DLR magazine

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SUN AT YOUR FINGERTIPS

TWO SPACE ODYSSEYS: Celebrating MIR '92 and MIR '97 anniversaries

100 SECONDS OF ADDITIONAL THRUST: Rocket boosters made of carbon fibre reinforced plastic

TRACKS IN THE SNOW: Research in Antarctica

DLRmagazine 153

Image: DLR/Gesine Born

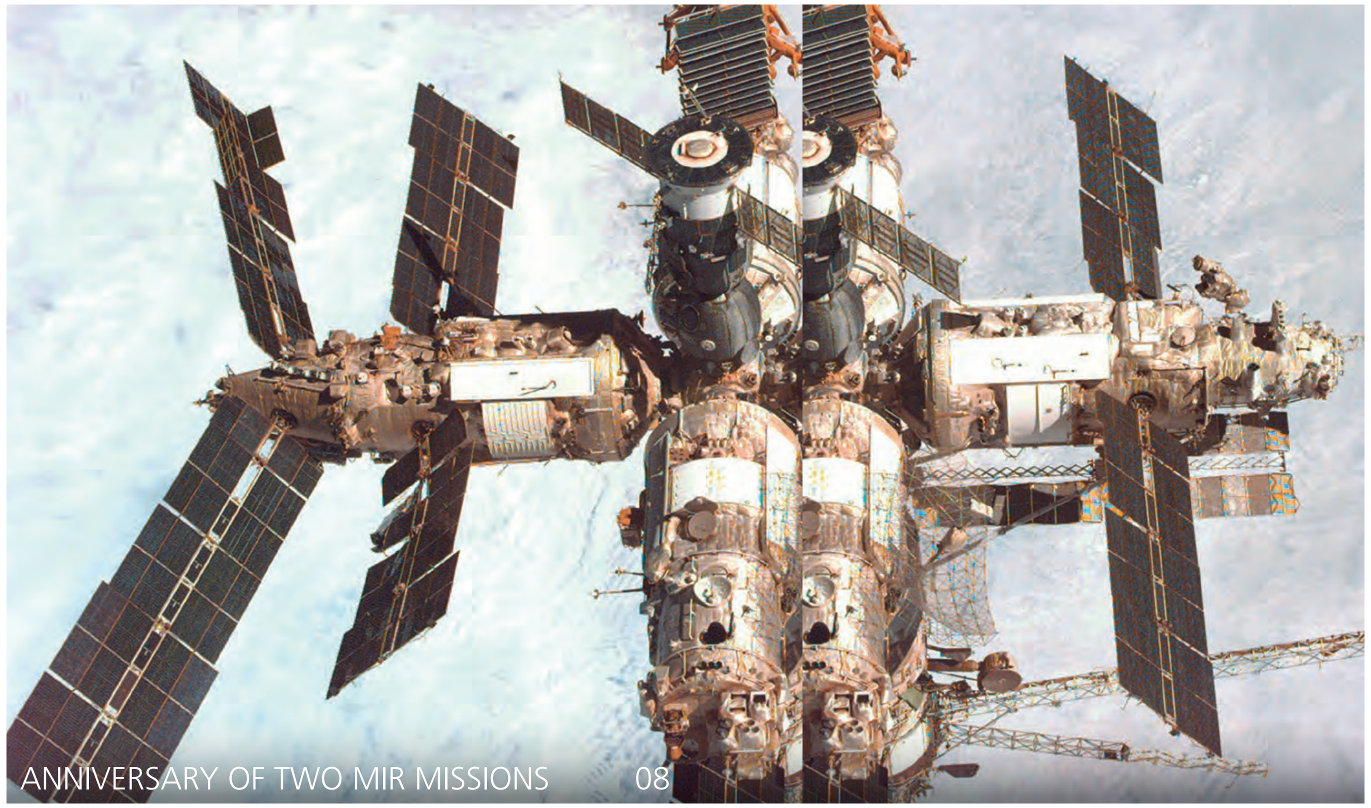
Dear readers,

Sunlight at the push of a button would be wonderful, especially after this winter. Light lifts not only the temperature but also the spirits, which is much needed after winter hardship – and I don't just mean the weather. But unfortunately we are not all researchers in Jülich, who have access to an artificial Sun. Using a kind of honeycomb pattern made of 149 individually controllable radiator modules, they have achieved a total output of 10,000 times solar radiation. That exceeds that of any of the currently available high-flux solar simulators in the world. High ultraviolet radiation is a hot topic in spaceflight, but the Synlight research facility inaugurated in March is primarily tasked with developing solar chemical processes. In future, it could provide a way to produce solar-generated fuels.

Clean engines do not emit any soot, which is important as soot can darken the snow in Antarctica. This is crucial to the environment, as the reflective capabilities of snow affect the climate. A joint project between DLR and Chile is aiming to look into this relationship more closely. For this reason, DLR researchers swapped their computer workstations for shovels and pickaxes and headed to Union Glacier in Antarctica to take snow samples. These are now being examined in their Chilean colleagues' laboratories.

A positive effect on the climate is found in less remote areas – in cities. Everyone knows that greenery is required for a healthy inner city climate, and thanks to satellite data, suitable places for greening have been easily recognised – on rooftops. So, if you long for winter to pass, try planting flowers on your roof. Spring might come sooner.

Sabine Hoffmann
Head, DLR Corporate Communications



ANNIVERSARY OF TWO MIR MISSIONS 08

COMMENTARY 04

TRACKS IN THE SNOW 40

CARGO TRANSPORT 24

STAR TREK AT THE MUSEUM 52

ONE BLACK POWDER – MULTIPLE IDEAS 16

Image: DLR/Gesine Born

"CHANGE IS THE ONLY CONSTANT IN LIFE"

Commentary by Pascale Ehrenfreund, Chair of the DLR Executive Board

Nature and society are constantly changing, not least due to human influence. In awareness of this, we must reconsider our actions and act accordingly. Knowledge is key to this and will allow us to implement measures that will secure our future on Earth, as well as that of the generations that follow. The time for action is now.

The results achieved through the research we conduct in various fields will help us meet the need for the knowledge of tomorrow. Among the challenges we face today are intelligent mobility, energy efficiency, climate protection and big data. Addressing these will allow us to smartly and sustainably shape the future.

We are on the right path. The entire city of Braunschweig became the testing ground for the mobility of the future. Laser data transmission has set a world record, marking the start of Internet availability in remote regions. And research into alternative fuels is intended to significantly decrease the environmental impact of air transport: The virtual product – from the design of the aircraft to the maintenance intervals – should significantly improve the industrial process chains.

Equally key to the success of our current research is ensuring interconnectedness among the various fields to better address social needs. In this way, our research will be the basis for securing Germany's position as a scientific and economic hub.

GREATER SAFETY AND EFFICIENCY AT AIRPORTS

DLR leads EU-funded research projects

For better air traffic management, the European Union launched the Single European Sky ATM Research Program (SESAR) that includes a total of 25 projects. Two have now been launched under the leadership of DLR. They will focus on the use of remote tower technology that enables the provision of single or multiple aerodrome ATS from a remote tower centre and extensive testing of new air traffic management developments on the ground.

The Remote Tower concept enables air traffic controllers or flight information service officers to provide air traffic service to rural airports with usually low traffic densities from a Remote Tower Center instead of, as is conventional, from the local tower. Thirty-nine international partners from industry, air navigation service providers and research organisations are collaborating on developing solutions with which multiple airports can be operated safely and efficiently using camera video streams from a Remote Tower Center.

The 'Integrated Airport Operations' project is designed to demonstrate how the solutions developed and validated in the SESAR1 predecessor programme can be applied to increase safety and capacity while reducing fuel consumption and delays. To this end, individual large-scale field tests are planned at Hamburg, Nice and Budapest airports. The test runs at the airports will be supplemented by two onboard demonstrations that will involve the use of new solutions in the aircraft. Eight European partners and consortia are participating in the tests, including Thales, Honeywell, DSNA, Airbus and Indra, plus the NATMIG and B4 consortia.

s.DLR.de/75a1

Several airports are monitored and managed remotely from the Control Centre. Here, a single controller can handle air traffic management for several airports, depending on the level of traffic.

ALCOHOL AS ROCKET FUEL

German-Brazilian cooperation project is based on 'green' propulsion

Aerospace engineers from Brazil and DLR are one step closer to environmentally friendly rockets. The first burn tests for the upper stage engine of a future Brazilian small launch vehicle were sucessful. In order to find the optimum technology for the propulsion of a future German-Brazilian rocket, two injector heads were developed in parallel and put to the test at the P8 test facility of the DLR Institute of Space Propulsion in Lampoldshausen. During 42 ignitions carried out over 20 days, scientists were able to closely analyse the ignition behaviour and stability of the system during ignition and start-up of the thrust chamber.

The new technology makes it possible to use ethanol – ordinary alcohol – as fuel. Ethanol, like methane, is one of the so-called 'green' fuels. These are becoming increasingly important as they are more environmentally friendly and have less adverse health effects than the hydrazine compounds generally used for space travel. In addition, they are economical, since the cost of safe storage and handling of the substances is considerably lower.

The two new injector heads, envisaged to one day be at the core of the new L75 engine, differ in how the fuel is sprayed into the combustion chamber and mixed. One system was developed by the Instituto de Aeronáutica e Espaço (IAE) in Brazil; the other was developed and built in Germany by the space company Airbus Safran Launchers as part of the SALSA project (system design of an alcohol LOX propulsion as a substitute for storable fuels).

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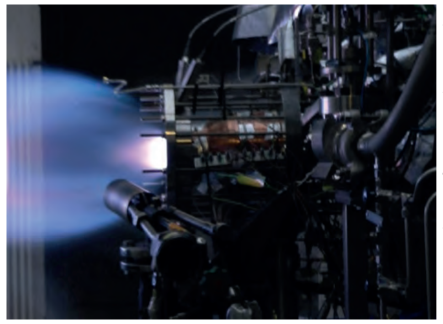
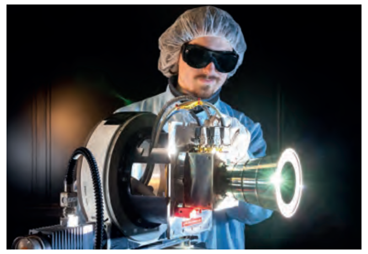


Image: Airbus Safran Launchers GmbH

Two different injector heads were tested in the burn: On the left, the system developed by Airbus Safran Launchers GmbH. On the right, the system designed in Brazil. During the test, fuel is sprayed into the combustion chamber by the injector head and then ignited.

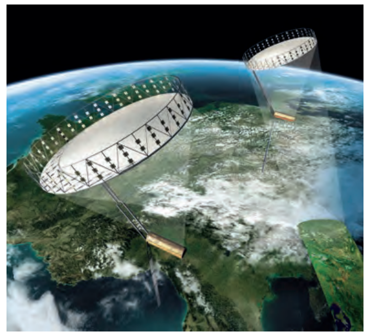


FIRST 'MADE IN GERMANY' SMALLGEO SATELLITE IS IN SPACE

Launched on 28 January 2017, Hispasat 36W-1 is the first in a platform of telecommunications satellites largely developed and built in Germany. The satellite will supply the Iberian Peninsula, the Canary Islands and South America with multimedia services. The payload includes a Ka-Band Demonstrator – a communications unit with a particularly wide range of frequencies. A new control unit and three power amplifiers are being tested in space. Until now, telecommunications satellites have been relatively inflexible: Once launched into space, they transmit in the same frequency range and at a fixed power for their entire service life of about 15 years. The new development is expected to make satellite communications more flexible.

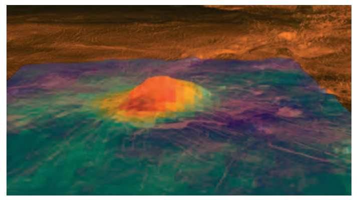
GLACIAL ICE IN SLICES

In collaboration with the Alfred Wegener Institute for Polar and Marine Research (AWI), 3D Earth observation methods developed by DLR have been used on glaciers and areas of ice. The satellite-supported radar concept enables areas of the cryosphere to be recorded and analysed in slices. It is still not possible to comprehensively capture the rapid movements of numerous glaciers and areas of ice. The forthcoming Tandem-L satellite mission should fill this gap and provide information on the global consequences of the changes. The melting of glaciers and ice and the resulting rise in global sea level represent a threat for many countries. At present, the proposal for this satellite mission is being reviewed by the German Council of Science and Humanities. A decision is expected in mid-2017.



MAP OF VENUSIAN VOLCANO

The Idunn Mons volcano in the southern hemisphere of Venus, with a diameter of 200 kilometres at its base, shows signs of geologically recent volcanism. DLR scientists used the VIRTIS spectrometer to identify lava flows and found unusually high temperatures, even for the surface of Venus. VIRTIS is part of the European Space Agency Venus Express orbiter mission, which acquired images of the atmosphere and surface of Earth's 'twin planet' from 2006 to 2014. Researchers combined VIRTIS infrared data with much higher-resolution radar images from the NASA Magellan mission, which mapped Venus from 1990 to 1992. It is the first time that a high-resolution geologic map of a recently active volcanic structure on the surface of a planet other than Earth has been generated combining the datasets from two different missions.

