-room Ryugyong Hotel in Pyongyang in North Korea …

Manuela Braun

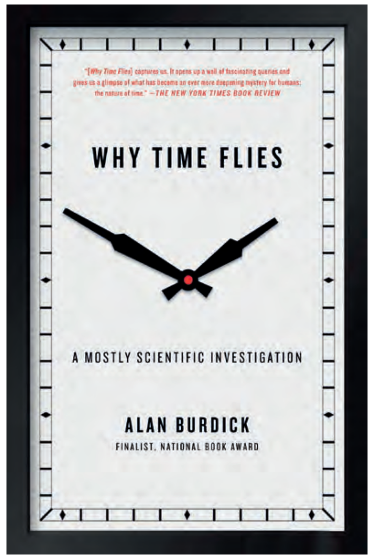


THE COMPLEX WORLD OF GRAVITY

Have you ever wondered what gravity is all about? Then this is the book you have been waiting for. **The Ascent of Gravity** by Marcus Chown is an accessible book about gravity – the 'force that explains everything'.

Although it is an introduction to a complex subject, the author manages to explain the topic clearly and with great enthusiasm. With quotes and funny anecdotes, Chown takes the reader on an interesting journey to explore Isaac Newton's discovery of the force of gravity, Albert Einstein's reformulation of gravity as warped space-time and the recent search for the origin of the Universe. And for those who cannot get enough of the complex world of gravity, the book also provides a handy list of further reading.

Dirma van Eck



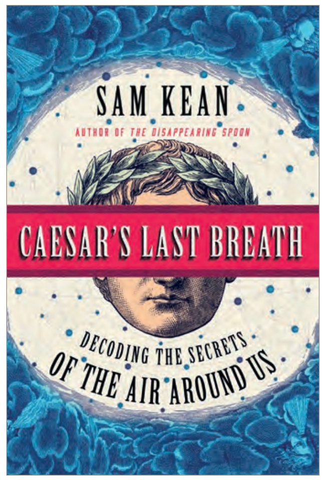
WHY TIME FLIES

Did you know that Coordinated Universal Time (UTC) does not derive from a single high-tech time-keeping device, but is actually the average time of laboratory clocks in 58 countries around the world? Or that, for centuries, the second existed only in the abstract, as a mathematical subdivision, until the seconds pendulum was added to a clock in 1670? These are some of the surprising facts that Alan Burdick uncovers in **Why Time Flies** on his quest to understand time.

In a meandering narrative, Burdick interweaves his own observations and struggles to manage time with philosophical and scientific research into the nature of time. He reads the Time Machine by H.G. Wells, participates in a time-isolation experiment in the Arctic, and has a brain fMRI scan. He delves into the history of time-keeping, analyses how time is encoded in language, and explores how our bodies and brains experience and process time. He makes some interesting discoveries along the way, for instance how to counteract jetlag (schedule your airline meals and exposure to light according to the time at your destination) or why newborns have such irregular sleeping schedules (their circadian clock is not yet fully operational).

Burdick warns his readers early on that there is no one truth about time and raises as many questions as he answers. Nevertheless, reading his book is a delightful way to lose track of time.

Merel Groentjes



THE AIR AROUND US

Is there any truth in saying that the trillions and more of molecules in the air that we breathe have passed through millions of bodies before us and that we all share the same precious oxygen at certain points in our life? For an anecdotal yet scientific answer to these questions turn to the wonderful book **Caesar's Last Breath** by Sam Kean. The reader is taken back to the memorable time in history when Julius Caesar passed his last breath in Rome. An incredible journey takes place from there. Going back even further in time Kean takes us into our atmosphere (one of many), its evolution over millions of years, and tells us how it has shaped the Earth to what it is today and how it slowly, gradually enabled life to emerge. Mix into this humankind's drive to understand its surroundings and you get a pleasant, near-enough accurate account of how the world shaped us and vice versa. All that is required from the reader is a general knowledge of Earth's history and a basic understanding of physics and chemistry (or the will to just read for pleasure and skip the more scientific bits). For those wanting to know why Einstein is said to have choked on his eggs one morning, why it was goats that were used to test how badly the fall-out was after a nuclear bombing, or what really happened in Roswell, there is a considerable section in the back of the book with more funny tidbits and useful want-to-knows. How some great inventions have taken us through the Industrial Revolution and into the technological age and how it will be technology that might save us again one day. This book is (literally) breathtaking.

Linda Carrette

RECOMMENDED LINKS

FOLLOW FLIGHTS LIVE
flightradar24.com
It started out as a hobby in 2006. From 2009, its creators – two Swedish aviation enthusiasts – made it possible for anyone to follow thousands of aircraft around the world in real time. With flightradar, you can track regular flights, parabolic flights and even research flights across the globe.

ENGINEERING FOR MARS
youtu.be/ZSXnw-fJbGk
The Red Planet will soon be welcoming a new guest – InSight, which carries DLR's 'Mole'. Virtually explore a Mars simulation facility used by engineers to practice operating NASA's InSight lander. And explore the Instrument Lab at the Jet Propulsion Laboratory in Pasadena, California, and take a look at how the space probe will deploy its seismometer.

SUSTAINABLE DEVELOPMENT
sustainabledevelopment.un.org
Sustainable development concerns us all. But what is sustainable development, and why is it so important for everyone? Find all about sustainable development, the current goals and how to achieve them. And, if you want to contribute, join one of its many projects and help shape a better future for everyone.

REAL-TIME THUNDERSTORM INFORMATION
youtu.be/YIt_QgcuJqs
Thunderstorms can seriously disturb air traffic. Until now there were no appropriate technical systems to provide information about current weather conditions and upcoming thunderstorms. But thanks to the technology developed by DLR and WxFUSION, there finally is. Find out how WxFUSION was developed and how this system works.

DISTANCE TO RYUGU
hayabusa2.jaxa.jp
The JAXA Hayabusa2 spacecraft, and the DLR/CNES MASCOT asteroid lander on board are en route to their destination, asteroid Ryugu. When they arrive in the second half of 2018, MASCOT will land on the surface and take measurements at various locations, and Hayabusa2 will take a sample, which will be returned to Earth. But, where are they now? Follow their journey and check the distance between the spacecraft and Ryugu in real time!

About DLR

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

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

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Cover image

Spectacular tracking flight in the name of research: NASA's DC-8, which has been converted to a flying laboratory, sniffs in the exhaust plume of DLR's Airbus A320 ATRA. The flight campaign aims to clarify the impact of biofuels on emissions and contrails.

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