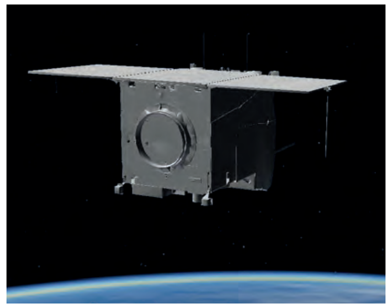


WORLD RECORD IN FREE-SPACE OPTICAL COMMUNICATIONS

DLR has set a new record in data transmission using laser. In a test environment, a transfer rate of 1.72 terabits (corresponding to 45 DVDs) per second was achieved over a distance of 10.45 kilometres. The data link to space has, at its worst, the same interference as that encountered when transmitting from ground to mountain in the test area between Weilheim and Hohenpeißenberg. The test, which was part of the DLR THRUST (Terabit-throughput optical satellite system technology) project, is a step towards connecting satellites to the Internet on Earth via a laser link. This means that large parts of still under-served rural areas could be supplied with broadband Internet services. With the new records, the scientists have successfully demonstrated that the vision of wireless optical data transmission in the terabit range is possible.

RENDEZVOUS IN SPACE

DLR scientists have launched the Autonomous Visual Approach Navigation and Target Identification (AVANTI) experiment to demonstrate how a satellite can detect a spacecraft in space and approach it autonomously. This capability will be necessary in the future for capturing old and inactive satellites, as well as space debris, and bringing them into a safe orbit. To do so, they used the small BIROS satellite as a 'catcher' and the BEESAT-4 pico-satellite as an 'inactive object'. AVANTI only requires a simple sensor system for relative navigation, which is why the star camera, already on BIROS, was used as a monocular camera. After imaging the target area, processing the image and identifying the object, AVANTI can make its approach. With the data from the flight manoeuvre, the relative movement of BEESAT-4 can be calculated and the manoeuvres to capture space debris planned.



FLYING AROUND WAKE VORTICES

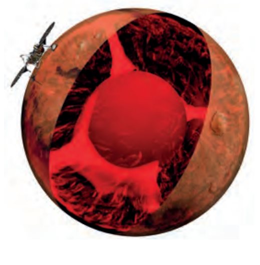
In late 2016, DLR conducted tests over Braunschweig into how wake vortices can be avoided. These can have safety implications for following air traffic. Therefore smaller aircraft must maintain an increased safety distance of up to 15 kilometres behind larger aircraft. The new system is able to predict potentially dangerous wake vortices, determine possible conflicts and propose avoidance manoeuvres. The DLR A320 ATRA research aircraft was used to test the new avoidance system. The interface with the pilot is a display that shows the position of the wake vortex. The DLR Falcon following behind is used to determine how the automatically suggested manoeuvres are working. Tests using the Falcon have shown that the chosen approach delivers high-quality vortex predictions and improves the pilots' situational awareness.

DLR TECHNOLOGY SAVES LIVES

The work of the International Search and Rescue (ISAR) aid organisation has been supported with satellite data from DLR for several years now – most recently after Hurricane Matthew in the Caribbean in October 2016. This gave the rescue teams an overview of the situation so they could better coordinate their efforts. The collaboration will be developed during the course of 2017. Cameras from the DLR Institute of Optical Sensor Systems should then be available for use on unmanned aerial vehicles (UAVs) to look for people lost in earthquakes and floods. DLR is developing special compact camera technology for the small UAVs. The collaboration with ISAR has the advantage that new technology can be adapted for actual use from the outset.

GREENHOUSE GASES RECORDED

Too little is known about the effects of methane and carbon dioxide on the climate. The CoMet (carbon dioxide and methane) mission led by DLR will provide information on this. Methane is considered to be the 'little brother' of carbon dioxide. Despite the fact that its concentration in the atmosphere is 200 times lower than carbon dioxide, its relative global warming potential is huge and it is important to take this into account in more detail for future climate forecasts. The High Altitude and Long Range Research Aircraft (HALO) is collecting data on the two most important greenhouse gases, from northern Europe to North Africa. The focus is on the Upper Silesian Coal Basin – one of the largest sources of methane in Europe – and the Berlin region that, due to its remoteness surrounded by sparsely populated regions, is an interesting area to explore the greenhouse gas flows of a metropolis.



3D IMAGES FOR MOLE USE

On 5 May 2018, DLR will send the HP^3 (Heat Flow and Physical Properties Package) probe, also known as the 'Mole', to Mars with NASA's discovery class mission InSight. The objective of HP^3 is to explain things such as how Mars transports its heat from its interior to the surface. 3D simulations carried out by DLR have demonstrated that the Mole will not encounter misleading anomalies on site and that the landing site in Elysium Planitia has a heat flow represenatitve of the planet. The probe's nickname was chosen on the basis of the way HP^3 works, as it will autonomously penetrate several metres into the Martian surface. The researchers plan to use the data to draw conclusions on the composition of the Red Planet and compare Mars and Earth as 'heat generators'. The HP^3 instrument design is based on the MUPUS sensor, which flew on board ESA's Rosetta mission to Comet 67P/ Churyumov-Gerasimenko.

REGIONAL NEWS

BRAUNSCHWEIG: A new guidance system is intended to avoid the frequent crossing of a runway at Zurich airport. Air traffic controllers from Zurich are testing the new taxiway in the Apron and Tower Simulator (ATS) at DLR Braunschweig. The controllers issue clearances via a simulated radio system; 'simulation pilots' carry out the commands. Just like real pilots, they also manage radio communications and can simultaneously control several virtual aircraft. DLR is therefore able to test the new taxiway under various traffic and weather conditions.

STUTTGART: The project to develop a digital bus concept with no fixed stops has gained a new partner – namely Mercedes Benz Vans. The automotive group is providing a 'Sprinter City 35' minibus for the 'Schorndorf real-life laboratory'. It is being used to test the interior design and the access for people with disabilities.

COLOGNE: How can solar technologies become more efficient? DLR researchers addressed this issue in a study into the development of photovoltaic and solar thermal power plant until 2030. The result: the greatest benefit is achieved by combining the two power plant concepts. The photovoltaic plant delivers power directly to the grid, while the solar thermal facility stores energy for future use.

OBERHAUSEN: The 'Wonders of Nature' exhibition will run until the end of November 2017 at the Gasometer Oberhausen. Over the past year, 750,000 people have visited the 100-metre high industrial monument. The highlight is the hovering Earth, for which DLR researchers have produced 1.5 million images.

OBERPFAFFENHOFEN: Once a year, DLR invites the winners of the 'Jugend forscht' competition to the DLR_Talent_School. In February 2017, topics included remote sensing. The focus was on issues such as the opportunities offered by Earth observation using radar sensors, and how satellite data can provide emergency services on the ground with rapid guidance during natural disasters. The lectures, guided tours and background discussions with the Institute's Directors also covered atmospheric research and robotics.

GÖTTINGEN: DLR participated in Göttingen's third Night of Knowledge with a lighting installation depicting the origins of aviation research. 2950 visitors were able to view the replica of the world's first series-production aircraft by Otto Lilienthal, among other things.

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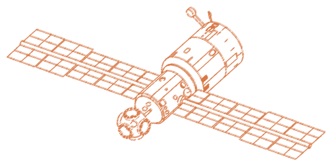
TWO SPACE ODYSSEYS



Anniversary of the two space missions MIR '92 and MIR '97 – Looking back at DLR's involvement

By Julia Heil

A long time ago, in an orbit not so far away… It is 19 March 1992. At almost 400 kilometres from Earth, the Soyuz TM-14 spacecraft approaches the Russian space station Mir. At precisely 13:33 CET, the transport module docks with the orbital station. Approximately one hour later, the hatch opens. After a 50-hour journey, the astronauts have finally reached their destination – the MIR '92 mission begins. It is the first space flight since the dissolution of the Soviet Union on 25 December 1991 – and the first time that a German astronaut, Klaus-Dietrich Flade, is entering the Station. Before the end of the Mir station in 2001, three German astronauts followed in his footsteps – Ulf Merbold in 1994, Thomas Reiter in 1995 and Reinhold Ewald on the MIR '97 mission.

The Mir – which in Russian means peace or world – was the first long-standing, permanent outpost in space. The man-made satellite orbited Earth for 15 years before the station re-entered Earth on 23 March 2001 – its remains falling in a ball of fire into the Pacific Ocean south-east of Fiji.

The MIR '92 mission – Getting acquainted

"MIR '92 was an initial cautious joining of the two partners," recalls Hans-Ulrich Hoffmann from the DLR Space Administration, who was and continues to be responsible for human-physiological and medical experiments in microgravity. "In discussions that lasted for hours, we negotiated every experiment of the mission in detail with our Russian partners. Five years later, during the MIR '97 mission, we had become better acquainted with the Russians' way of working, such as their technical descriptions. They were very concise, but always included all the necessary information."

Both the 1992 and 1997 missions to the Mir were led by the German Space Agency (previously known as DARA; now the DLR Space Administration), which also selected the scientific experiments from various German universities and DLR research institutes with the help of external experts. The German Test and Research Institute for Aviation and Space Flight (since 1997 German Aerospace Center) had the task of selecting the astronauts and preparing them for the mission. From 1990, Klaus-Dietrich Flade trained alongside his later backup crewmember, Reinhold Ewald, at the DLR site in

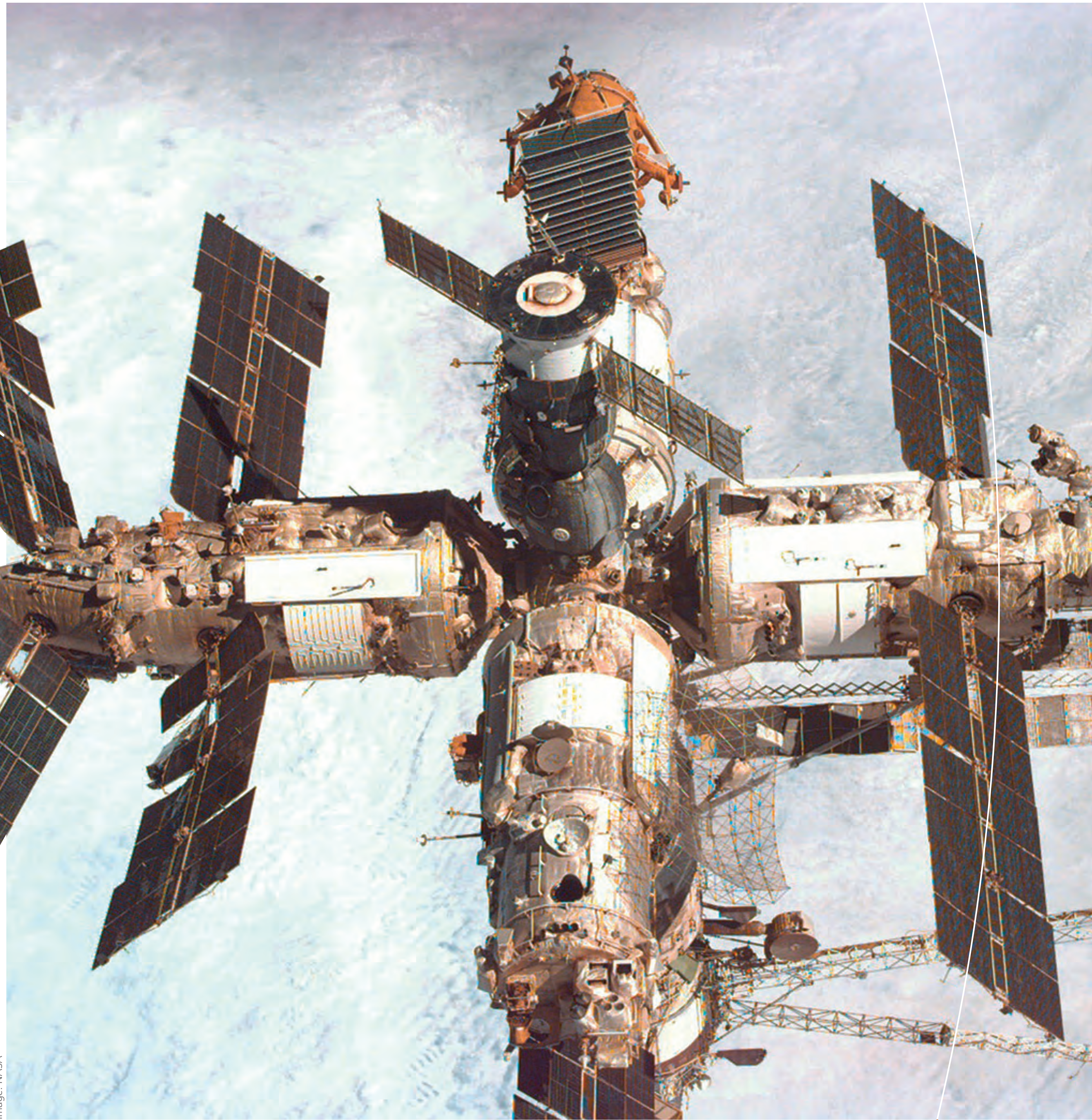


Image: NASA

The Russian space station Mir in 1998 in its final expansion stage

THE EXPERIMENTS MIR '92 MISSION

Launch: 17 March 1992
Landing: 25 March 1992

During the MIR '92 mission, German cosmonaut Klaus-Dietrich Flade performed 14 experiments, five of which were from DLR.

Life sciences
- Body fluid distribution
- Sleep and circadian rhythm
- Psychological performance tests

Radiation protection
- Dosimetric measurements

Materials science
- Specific heat of cooled molten metal

THE EXPERIMENTS MIR '97 MISSION

Launch: 10 February 1997
Landing: 2 March 1997

The MIR '97 experimental programme was performed with the involvement of scientists from German universities and research institutes. Twelve of the 38 experiments were from DLR.

Life sciences
- Cardiovascular regulation in microgravity and upon return to normal gravity
- Heart rate variability and skin blood under orthostatic stress in microgravity
- Body fluid and sodium homeostasis during weightlessness
- Analysis of cognitive, psychomotor and time-sharing performance of an astronaut during space flight
- Characterisation of changes in aerobic and anaerobic work capacity, electrical muscle activation, morphology and fluid volume regulation in human calf muscles before and after space flight
- UV radiation climate on the Mir station and its role in vitamin D synthesis

Materials science
- Microstructure evolution in immiscible aluminium alloys

Operational tests
- Application of a new on-board procedure tool – OPIS
- Field training
- Teleoperation of the TITUS furnace
- Telemedical monitoring and consultation
- Timelining experiment

DLR scientists were involved in six further experiments.

Writing in microgravity: Klaus-Dietrich Flade had to write down the results of experiments by hand during his mission back in 1992.

Russian for beginners. "At first, we simply copied what was on the board into our notebooks," says Reinhold Ewald, "but my team helped me enormously and we ultimately felt perfectly well-prepared."

A temperature problem: Valeri Korzun, Vassili Tsibliev and Reinhold Ewald are trying to set the main recording unit for the MIR '97 experiments. As a team, they finally succeeded.

The fourth German astronaut on the Mir, Reinhold Ewald was selected by the German Test and Research Institute for Aviation and Space Flight (DLR) and spent 18 days at the space station with the MIR '97 mission. Upon his return to Earth on 2 March 1997, he brought back 10 kilograms of samples and scientific data. The remaining frozen samples (including blood and saliva) came back on board the US Space Shuttle.

While Klaus-Dietrich Flade had to write the results of experiments by hand during his mission back in 1992, Reinhold Ewald used a laptop in 1997 to enter his data. This also made the fax machine unnecessary.

Images: DLR archive

Cologne and later in Star City, near Moscow. On the Mir, Flade performed a total of 14 experiments from the fields of life and materials sciences, before bidding farewell to his Russian crewmembers Aleksandr Viktorenko and Sascha Kaleri after a six-day stay.

The focus of the MIR '92 mission was on biomedical experiments, which examined not only the sense of balance, but also the cardiovascular system, the movement of body fluids, the effect of space radiation on the human body as well as the psychological and physical performance of the astronauts. Many of the experiments were pursued in subsequent space travel projects or in research series on Earth. From 2005 to 2010, the working of the human balance system was measured on the International Space Station ISS using the 3D Eye Tracking Device (ETD). A diagnostic instrument for measuring eye movement was already developed for MIR '92. Some developments achieved in the mission even allowed its use on Earth. For example, scientists and engineers developed a tonometer for MIR '92 and the Spacelab mission D2 so that the astronauts could measure their own intraocular pressure during their flight in the Soyuz capsule and the Space Shuttle. Today, this device is used by patients with glaucoma.

With the signing of the contract on 18 April 1990, the MIR '92 mission began as a Soviet-West German space project. It came to an end in 1992 as a Russian-German project. "Things became a bit tense when we had to change the mission logo in the midst of preparations, as we had naturally used the flag of the Soviet Union on the first logo," Hoffmann recalls. MIR '92 was, above all, an ambitious experiment in cooperation. It paved the way for continuous scientific collaboration in the space research activities of two countries, which is still reflected today in the operation of the ISS.

MIR '97 – Old acquaintances

Five years later it was German astronaut Reinhold Ewald who, together with commander Vasily Tsibliev and flight engineer Aleksandr Lazudkin, set off on an 18-day mission to the Mir from the Baikonur Cosmodrome in Kazakhstan on 10 February 1997. The Station had since developed into a significant complex: Six modules had been gradually attached to the Core Module. When, on 12 February 1997, the hatch of the Soyuz spacecraft opened for the three astronauts, leaving them to float into the Core Module of the Russian space station, the Mir was already in its final expansion phase.

Ewald spent more than two weeks on the Mir during which he carried out approximately 30 experiments, largely from the field of biomedicine. Life science experiments took up almost half of the entire crew's time. They principally investigated the effects of microgravity on the human body. Materials science and technological experiments were also conducted. In addition, the astronauts tested technologies that were to be subsequently used on the ISS.

Aerospace medicine rediscovers the human body

Research in the absence of gravity is particularly interesting for medical science. Astronauts suffer bodily changes such as muscular atrophy, a loss of bone minerals (developing osteoporosis) and cardiovascular problems after just a short period of time in microgravity. In contrast to the ageing process on Earth, according to all available knowledge, the symptoms for astronauts are reversible. "The adaptation of astronauts to microgravity provides us with fresh insights into the functions of the human body and we can ultimately use this to help people with health problems on Earth," says Jochen Zange, head of the Integrative Muscle Physiology working group at DLR. He began studying the energy metabolism of the calf muscle and its decline, even before the MIR '97 mission. Today, astronaut training on the ISS is much more efficient. On the treadmill, a pneumatic restraint belt system that replaced the former 'bungee cord' system on the Mir treadmill ensures uniform, artificial weight, thereby facilitating a more natural, Earth-like running style. The Advanced Resistive Exercise Device (ARED) now also provides a sophisticated, pneumatic system for the targeted strength training of individual muscle groups. Zange is witness to the success: "Shortly

"When I visited the Mir station back in 1994, it had already been in orbit for eight years. Compared with the United States Space Shuttle – which had to return to Earth after just 10 days – this was an unbelievably long time. From a scientific standpoint, however, a day in the Shuttle was more fruitful than on the Mir, because the ESA-built Spacelab in the cargo bay provided a much more powerful platform compared with Mir. But operating a station over the long term is a different challenge altogether. It requires robust logistics to provide the men and women in space with all the items they need to survive there – whether it is oxygen, drinking water, spare parts or even undergarments. It is miraculous that humankind, by virtue of its creative abilities, is able to create an artificial world, in which humans are able to survive and even work in a Universe that is hostile to life."

Ulf Merbold
Ulf Merbold completed a total of three space flights. In 1983, he became the first foreign national to fly into space with the United States Space Shuttle and, 11 years later, to the Russian space station as a German ESA astronaut on the EuroMir 94 mission.

Image: bettinaflitner.de Initiative Mein Erbe tut Gutes

"Together with my two Russian colleagues, Yuri Gidzenko and Sergei Avdeyev, I gathered a lot of experiences on the Mir that will stay with me for the rest of my life. I was deeply impressed and inspired by the extremely interesting work conducted on board, the breathtaking view of our planet and the excellent collaboration with both my colleagues in orbit, as well as the many colleagues at the Russian control centre, ESA colleagues and the European scientists. Although life on board the ISS is somewhat more comfortable today, and scientific research can without a doubt be carried out even more efficiently with the help of the state-of-the-art technologies available there, I have fond memories of this early period."

Thomas Reiter
A German ESA astronaut, he spent 179 days in space for the EuroMir 95 mission (3 September 1995 to 29 February 1996).

Image: ESA/P. Sebirot

after his return, Reinhold Ewald continued to be hunched over and it took him a while to regain his normal posture. When Alexander Gerst returned from the ISS in 2014, however, the change in his normal posture was hardly noticeable."

Salt under the skin

Günter Ruyters, former head of the Life Sciences section at DARA, explains: "In those days, the space station provided biomedicine with the only opportunity to examine the human body in microgravity for long periods of time. We were, for the first time, also able to monitor the effects of microgravity on bones and muscles – not just sense of balance and the cardiovascular system – over this longer time period. We made some astonishing findings in the process." A DLR experiment focusing on the effects of microgravity on water and sodium retention under controlled nutrient intake resulted in one of these scientific surprises. In 1997, Martina Heer from the DLR Institute of Aerospace Medicine headed to Star City shortly before the launch of Soyuz in order to devise a controlled meal plan for Reinhold Ewald during his mission. "I took everything with me: food, water and even a blender, which the Russians found quite amusing," Heer explains. "But they did everything to ensure I obtained the best-possible results for our experiments. In Moscow, I was even assigned a 'shopping assistant'."

The samples that Reinhold Ewald brought back to Earth after his mission were quite the sensation: His body appeared to have stored relatively more salt than water. Until then, it was assumed that salt-water retention occurred proportionately. These findings provided the initial impetus for salt research in the years that followed. The Salty Life studies at DLR were launched, which initially focused on salt retention in the body and then on the effect of salt on bone metabolism. Scientist Jens Titze from the University of Erlangen later discovered that the excess salt is stored under the skin. DLR scientists from the Institute of Aerospace Medicine continue to investigate the topic of salt; instead of examining retention, they now increasingly look at its impact on bone loss. From 2008 to 2013, the SOLO experiment on the ISS studied the bone metabolism of nine astronauts on a prescribed diet. The results showed that high salt intake can accelerate bone loss, and that it does not only affect astronauts, but the ageing population on Earth as well.

From an alarm on the Mir to ISS operations

A large proportion of the materials science experiments during MIR '97 were carried out using the TITUS furnace (Tubular furnace with Integrated Thermal analysis Under Space conditions), which had already been installed at the station for the EuroMir 95 mission. The furnace was developed by scientists from the DLR Microgravity User Support Center (MUSC) in Cologne and was built in cooperation with Czech industrial partners. With MIR '97, a programme was to be implemented for the first time to enable the scientists to control the furnace from the ground. However, this ambitious plan was not realised, partly because an alarm suddenly went off on board – a fire had broken out on Mir.

"I was working the early shift and as I reached the control room, I could see that something wasn't right," recalls Manfred Exner, who worked as a technical assistant in the MUSC at the time. During the night, one of the oxygen cartridges had misfired and, after burning for some minutes, enveloped the entire station in a thick cloud of smoke. The crew spent several hours wearing oxygen masks, not knowing whether the air conditioning system would be able to clean the sooty, toxic air quickly enough. When the air in the masks had been used up, the crew decided not to abandon the Mir and escape into the two Soyuz spacecraft. The crew cleaned the walls and filters of the affected modules for hours to remove all of the harmful soot and particles. After a few days and a lot of rescheduling of tasks and procedures, the station was in regular operational mode again.

"Communication with the station was a big problem back then," says Joachim Kehr. Located at the DLR German Space Operations Center (GSOC), he was in direct contact with the Russian operations team at the Flight Control Centre ZUP in Kaliningrad. "Back then, Mir had very little contact time – namely only when it flew over the Russian receiving stations, sometimes only about 10 minutes per orbit." Following the fire on board, GSOC in Oberpfaffenhofen made a small contribution to clarify the uncertain situation: Using an antenna on the roof of the building a brief voice contact could be established even before Mir could be tracked by the Russian receiving stations. Those approximately three to four minutes proved to be valuable time during which the teams on the ground could be reassured that the Mir crew was not in immediate danger.

Direct data connections between Moscow and Oberpfaffenhofen allowing remote access to the Mir station represented a break with tradition. In 1992 during the MIR '92 mission, all European scientists, operations personnel and managers had to be based at ZUP near Moscow. "The positive experience with direct data exchange between the control centres, together with previous experiences within the NASA Spacelab programme, were key preconditions for establishing the decentralised system – and payload operations concept for the ISS Columbus module," Kehr explains. In the 80s he had begun to establish the Columbus Control Center (Coll-CC) under ESA contract and was in a leading position for many years. Today, approximately 80 scientists and engineers look after European activities on the ISS from Oberpfaffenhofen. Scientific systems and experiments are operated in a decentralised way by user support centres from different locations across Europe.

In media reports, the Mir is often depicted as a 'problem station'. The fire during MIR '97 and the collision with the Progress cargo spacecraft that four months later poked a hole in the outer layer, severely damaging the station, in retrospective received more coverage than the scientific successes of the experiments and the newly developed scientific facilities. Mostly forgotten is that Mir represented a milestone in human space exploration and was the forerunner for the International Space Station. Beyond political differences, the Mir acted as a catalyst marking the beginning of international space research and cooperation across national borders without reservations. German-Russian ties that were established back then still bear fruit today in experiments and projects carried out on the ISS. At the ESA Council Meeting at Ministerial Level in 2016, the course was set for the future of humankind's outpost in space: Representatives from the United States, Russia and Europe tentatively committed the funds to extend ISS operations to at least 2024.

Modules of the Mir space station

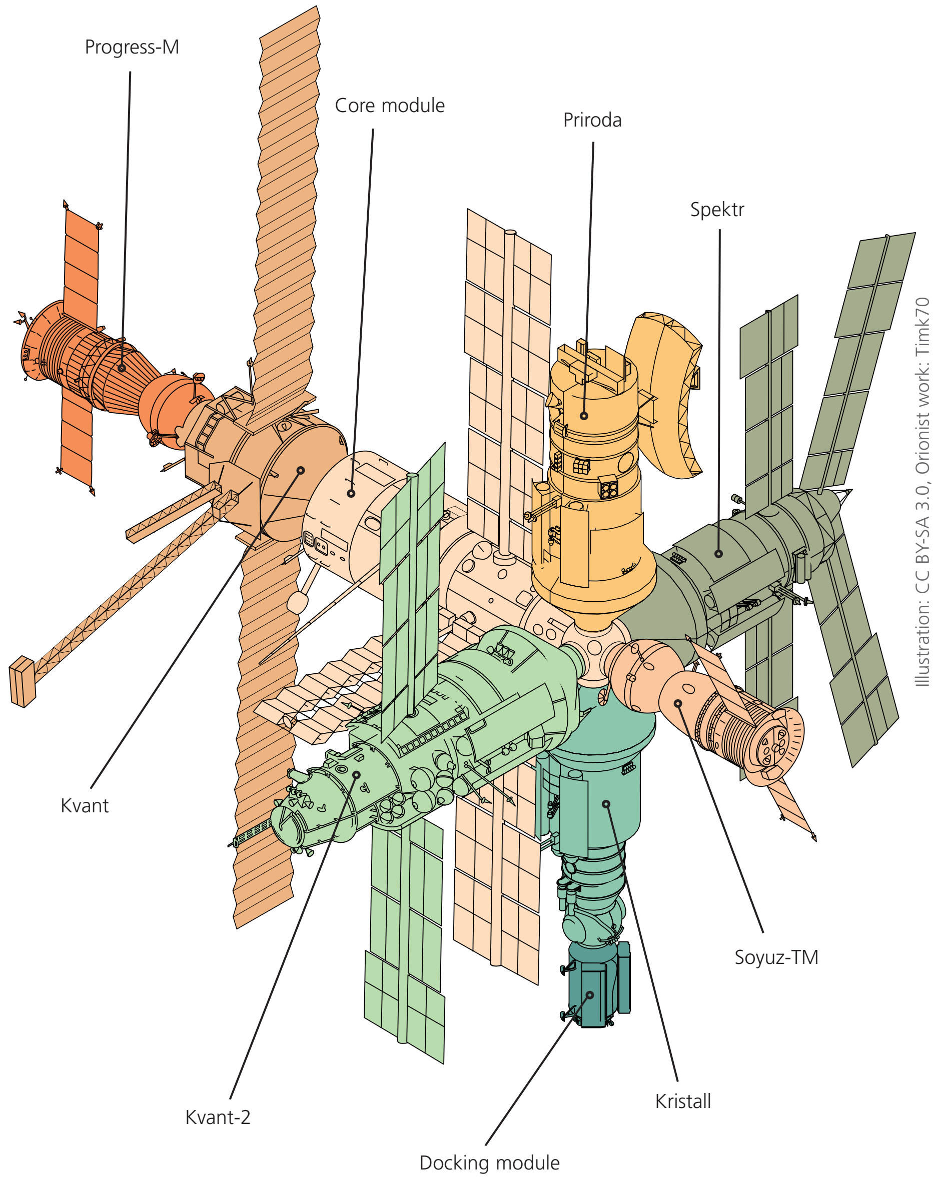
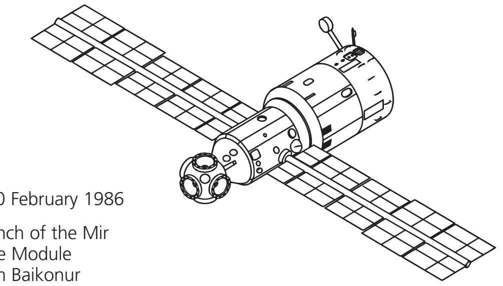
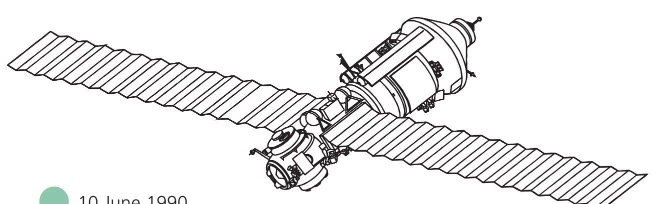
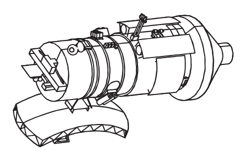
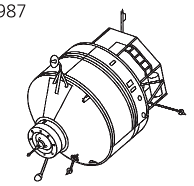
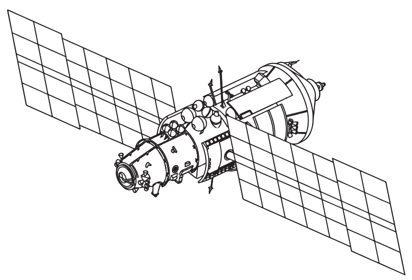
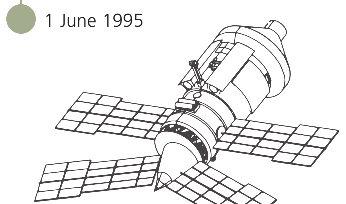


Illustration: CC BY-SA 3.0, Orionist work: Tim70

20 February 1986 – Launch of the Mir Core Module from Baikonur Cosmodrome

13 March 1986 – Launch of the first crew

12 April 1987 – Attachment of Kvant-1 module for astrophysical research

6 December 1989 – Station is expanded to include the Kvant-2 module

10 June 1990 – Attachment of technological docking module Kristall

1 June 1995 – Geophysical module Spektr is added

29 June 1995 – 'Atlantis' Space Shuttle docks with the Mir for the first time

26 April 1996 – 'Environment module' Priroda is attached. After 10 years, the station is complete.

23 February 1997 – Fire breaks out on the Mir on the night of 24 February and is extinguished

25 June 1997 – A Progress resupply vehicle collides with the station and tears a hole in the outer layer of the Spektr module

4 June 1998 – For the ninth and final time, a Space Shuttle docks with the Mir with STS-91 (Space Transportation System).

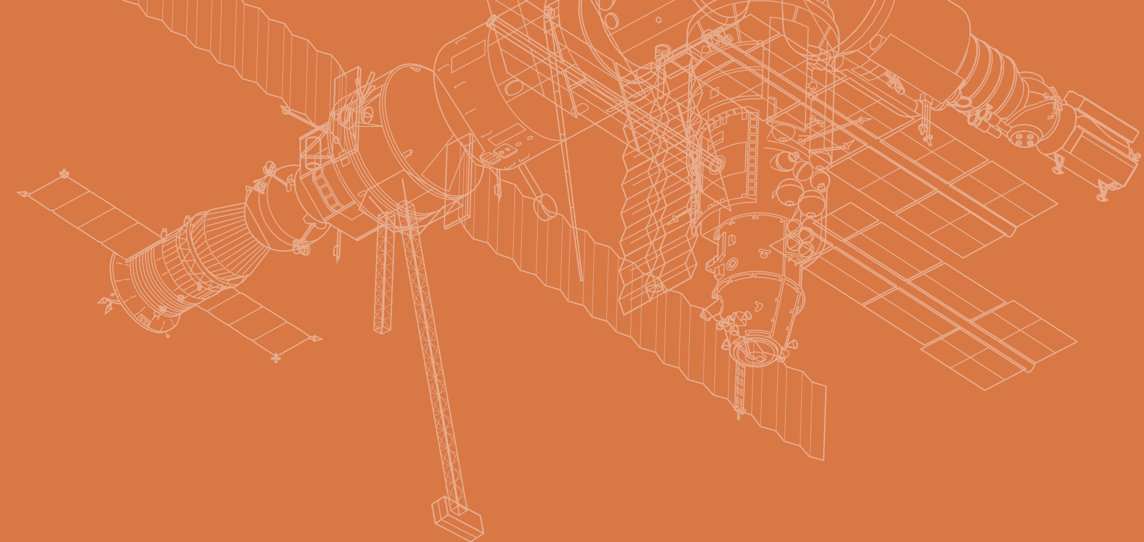
16 June 2000 – Cosmonauts Sergej Saljotin and Alexander Kalerij return to Earth as the final space station crew

16 November 2000 – Russian government decides to abandon Mir

23 March 2001 – Controlled re-entry of Mir; its remains sink into the South Pacific.

1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001

Illustrations: NASA



WHEN THERE WAS FAXING IN SPACE

Human spaceflight has changed greatly over the decades. Julia Heil talks about this with German astronaut Reinhold Ewald.

Reinhold Ewald ...

... is the ninth German astronaut. He flew to the Russian space station Mir on 10 February 1997. For the human-physiological experiments, he had to adhere to a strict nutrition plan, which involved the repeated consumption of broccoli. This inspired the author to bring him some florets as a gift.

Today, Ewald provides support to ESA astronauts who are preparing for their space flights... and he still enjoys eating broccoli, especially when his wife cooks it.

Mr Ewald, do you remember how it felt when you opened the hatch of the Soyuz capsule and 'entered' the Mir space station?

: I was surprised by how much space there was to move around in. Before this, we had been in the Soyuz capsule for two days during which the three of us had to share just 10 cubic metres. When the hatch opened, I felt disoriented. In the training sessions, we had become acquainted with the individual Mir modules, but this three-dimensional configuration – where one module moved upward, another down, one to the right and one to the left – was new to me. What was also fascinating was that after just two to three days, I 'floated' exactly into the right module and even with the correct orientation – every single time.

With the MIR '97 mission, digitalisation found its way into space. Crew instructions were no longer faxed to space page by page; you were given the procedures on a laptop.

: At the time, we tested automatic procedures that are now standard on the International Space Station. On my laptop, for example, there were clickable areas in the daily plan where we could enter our measured values. We managed very well with this software. Since then, two things have changed considerably. Firstly, internal digitalisation, meaning the widespread presence of computers for all purposes and applications. Secondly, the communication of data. We were unlucky that the Russian satellite link was disrupted at the time of the MIR '97 mission, and were completely reliant upon ground-based radio communications. This is a line-of-sight connection; our colleagues at the first Russian ground station in the West detected our signal right when the Mir rose over the horizon. We then had a maximum of 15 minutes of radio contact before flying over Kamchatka and out of radio range once again. During that time, we sent a data stream down to Earth that seems almost ridiculous today. Nowadays, volumes of data are sent to Earth at a transfer rate of 50 megabits or more per second. On the Mir, part of the voice-frequency range for radio communications had to be suppressed so that information could be sent to us at a transfer rate of 1000 bits by fax. At the time, my colleagues Ulf Merbold and Hans Schlegel were based in the GSOC in Oberpfaffenhofen and tried to obtain as much information on the console as possible during the call – but the Bundesliga results were always the first bit of information Ulf gave me ...

Image: Martin Lässig

Weightless for three seconds. Reinhold training for the MIR '97 mission in Star City, Russia.

Completely detached. Reinhold Ewald in Russian space station Mir in February 1997. The amateur photographer brought many film recordings and images back to Earth.

Many of the technologies that are used on the ISS today were tested on the Mir. Would the ISS have been possible without the Mir?

: The ISS was a first in many ways. In particular, there was – and still is – a need to overcome hurdles to cooperation between the East and West. At the time of the Mir station, however, important working foundations were laid. On the Mir, we tested a lot of what currently takes place on board the ISS, whether this be the automatic procedures already mentioned, the bilingualism in the documentation or the air-to-ground consultations with several control centres. An important development for the individual parties that were subsequently involved in the ISS was that they trusted the partners and valued their skills. At the beginning, there were, on the one hand, the US-Americans, Japanese and Europeans with the Space Shuttle and their innovative experimentation techniques and, on the other hand, the Russians with their long-standing operational experience. The period in which the US-Americans were on board the Mir as guests for the first time brought many eye-opening experiences with it. If these two space travel traditions had not come together in the form of a cooperative partnership, today's ISS partners would probably not have been able to realise a project as enormous as the ISS.

In your opinion, what role does the ISS play in the international framework of states?

: As I see it, it is a hopeful prospect for future international (space travel) projects. I believe that the ISS is the largest and, in my opinion, the only East-West cooperative project in this price range that is still functioning. And despite the political alienation of recent times, there are no major issues that threaten this collaboration or partnership. The operational teams in Houston, Munich, Moscow and in Tsukuba, Japan, continue to work effectively together, as do the astronauts and cosmonauts on the Space Station. At the moment, we once again have a Russian-French-US crew. And this is a model about which we can say: This is how people will fly to Mars and eventually return to the Moon.

What, in your opinion, are the greatest differences in space flight between 1997 and 2017?

: In the past, training for space flight was challenging in a different way. We, of course, had to contend more with the hardships of life in post-Soviet Russia and the somewhat 'bumpy' travel options, which is easier nowadays. Today's astronauts travel the world for two and a half years during their training. They do not stay in peaceful Star City – 40 kilometres from Moscow – with its beautifully coloured trees in autumn followed by a crisp winter. In winter they travel from Houston, Texas to the European Astronaut Center (EAC) in Cologne, and then to the warm, tropical climate of Tsukuba. The communication tasks of today's astronauts have also changed. When I see the social media programme carried out today by young colleagues as a matter of course in addition to the regular mission programme, this is a completely different challenge. I had to write documentation for experts. Nowadays, astronauts have an entirely different responsibility to explain what they do. The six current ESA astronauts are absolutely fantastic at this. All of them have recounted their missions in a fascinating way and in a language that is accessible to many people.

You assisted Alexander Gerst on his first mission. Will you be by his side once again when he flies to the ISS as commander?

: Gladly, yes. When I flew to space, I was there for 21 days, and 21 years later, I'll also gladly be there when astronauts set out for humankind's outpost in space. In this job, there are always moments in which practical space experience can be useful.

The two German cosmonauts for the MIR '97 mission: Reinhold Ewald (left) and his backup crewmember Hans Schlegel in Star City, near Moscow.

Reinhold Ewald during training at sea. The flare is used when the transport ship lands in a difficult area.

Image: DLR/Frank Eppler

The metal hydride powder is put into an experimental set-up. The scientists work in a so-called glovebox that shuts out oxygen.

ONE BLACK POWDER – MULTIPLE IDEAS

Versatile – Metal hydrides can be used as hydrogen storage systems and for thermal management

By Denise Nüssle

Metal hydrides are created when hydrogen is bonded to certain metals or alloys, such as magnesium or titanium-iron compounds. These shiny black metallic powders are extremely versatile – depending on pressure and temperature, they can store hydrogen gas and provide both heat and cold. A team of researchers at the DLR Institute of Engineering Thermodynamics in Stuttgart is investigating the technological applications of such properties – particularly in the field of sustainable mobility.

Storing hydrogen at low pressure and normal temperatures

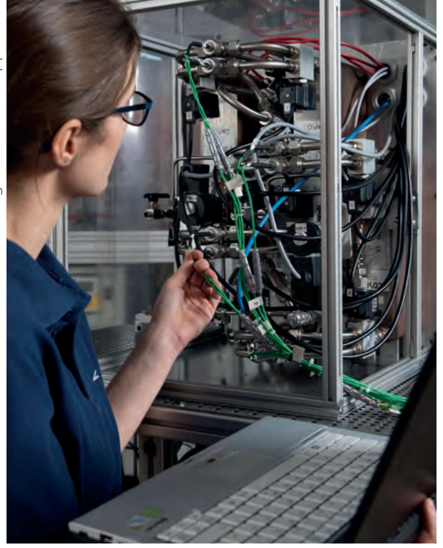
Metal hydrides have long been known to be effective storage medium for hydrogen gas. Their advantage – the powder absorbs hydrogen like a sponge. Metal hydrides can store more hydrogen at the same volume than the hydrogen would occupy in liquid form. For instance, one kilogram of metal hydride powder, which fills about one large cup, can absorb approximately 20 grams of hydrogen. "Hydrogen can be stored and transported very safely, compactly and efficiently using metal hydride storage systems. In contrast to conventional compressed gas cylinders, a relatively low storage pressure of approximately 30 bar and normal outside temperatures are sufficient," says Marc Linder, team leader at the Thermal Process Technology Department. "A few things that need to be considered, however, are the greater weight of such storage systems due to the massive metal filling, the heat release that occurs when the hydrogen is absorbed, and the dependency of material costs on the corresponding metal prices," Linder adds.

The potential of metal hydrides as storage systems lies predominantly in fuel cell vehicles, but also in stationary applications where fuel cells are used as part of a decentralised energy supply concept. Together with research and industry partners, DLR researchers have successfully implemented and tested such storage systems in several projects. For example, they developed an Auxiliary Power Unit (APU) that was used in a small van, and which in combination with a high-temperature fuel cell, generated additional power for the on-board system. "The topic has gained momentum in recent years – during the Energy Transition – due to the increasing use of renewable energies and, above all, the growing use of hydrogen as a source of energy for mobility, electricity and heat," says Antje Seitz, Head of the Thermal Process Technology Department, explaining the present research situation. The current research objective in this field is therefore to develop intelligent storage concepts in order to make optimum use of the available materials for the respective purpose.

Hot or cold at the touch of a button

Linder's team has identified the thermal management of vehicles as another interesting field of application. By conducting the heat flows and cold currents as optimally as possible, the energy consumption and emissions can be reduced, which ultimately also leads to increased passenger comfort. Another property of metal hydrides plays an important role here: The

Image: DLR/Frank Eppler



Inga Bürger configures the HyCo module for further measurements. The process engineer is aiming to make waste heat usable for more efficient climate control.

Image: DLR/Frank Eppler

Auxiliary power unit (APU) for small-scale transporters in the laboratory test

The small tubes inside the cold start module contain the metal hydride. The heat transfer fluid flows around them.

chemical reaction between the metal and the hydrogen is reversible (see infographic). The direction of the reaction depends on the respective pressure and temperature conditions. If pressure is applied to the base products – metal and hydrogen – these react to form a metal hydride. Heat is released in the process. If more heat is applied to the metal hydride, the opposite reaction takes place. The metal hydride compound breaks down again, the hydrogen is released from the metal, and the surroundings cool down. "By controlling the pressure and temperature in our storage systems, we can generate heat or cold in a targeted way – at the touch of a button," says Inga Bürger, project manager in Linder's group.

Farewell cold – Releasing heat selectively

For example, metal hydrides could be used for preheating drive systems. A cold start causes strain on a fuel cell system or a traditional combustion engine. In the latter case, the engine oil is very viscous initially, meaning the bearing and greasing points are not sufficiently supplied with oil. This increases resistance in the engine and increases fuel consumption, along with exhaust emissions, until the normal operating temperature is reached. In a metal hydride system, large quantities of heat can be released very quickly – even at low temperatures down to -20 degrees Celsius – to preheat the engine oil or fuel cell system. This technology is particularly interesting for fuel cell vehicles for another reason: Preheating does not consume any hydrogen and therefore does not reduce the vehicle's range, which is limited by the volume of the hydrogen tank. As soon as the fuel cell system has reached its operating temperature, the reaction in the metal hydride system takes place in the other direction. The stored hydrogen is then released again and can be used as operating power.

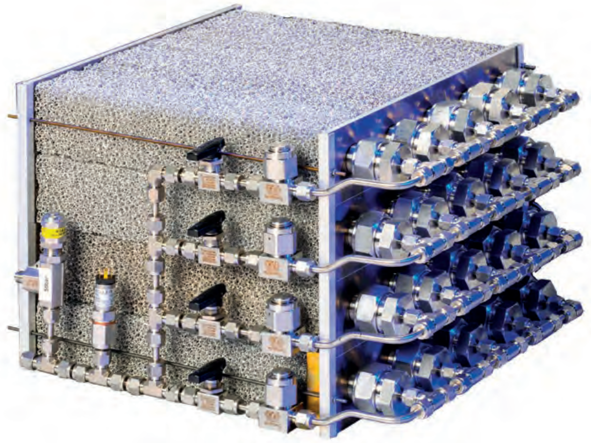
Based on this principle, the DLR researchers have built a special cold-start module. It is being used in a cargo bicycle with a fuel cell drive, developed by both the DLR Institute of Vehicle Concepts and the Institute of Engineering Thermodynamics with the support of DLR Technology Marketing. An easily replaceable cartridge holds the hydrogen that is required as the energy source for the drive. In contrast to battery-powered e-bikes, a greater range can be achieved with this fuel cell bicycle, even on slopes and carrying heavy loads. This would considerably expand the possible uses of cargo bikes. The cold start module ensures reliable operation at sub-zero temperatures and can be integrated into the drivetrain, if necessary. Without the metal hydride module, an additional electric heater would otherwise have to be used, which would consume energy and therefore negatively impact the range. "The metal hydride reactor, as we call it, is cylindrical – 25 centimetres long with a diameter of three centimetres. It was created using 3D printing and contains several small tubes filled with metal hydride. A water/glycol mixture flows around the exterior and functions as a carrier fluid to transport the heat to the fuel cell system," says Bürger, describing the structure of the cold start module.

Keeping cool – Use as air conditioning system

To stay cool when it gets hot, air conditioning systems are usually included in today's vehicles. However, they require power that must first be generated and reduces the range of the vehicle – by approximately 15 percent in the case of combustion engines, and by up to 50 percent in the case of electric drives, depending on the outside temperature. "We see a lot of potential here for the use of systems based on metal hydrides. These have the added advantage that we can do away with traditional coolants that are flammable and contribute to the greenhouse effect," Bürger adds.

Open system for fuel cell vehicles

As part of DLR's 'Next Generation Car' (NGC) meta project, the team is currently developing special metal hydride reactors to be used as air conditioning auxiliary power units (AC-APU) to provide air conditioning for a future-oriented concept vehicle with a fuel cell drive. This auxiliary power unit consists of two reactors, each the size of a small shoebox. Stainless steel plates are layered on top of one another in the interior and are filled alternately with metal hydride and a heat carrier fluid. "Our air conditioning system is an open system," explains Linder. "We are, so to speak, cheating our way into the existing hydrogen infrastructure of the fuel cell drive, but are not consuming any hydrogen." Alternately, one reactor cools the air conditioning system, and the other generates heat that is dissipated into the surroundings. To start the reaction process, the DLR engineers use the existing pressure difference between the several hundred bar of the hydrogen tank and the five bar needed for the fuel cell. On a laboratory scale, the scientists have already generated approximately 2.5 kilowatts of cooling capacity, which provides continuous air conditioning for a car's interior or the driver's cabin of a bus, for example. As a next step, together with colleagues from the Institute of Vehicle Concepts, they want to use a test bench to couple the system with a fuel cell and take further measurements.



Metal hydride storage unit for a decentralised energy supply

"One challenge, as the process continues, lies in improving the design of the stainless steel plates and make them more compact. We also want to more closely investigate the expansion of the metal hydride powder during the reaction to determine how much powder we can use, how hard the plates need to be and what spacing is most suitable," says Linder.

Closed systems offer independence from drive train

Linder's team also developed an idea for battery-powered electric buses. When the heating in an electric vehicle is run with power from the battery, this has a negative impact on its range. Only around 20 or 30 percent remains for the drive. This is why most of these buses have an additional biodiesel burner that generates thermal energy for heating. In summer, metal hydride reactors could transform this energy into a cooling capacity for the air conditioning system. "In this case, we are talking about a closed system; there is no hydrogen infrastructure that we connect to and no pressure difference that we can use," Bürger says. "We therefore need four reactors: Two to provide cooling, and the other two as buffer storage."

Last but not least, commercial vehicles with a traditional combustion engine could also benefit from metal hydride solutions. If, for example, the driver's cabin could be air conditioned more efficiently through the utilisation of waste heat, a few extra gains in efficiency would be made for conventional systems. For this application, DLR scientists have completed the HyCo module in the form of a black box and tested it in the laboratory. It contains all necessary components – from the metal hydride reactors, to control units for valve switches right up to temperature sensors. The module is controlled automatically by the vehicle's electronics, meaning that the user does not need to take an active part here.

"We have plenty of ideas as to how we can exploit the potential of metal hydrides, particularly for mobility. The automotive industry has already shown a keen interest. As far as this technology's degree of maturity is concerned, we have completed the laboratory stage and the principle functional demonstration. As a next step, through various projects, we want to show that metal hydride systems can prove their worth in application environments," Seitz summarises.

Reversible reaction of metal hydrides

Which processes occur when?
Shown here using the cold start module example:

FORWARD REACTION

Me + H_2 → **MeH + Heat**

5 bar
-20 degrees Celsius

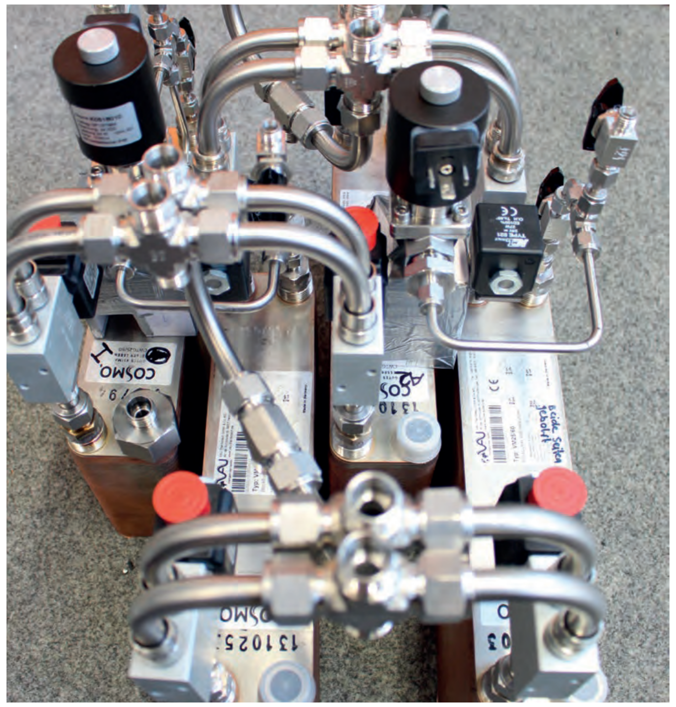
40 – 50 degrees Celsius
for preheating the fuel
cell system

REVERSE REACTION

MeH + Heat → **Me + H_2**

60 degrees Celsius
from operating
fuel cell system

1.5 bar
60 degrees Celsius

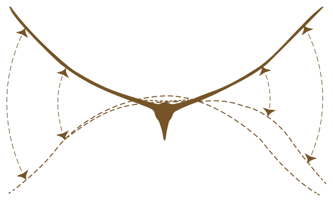


Climate control module with four metal hydride reactors. With this closed system, cold air can be generated in an electric bus, for example.

Under the sea

Metal hydride storage systems are already being used underwater. To be precise, in the 212A submarines of the German and Italian navies. They are the world's first air-independent diving submarines with a fuel cell drive. The required hydrogen comes from metal hydride storage systems. In contrast to pressure tanks with compressors, they provide the hydrogen noiselessly. Their greater weight is not so crucial in this case.

OF BIRDS AND AIRCRAFT



How biological examples are optimising technology in aviation

By Jana Hoidis

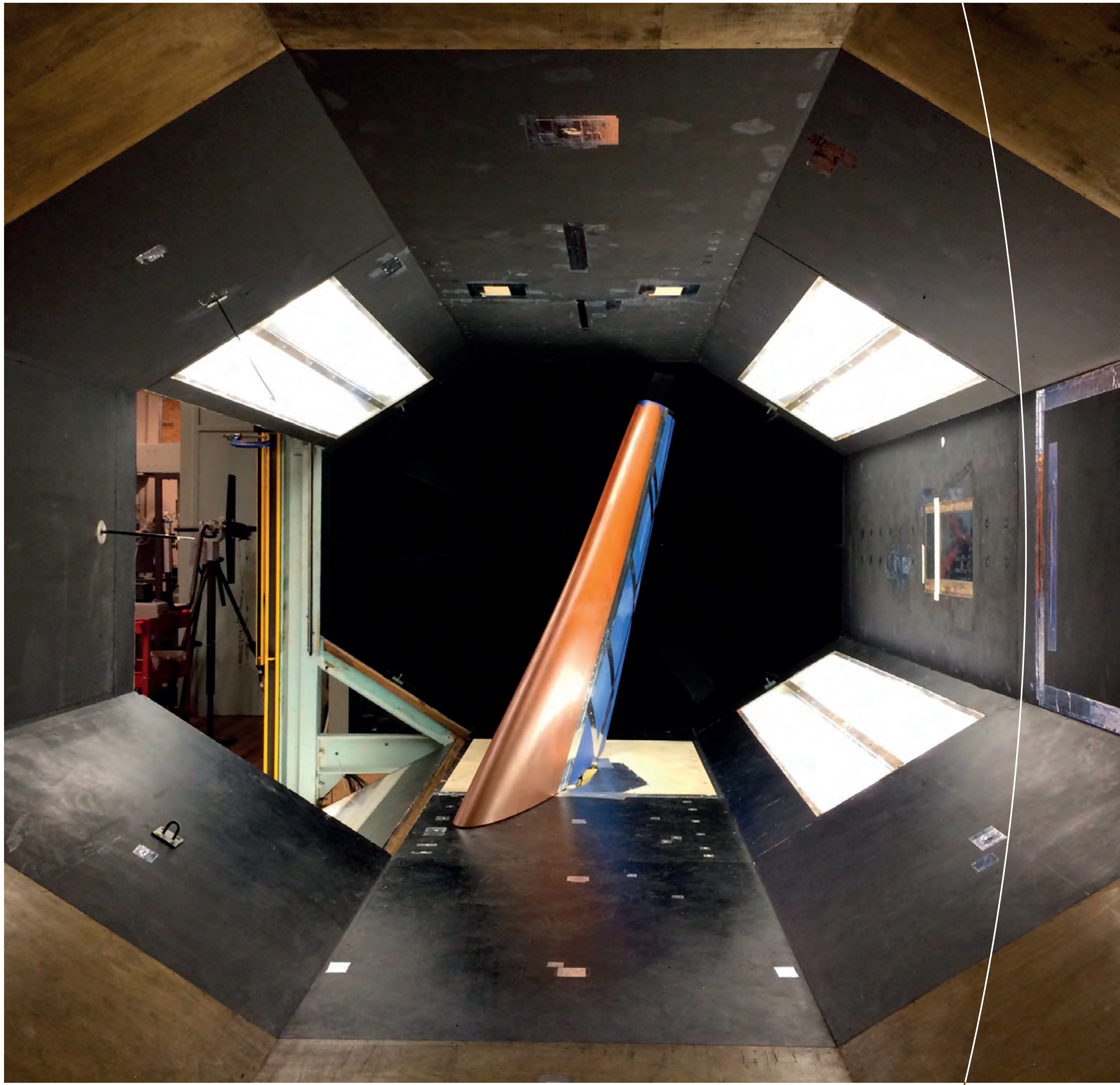
The human desire to fly was the original inspiration for bionics. Birds were the first models. As early as the sixteenth century, Leonardo Da Vinci designed flying machines that worked according to the principle of bird flight. In the nineteenth century, Otto Lilienthal described wing camber as a prerequisite for lift in his work 'Birdflight as the Basis of Aviation' and was the first of his time to accomplish short human flights. However, copying nature one to one is not possible. Nature can only suggest ideas and principles from which new technological developments can be generated. It has been a long journey to the aircraft we are familiar with today. Even today, scientists and engineers are working on making aircraft safer than they already are and increasingly efficient. The models behind these continuous developments are sometimes again taken from biology.

Helicopter rotor blade with back-flow flap

At first glance, a helicopter and a bird are nothing alike and – in contrast to aeroplanes – their construction generally is not modelled on birds. Nevertheless, the landing approach of birds has provided engineers with the inspiration for innovative helicopter rotor blades. Upon landing, the covering feathers on a bird's wings are deployed at a very high angle. This prevents stalling, and consequently, loss of lift. If this were not the case, the bird would tumble and, in the worst-case scenario, collide with the ground.

Particularly arduous flight conditions for helicopters, such as narrow curves, turning manoeuvres or rapid forward flight, can induce a dynamic stall on the retreating rotor blade. This results in high structural loads on the control system and rotor head. Inspired by the landing approach of birds, a flap that is integrated into the rotor blade and can be arranged like a bird's feathers should influence the flow separation in such a way that the loads are reduced. Such technology has already been tested on gliders, but not on helicopters. Here, this concept is new scientific territory.

An interdisciplinary research group was formed at DLR to work on this, based on a patent granted to the Institute of Flight Systems. The Institute of Composite Structures and Adaptive Systems was responsible for developing the structure, which was then to be investigated in a wind tunnel test in collaboration with the Institute of Aerodynamics and Flow Technology. "What proved particularly tricky was designing the delicate flap and its opening mechanism in such a robust and reliable way that both could withstand the loads in the wind tunnel without suffering damage," says engineer Steffen Opitz.



System test on a winglet with variable shape wing leading edge in the wind tunnel at the University of Bristol: A bionic, superelastic mechanism inside the winglet enables a deformation of two degrees. This potentially reduces the air resistance and improves the flight behaviour of the aircraft.

BIONICS

Bionics unites the fields of biology and technology. Its purpose is the technical implementation of constructions, procedures and development methods derived from biological systems. In the course of evolution, animals and plants have adapted to changing environmental conditions and optimised their features through natural selection. Whether in water, on land or in the air, living organisms are perfectly adapted to their habitat. Nature has given them the ability to ensure their survival – finding a solution to almost every problem. Humans are cleverly making use of this – engineers are developing technical innovations whose processes, materials, structures and functions have been inspired by nature.

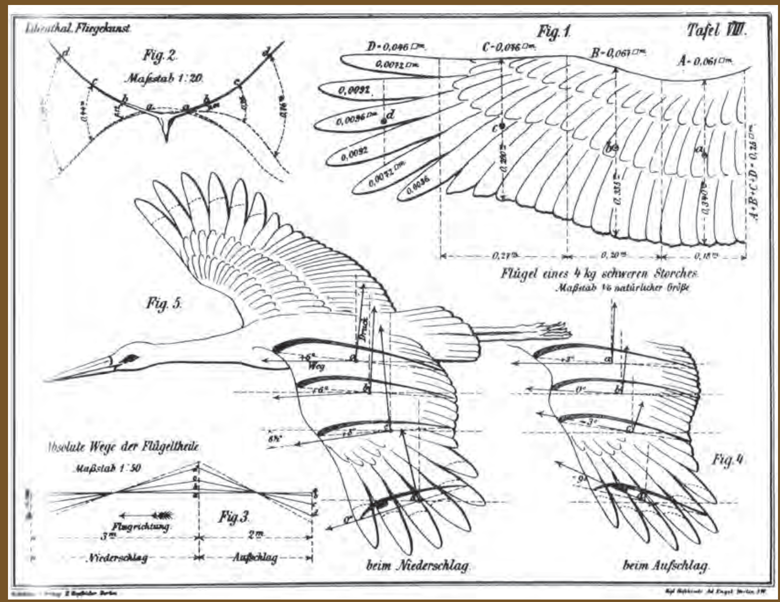


Image: Otto Lilienthal, Birdflight as the Basis of Aviation, Berlin 1889 – Michael

Lilienthal demonstrated the properties of a stork's wing and illustrated the bending torsion. The stork ultimately inspired him to build his flying machines.

Image: Pixabay

Upon landing, the covering feathers on a bird's wings are deployed at a very high angle to prevent stall. A back-flow flap on the rotor blade of a helicopter reduces the loads for its control system based on this example.

Image: Pixabay

Image: Pixabay

Winglets are modelled on the wing motions of large birds and improve the aerodynamic properties of aircraft

The flow simulation led to a new rotor blade design with an integrated flap. Open questions – such as how large the flap had to be and what position it had to be incorporated at – were resolved using computational fluid dynamics calculations performed at the Institute of Aerodynamics and Flow Technology. The most suitable material for the blade and flap appeared to be glass fibre reinforced polymer. The flap is attached using a rubber-like elastomer with additional glass fibre reinforcement. "The flexure joint is the key to making the flap durable, since neither friction nor wear occur in the joint," says Opitz, explaining the advantages.

For test purposes, the wind tunnel models of the rotor blades are fitted with numerous sensors to, for example, measure the loads that occur. The flap itself is integrated into a thin glass fibre cover and is simply pulled over an existing rotor blade wind tunnel model like a glove. "For subsequent applications, this solution also offers the option of retrofitting conventional rotor blades. This would make the practical introduction of the technology easier and more cost-effective," Opitz adds.

The flap was tested both as a passive and an active system. In the passive version, the flap opens by means of forces generated by the airflow alone. The active system contains a number of other components. Permanent magnets are integrated into the structure of both the flap and the rotor blade underneath the flap. A connected electromagnet is used to move the magnets in the blade; the flap can be opened through interaction with the magnets in the flap. Even in the active mode, the actuation system is only used as a trigger. The complete deployment of the flap is caused by the flow.

The new rotor blade has already been put through its paces in the one-metre wind tunnel at the DLR site in Göttingen. At an airflow velocity of 50 metres per second, the rotor blade angle of attack was changed cyclically to simulate the flow conditions around the rotor blade that occur during flight. The direction of flow and the speed were visualised using a high-precision imaging measurement method (PIV: Particle Image Velocimetry). In this method, an oil particle mist is sprayed into the wind tunnel and this is then illuminated with a laser beam pattern. The particles in the mist are imaged at two short intervals, enabling the direction and speed of the flow to be determined. "From an aerodynamic point of view, it was particularly exciting to investigate two different flow conditions – one with and one without the back-flow flap. The flap, which effects a controlled disruption of the airflow, has a positive effect on the rotor blade aerodynamics," says Anthony Gardner from the DLR Institute of Aerodynamics and Flow Technology, explaining the advantages of the back-flow flap.

More than 40 pressure sensors also provided information on the loads to which the rotor blade was subjected. "We were really pleased with the results of this measurement," Opitz says. "The flap reduced the loads by up to 30 percent." This means that longer maintenance intervals are possible and that the helicopter rotor head can be constructed using a more lightweight design.

Winglets with variable shape

In contrast to helicopters, the first-ever aeroplanes did take their design inspiration from birds. The tips of the wings on modern-day passenger aircraft, known as winglets, are similarly based on features from our feathered friends. Large birds, such as buzzards, condors and eagles, use their long flight feathers to improve their aerodynamic properties in slow flight. They spread these upward in a fan-shaped and staggered fashion. Instead of one large vortex, a number of smaller vortices are thus created, which consume less overall energy. The idea for winglets was patented back in 1897 by Frederick W. Lanchester. Since the 1980s, they have been installed on passenger aircraft in their current form and reduce fuel consumption by five to six percent. At DLR, research is currently underway to further improve the aeroelastic properties of the winglets. "Changing their shape, referred to as 'morphing', is intended to optimise the aerodynamics and structural behaviour of the wing, thereby enhancing flight performance," says Srinivas Vasista from the Adaptronics Department, describing the idea behind the new development. "For an Embraer regional aircraft, we have developed a wing tip that can actively morph by two degrees. Such a winglet is the first of its kind in the world, making the project particularly exciting for us." This variable-shape structure brings the wing tip even closer to the functionality of an eagle's wings.

In general, nature prefers integrated, rather than assembled, construction. What does this mean? In the case of an assembled construction, each individual element has a primary function. A screwed connection between Part A and Part B comprises a screw, a nut and, if necessary, a washer and a circlip or retainer. In nature, individual elements are usually multifunctional and merge together. Furthermore, nature prefers structures that are balanced in flexibility and stiffness. Load-bearing, rigid structures, such as tree trunks, bones and teeth, are only used where absolutely necessary. Flexible structures, such as bees' wings, tree branches and the bones in birds' wings, are predominant in living organisms.

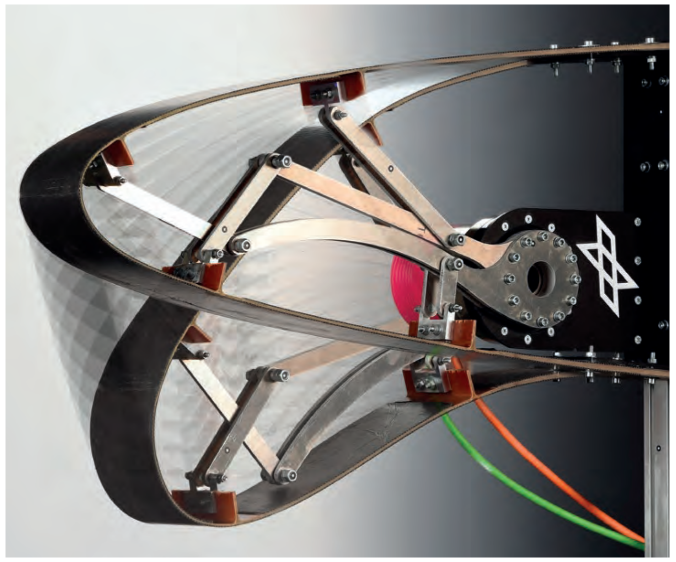
"In the case of morphing structures, the challenge lies in optimally distributing flexibility and stiffness. Adapting the material and geometry to control the shape precisely has to be consistent with a lightweight design and system integration," says Vasista, describing the task. The key components of the new wing tip are an outer skin and a shape- changing compliant mechanism. The geometry of the compliant mechanism was optimised and designed using an algorithm. There are numerous examples of the mechanism concept in nature; a particularly illustrative example is the beating of bees' wings. Their wings are connected to their bodies by means of a flexure joint. The wings move up and down by shifting energy in the whole of the bee's elastic body.

The validation of the completed winglet took place in a wind tunnel at the University of Bristol. There, the previously calculated structural properties were tested at low wind speeds, far below the speed of sound. "In wind tunnels, typically the airflow around the profiles is examined. What was special in this case was that we examined an entire system, consisting of the trailing edge and the flexible skin of the leading edge along with the superelastic mechanism in the interior," says Vasista, describing the uniqueness of the experiment. In the seven-by-five-foot wind tunnel, the winglet was placed on a balance and then connected to several pressure-, displacement- and strain-measurement sensors. The balance displayed the forces acting on the structure under airflow load. "We were pleased that the measured values were consistent with those previously simulated," Vasista summarises. "The structure changes shape under airflow loads, just as we calculated beforehand." The superelastic mechanism therefore withstands the necessary forces and is stable. "The results of these experiments are extremely important because they can also be applied to other shape-changing structures, such as the leading and trailing edges of wings, and be used to further develop and improve compliant mechanisms."

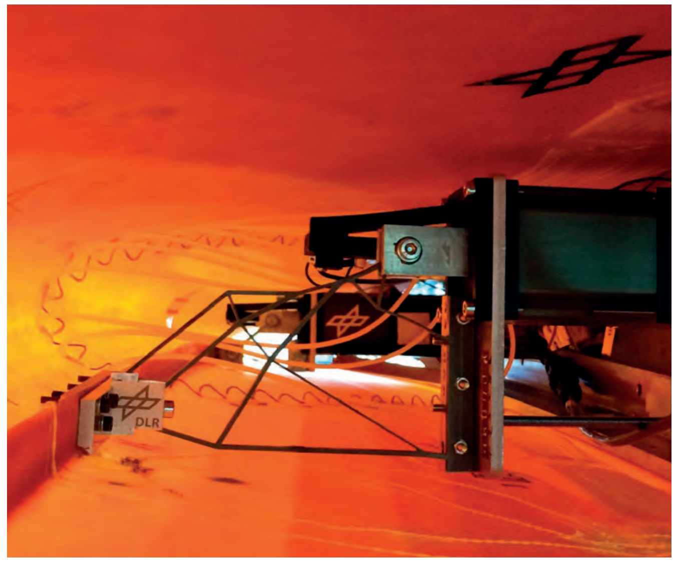
Closer to nature

The possibilities for optimising technology using bionic principles are just as limitless as nature's biodiversity. Bionic algorithms are already used today to calculate the optimal load distribution in structures. Nature uses these algorithms to grow 3D structures, such as trees, for example. In the production process, structures can be created layer by layer using additive manufacturing by means of a 3D printer. In this way, models can be calculated and created to closely match the original in a way that would not be possible using traditional manufacturing technologies. The transition between fixed and flexible structures can therefore be freely designed. An almost limitless variety of shapes is possible using 3D printing. For engineers, this also makes it easier to transfer a newly decoded principle from nature to an aircraft structure. This unlimited freedom in terms of design and construction may hold one or two surprises in the future with innovative components that help make flying even more efficient and environmentally friendly.

Jana Hoidis works at the DLR Institute of Composite Structures and Adaptive Systems, where she is responsible for public relations.

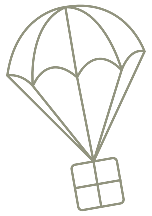


Conventional mechanics for lowering a wing leading edge. The internal mechanism consists of numerous rigid individual parts connected to each other with nuts and screws.



Bionics inside the winglet: The structure is deformed entirely by the force and displacement through the superelastic compliant mechanism.

OUT OF THE BLUE



Simulation tool predicts the drop behaviour of parachute loads

By Anna Boos

Airdrop test – so-called gravity airdrops involve the load first exiting the Transall cargo hold and pulling the parachute package out along with it.
Image: WTD 61

Military transport aircraft are required to complete tasks that exceed those of civilian airliners. The giants of the skies are used to deliver relief goods to disaster areas or to transport equipment and people to remote locations. To do so, they must travel long distances or take off and land on unpaved runways. A particular challenge is dropping relief supplies off the rear ramp using parachute systems. The extremely heavy cargo must be landed with as much accuracy as possible and remain undamaged – despite extreme air turbulence behind the aircraft.

Within the DLR project MiTraPor II (Mission-oriented Evaluation of Future Military Transport Aircraft) simulation and assessment tools were developed to be used as a virtual test bed for the evaluation and optimisation of new technologies and procedures applied to airdrop missions. The PARALAB (Parachute and Airdrop Evaluation Laboratory) simulation tool was developed for this purpose at the Institute of Flight Systems in Braunschweig. "This tool enables the simulation and optimisation of new airdrop configurations and scenarios before being tested in an actual test flight. This saves time, effort and money in the introduction and approval of new cargo airdrop procedures," explains project leader Thomas Jann. Sitting at the simulation computer, he enters numerous parameters into the dialog box: type of aircraft, altitude and speed, dimensions and weight of the cargo, wind speed and direction, as well as the type of parachute used for the airdrop process – they all play a role in calculating the trajectory. With the push of a button, Jann sees the result of the calculations on the screen: A military transporter flies just a few hundred metres above the ground, the rear flap opens, a pallet slides down the loading ramp. In a matter of seconds, several parachutes open and decelerate the multi-ton cargo so that it lands undamaged and with pinpoint accuracy.

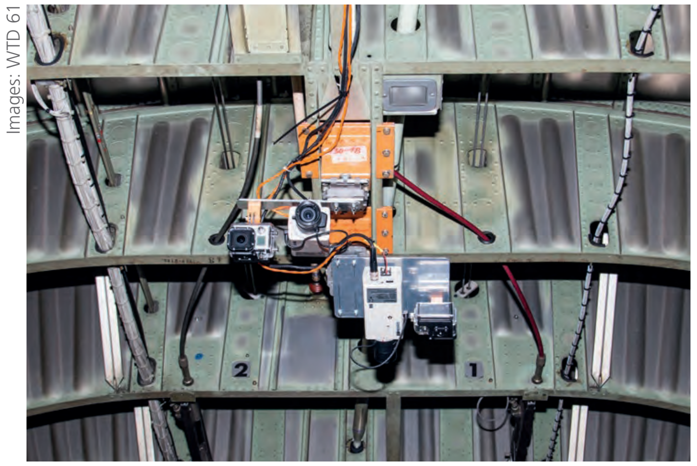
Load dispatch on film

It looks very good in the simulation. But how close is the theoretical calculation of the load drop scenario to reality? "To check how accurate and reliable the predictions of our simulation actually are, we need measurement data from real flight tests," says Jann. The project intended to show how accurately the simulation tool works is called PARAVAL (PARALAB Validation). Hence, DLR carried out two comprehensive flight tests in a Transall C-160 in tandem with the Bundeswehr Technical Center for Aircraft and Aeronautical Equipment (WTD 61). The campaigns – each two days long – took place at the end of 2016 and in early 2017 at the parachute drop zone close to Manching. "The drop tests carried out in PARAVAL are some of the best recorded and documented airdrops in the world," says Jann.

The researchers wanted to have a complete overview, so two cameras followed the load dispatch from the cargo hold. Two additional cameras attached to the up-to-two-ton load filmed the free fall. One of the world's most modern cinetheodolite stations, belonging to WTD 61, was also used for visual trajectory measurements. The distance measurement device has been specially developed to collect trajectory data of fast-moving targets on the horizon. It tracks the object with two or more cameras. Cinetheodolites provide angular measurements of the line of sight to the object. "With this highly accurate measurement process, in the flight tests we not only measured the trajectory of the dropped payload, but also documented the behaviour of the parachute systems. In this way, we can also precisely check whether they deploy as in the simulation."

But this is not all. The DLR researchers attached another small measurement box – the miniature Flight Data Acquisition System (mFDAS) – to each load. Also developed at the Institute of Flight Systems, these small measurement boxes record GPS data, accelerations and rotational rates, in all three axes, as well as components of the magnetic field vector and the barometric altitude (static pressure).

Images: WTD 61



The researchers also installed cameras in the cargo hold of the transport aircraft, in order to document the load as it exited the aircraft.

Three main parachutes ensure that the multi-ton load gently descends to the ground without being damaged

Thirteen seconds of gentle gliding

Two different procedures, in which loads of two different weights (one and two tons) were dropped, were measured with extreme accuracy in the flight tests. In the first flight test campaign, the loads were dispatched out of the Transall in a so-called gravity airdrop. To achieve this, the aircraft was put into a slight pitch attitude. The holding clamps for the load in the cargo hold were then released, and gravity did the rest, dragging the load downwards and out of the aircraft.

In the second campaign, the test pilots carried out one of the most complex drop procedures, the so-called MAINS method: the giant Transall sped along at 130 knots (approximately 240 kilometres per hour) just 150 metres above the ground and opened its loading ramp. The parachute package attached to the load was catapulted out of the cargo opening first, pulling the load out of the aircraft with it. A total of seven parachutes are used for the controlled drop. A small pilot chute opens first, unfolding the three main parachutes. After a short, sharp jolt, the load no longer falls like a stone but descends gently towards the ground. To counter the pendulum motion, another pilot chute unfolds, opening two auxiliary chutes to the sides that are intended to stabilise the vertical drop – all in just 13 seconds.

The DLR researchers will use the measurement data collected to check the PARALAB simulation tool and further develop it. Back in Braunschweig, the processing of the measurement data has begun for Jann. The recordings from the various instruments must be compared and synchronised. Next, the aeronautical engineer enters the output data from the flight test into the PARALAB simulation tool. Using these parameters, PARALAB calculates the corresponding trajectory of the dropped load – and ideally arrives at a prediction that matches the result of the actual drops. However, it will still take a few weeks for all the data from the flight tests to be processed and compared with the simulation results from PARALAB.

Flexible simulation tool

"One of the strengths of our simulation tool is that it can be used like a construction kit according to the modular principle," emphasises Jann. Any configuration – any variation of the various parameters – can be simulated using the tool. This means that PARALAB is capable of predicting the trajectory and behaviour of actual, complex parachute load configurations, such as multi-layered chute systems and parachute clusters, including their harness systems.

But the tool can be used for more than just the drop behaviour of loads from a transport aircraft – it can simulate many other configurations. Jann explains: "With the appropriate parameters, we can for example also calculate how an ultralight aircraft behaves when the emergency parachute is activated."

Anna Boos is responsible for public relations at the DLR Institute of Flight Systems.

Reality meets simulation: In order to test how precisely and reliably the simulation tool PARALAB can predict how the load and its parachutes will drop, DLR researchers compare the simulation results with real test flight data. Illustrated here is the simulated drop process from a low altitude. Once the collected data has been evaluated, the model parameters are adjusted so that the simulated and measured trajectories of the load and parachutes match as closely as possible.

Images: Simulation: PARALAB

Image: Deutscher Verkehrssicherheitsrat e.V. (German Road Safety Council), Bonn.

Frustration at the wheel is dangerous. DLR researchers are working on assistance systems that recognise signs of frustration in drivers and, if necessary, provide information to help them regain control. Saying that the traffic situation will improve after the next set of traffic lights, for example, might calm the driver down.

FRUSTRATION BEHIND THE STEERING WHEEL

Human factors and the mobility of tomorrow

By Meike Jipp

It is rush hour and you are on your way to an important meeting. But there are new roadworks and all of the traffic lights seem to switch to red just as you are about to pass the junction. Then, you find yourself stuck behind a 'Sunday driver' who, driving at a speed well below the limit, is blocking the fast lane. Nervously, you check the time. You start tailgating. You accelerate, change to the right lane, and then make a turn back to the left. Done! It went smoothly this time.

Unfortunately, this kind of situation occurs all too often – every day. Frustrated drivers have a tendency to take safety risks. Wouldn't it be great if there was an assistance system in the vehicle that could warn the driver about his or her state of frustration at such times, or in the event of congestion even suggest an alternative, less stressful route using public transport? Such a scenario is still just wishful thinking – for now. A team of psychologists, engineers, cognitive scientists and physicists at the DLR Institute of Transportation Systems is working on turning this vision into reality. Their field of expertise: human factors.

Danger: frustrated drivers ahead!

"Frustrated drivers take more risks on the road, and can cause safety-critical situations through their behaviour," says cognitive scientist Klas Ihme. "Frustration is triggered when the driver's expected choice of action to reach his or her goal is interrupted, for example by a string of red traffic lights." The connection became particularly apparent in a driving study carried out as part of the UR:BAN project in the coupled driving simulator at the DLR Institute of Transportation Systems in Braunschweig. UR:BAN stands for 'Urbaner Raum: Benutzergerechte Assistenzsysteme und Netzmanagement' (Urban space: user-friendly assistance systems and network management). For the study, three people traversed an inner-city traffic scenario – one after the other. The first driver used so-called traffic light assistance. This tells the driver when traffic lights are changing and how quickly he or she needs to drive – while observing the speed limit – in order to make it through the crossing when the traffic lights are green, or start to slow down long before reaching the stop line. The latter has the advantage that the driver arrives at the stop line right as the light switches from red to green, and it is possible to drive through without stopping. The second driver did not have this assistance nor was he informed about this additional functionality. He was surprised at the other driver's way of driving. It did not appear to be forward thinking and he became increasingly frustrated. He ended up tailgating the front vehicle – behaviour typical of people who feel they are being prevented from reaching their destination. They very often create risky situations. One of the drivers even caused a collision with the preceding vehicle during the driving simulation. For the cognitive scientist, this is clear evidence that frustrated drivers demonstrate more dangerous driving styles. An assistance system in the vehicle able to recognise when the driver becomes frustrated and create a relaxed atmosphere can lessen the stress of the situation and prevent safety-critical incidents.

Looking at tell-tale signs

But how can an assistance system determine whether the driver is frustrated or not? As part of the Critical Systems Engineering (CSE) project, DLR experts in Human Factors at the Institute of Transportation Systems investigated how an assistance system could determine whether a driver is frustrated – before the behaviour poses a safety hazard. The researchers used the Institute's Virtual Reality Laboratory to do so. Thirty volunteers were given the task of delivering packages to important customers within a specific period of time – driving through a simulated city in the Virtual Laboratory. To increase the pressure, they were told that they would be awarded two euros for each package they delivered. That was all the test participants knew. In the background, the researchers ran a 'frustration program' – traffic lights constantly turned red, pedestrians traversed the zebra crossing very slowly, vehicles were double parked, and the oncoming traffic left no gaps for overtaking. Unfortunately, it was impossible to deliver the packages in the specified time, and slowly but surely the drivers became aware of this.

While the drivers were struggling with the obstacles, they were being observed by the scientists via cameras. "We were particularly interested in the facial muscles of the test participants," Ihme explains. "Because these muscles express emotions involuntarily." The results are very clear – when the drivers press their lips tightly, when dimples form on their cheeks, when they furrow their eyebrows, they are frustrated.

In addition to facial muscle activity, the researchers also used near-infrared spectroscopy (NIRS) to monitor the oxygen saturation in the blood of the test participants' brains. "This view into the brain gives us additional information on the driver's emotional state," Ihme explains. Scientists from the University of Oldenburg adapted the process for the study and evaluated the data together with the DLR scientists. "We found that the oxygen saturation in the blood of frustrated and non-frustrated car drivers differed in specific areas of the forebrain – those areas involved in the regulation of emotions," Ihme says. "The more frustrated the test participants were, the higher the oxygen saturation was in these areas."

On the screen, the increased oxygen saturation is displayed as large red areas in the brain. This indicates increased activity in the nerve cells. A lot of red means that the test participant is struggling to suppress impulsive behaviour in the particular situation. "This behaviour is very typical of frustrated drivers," Ihme explains. Based on these results, the researchers have developed intelligent algorithms that can detect changes in facial expressions and associate them with frustration. This is precisely how a vehicle is able to recognise the emotional state of its driver.

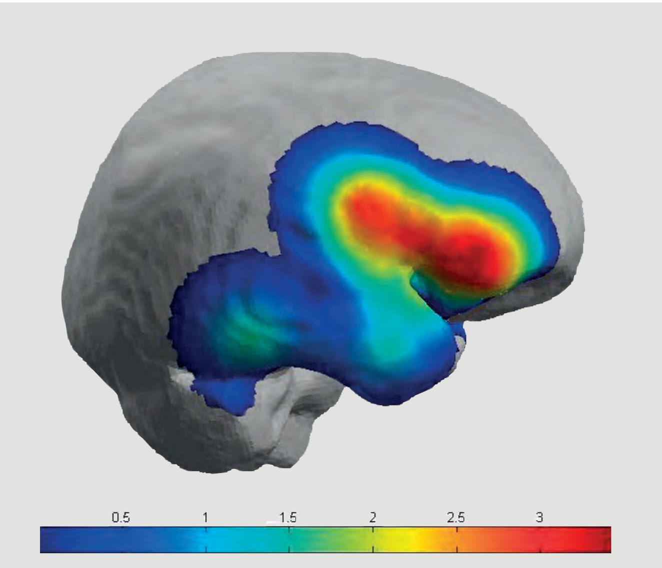
The antidote – Soothing smells and pretty pictures?

Just knowing that the driver is frustrated is not very helpful in itself. The scientists must now also add software to calm the driver down. "It might suggest anywhere from switching to another form of transport through to an alternative route," Ihme says. This, of course, requires that the vehicle has a networked knowledge of alternative modes of transport, and that it enables a timely arrival at the destination of choice. The vehicle could also give the driver a more objective perspective on the situation – for example that there is only a two-minute delay and that it is still possible to arrive at the destination on time. Another possibility would be that the driver is made aware of the fact that, although there are problems reaching the destination at the moment, at the next crossing there will be a green wave and not much traffic, so the lost time will be recovered. Such information may help the driver to regain control and view the temporary discomfort for what it is.

If such cognitive options are not available, the driver may also be soothed via the sense organs. Calming aromas, such as vanilla, are a possibility. Relaxing music or holiday photographs displayed on the windshield might also help, providing the images are not distracting, of course. In that case, the safety issue would no longer be frustration – but rather the lack of attention to traffic. Here, too, the researchers at the DLR Institute have come up with their first solutions. The main goal is for the vehicles of tomorrow to be tailored to their drivers and neither demand too much nor too little from them, but rather to optimally support people in achieving mobility. This is precisely where human factors come into play.

Author: Meike Jipp is Head of the Human Factors Department at the DLR Institute of Transportation Systems in Braunschweig.

Image of the human brain: The difference in the brain activity of frustrated and non-frustrated individuals is colour coded. The red regions are active areas of the brain and a sign of frustration.



In the DLR Virtual Reality Laboratory, the lights were constantly switched to red and pedestrians slowly crossed the street until the vehicle driver started showing clear signs of frustration.

INTELLIGENT TRAFFIC LIGHTS

Two new control methods for traffic lights should prevent unnecessary waiting at red lights, make traffic flow more smoothly and reduce emissions. Scientists from the DLR Institute of Transportation Systems have developed two intelligent control systems for traffic light systems (TLS) and tested them at the Tostmannplatz in Braunschweig. Researchers compared their waiting time based and cooperative control method – Vehicle-Actuated Intelligent Traffic Signal Control (VITAL) – with the previous traffic light control system with some astonishing results: For a traffic light control of a total of 16 hours per day, and a crossing rate of approximately 800 vehicles per hour, a total of about five to 15 hours of waiting time can be saved, depending on the traffic situation and type of control. The waiting time based control method extends a running green phase up to a point where all the vehicles that have already accumulated a certain waiting time have driven on, while observing a minimum and maximum permissible phase duration. The traffic-dependent control is linked to a traffic light assistant system.

Less waiting time thanks to intelligent traffic lights – two new control procedures make it possible: the waiting time at the traffic light can be reduced by up to 15 hours per day.

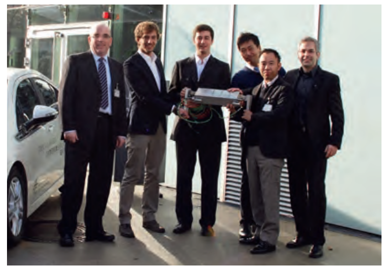
The novelty of the VITAL process is that waiting and arrival times are used as parameters for traffic control. Previous methods are usually controlled by observing fixed times or by using sensors that detect the crossing of a vehicle. With VITAL, vehicles can autonomously register the traffic situation via Car2X and, for example, provide the traffic light with information on their position, direction and speed. VITAL processes can be integrated in the form of prefabricated modules into many of the existing TLS controllers, which remain basically unaffected by the installation and operation. Only the criteria for adjusting release times are modified according to the waiting-time-based or cooperative procedure.

The Tostmannplatz crossing is one of a total of 36 traffic light crossings in Braunschweig that will be equipped with Car2X communication technology as part of the Intelligent Mobility application platform (AIM). With support from the German Federal Government, the state of Lower Saxony and the city of Braunschweig, AIM is a unique large-scale research facility that is unique across Germany and can portray the complete spectrum of traffic research.

ON-BOARD POWER FROM WASTE HEAT

Together with the Japanese company Yamaha Corporation, the DLR Institute of Vehicle Concepts is developing special vehicle systems based on thermoelectric effects. The aim is to develop novel modules for making use of residual energy from road and rail vehicles. The Japanese company is mainly contributing its expertise in materials procurement and the manufacturing of thermoelectric modules consisting of semiconductor materials, while DLR is contributing its broad knowledge in design, vehicle concepts and vehicle energy systems design and optimisation.

Vehicle combustion engines, for example, use only about one third of the energy in the fuel for propulsion; the remaining two thirds are lost as waste heat. Thermoelectric generators use this heat and convert it into electricity. The power can then be used in the vehicle for control units or convenience electronics and thus reduces the load on the alternator, which would otherwise have to generate this power itself. In hybrid and range-extender vehicles with internal combustion engines, the power obtained from a thermoelectric generator can be fed directly to the battery. The goal of the DLR researchers is to reduce fuel consumption by three to five percent by using thermoelectric generators.



DLR scientists and their cooperation partners from Japan hold the first version of the thermoelectric generator in their hands. It is intended to reduce fuel consumption.

The first system integrations based on thermoelectric generators have already been developed and successfully tested by DLR researchers together with partners from industry and research. Until now, industrially produced thermoelectric modules have been available only to a very limited extent. Therefore, the engineers had to resort to modules that were not specially designed for this purpose. With the Japanese partner, vehicle-compatible modules will now be developed for the next generation of thermoelectric generators.

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FLYING HIGH ON A FIRM FOUNDATION

INVENT GmbH exploits the potential of fibre composite technology for innovative products

By Jasmin Begli

3D printing a rocket engine sounds like a thing of the future. And the future, it seems, is already here. In 2016, the state of Lower Saxony awarded the company INVENT GmbH a grant for a technological flagship project. In tandem with the Technische Universität Braunschweig and DLR, a 3D-printed reusable rocket engine is to be developed. This will 'boost' the test rig for space rockets at the DLR site in Trauen. The new rocket engine is one of the many flagship projects of INVENT GmbH, which was founded 20 years ago as a DLR spin-off.

In 1996, three professors from DLR Braunschweig decided to start a company. The aim was turn ideas from the Institute of Structural Mechanics (now the Institute of Composite Structures and Adaptive Systems) into products. Elmar Breitbach, Axel Herrmann and Holger Hanselka recognised early on that the fibre composite technology they were investigating at the DLR Institute was a technology of the future. In terms of both mandate and spatial capacity, DLR was not set up to industrially implement its research results. In order to produce the new technology, ideally in a production series, an outlet to transfer DLR's fundamental research to the 'outside world' needed to be created.

"At the time, Dornier needed a component made of the fibre composite material that was being researched at DLR," recalls Henning Wichmann, Managing Director of INVENT GmbH. With the help of DLR Technology Marketing – which acts as the interface between research and industry and thus supports the development of DLR's research results into application-oriented technologies – Breitbach, Herrmann and Hanselka founded INVENT GmbH.

"At the outset, the three scientists did not consider actually managing the company," Wichmann says. "So at the age of 27, I went from being a dogsbody to Managing Director of a company almost overnight." Today, he is glad that he was given this opportunity immediately after he finished his studies. "At that age, you are young and just starting out in your career, so I took the risk. Later in life, with a family and children, I would probably have decided differently." And that is how INVENT GmbH was established in 1996, with just two staff members. Wichmann and his colleague Carsten Schöppinger, who has been Head of Engineering at INVENT GmbH since then, initially shared a 160-square-metre office in the centre of Braunschweig. For their manufacturing orders, they rented out DLR facilities. Wichmann still sees development as the link between INVENT and DLR. While DLR was responsible for research and – together with INVENT – development, INVENT focused on series production.

The entire process chain under one roof

"The collaboration with DLR was very close from the beginning, and it still is today," Wichmann is pleased to say. The company has grown substantially in the past 20 years. Where once there were just two people, today there are nearly 100. The company has moved from the inner-city office to its own office complex with production halls in the Braunschweig industrial district Hansenstrasse. And the series production of components was only the beginning. More and more new technologies were added to the INVENT portfolio, so that today the entire process chain for producing a fibre composite component is under one roof. Wichmann and his employees do everything themselves – from design to production, and quality assurance through to assembly. The cooperation with DLR is ongoing – the two work closely together, exchanging staff and projects, or acting as partners in aeronautics research programmes.

View into one of the production halls: The various projects that are being worked on here include a helicopter cabin made with fibre composites.

Images: DLR/Marek Kruszewski

The technical discussion with the employees is a part of everyday work for the Head of Engineering Carsten Schöppinger

Image: Marek Kruszewski

Involved from the very beginning: INVENT CEO Henning Wichmann (left), Susanne Braun (Personnel Management) and Head of Engineering Carsten Schöppinger.

Straight from the source

Wichmann's main focus is on the contracts, personnel and finances. "You have to permanently keep an eye on where the company's market is and where you want to go," he points out. "You have to look for new assignments, and if the quality is good, companies will come back with their next order." However, Wichmann is also aware that nothing happens without qualified, dedicated and satisfied staff. He knows the names of all his employees – because they are all important. "We all get along. Here at INVENT, good work is properly rewarded!" He wants to create jobs, not rake in the money, he explains. Nevertheless, dealing with banks is naturally an important aspect of his work. Series production requires money; the production must be constantly expanded – depending on the contract. As a result, there will be another move to larger facilities in 2017.

As a child, he dreamt of becoming the head of a company. After his studies, it was the last thing on his mind. Now that he is a CEO, Wichmann can say that he never once regretted his decision. His job is not stress-free; nevertheless, he would not want to do without the autonomy and independence he has today. "I am personally responsible for many things – that was the case at the start and has remained so until today." As the company grew, it was difficult to delegate tasks at times. But Wichmann had to learn to do so. Nevertheless, he continues to have many tasks and responsibilities. He has never missed the 'scientist life'. "I only ever worked in science as a student – then I went straight to being a managing director." Anyone who knows Wichmann knows that he would rather work as a businessman than in a laboratory.

The next four years is already booked with orders being fulfilled by 20 engineers, 60 specialists (15 of whom were actually trained at INVENT), six trainees, six degree candidates and eight assistants. "Obviously, you have more sleepless nights as a businessman," Wichmann says. "The moment when Dornier, the client for our first major series production job, went bankrupt shortly after we moved into a larger building, was worrying." However, new clients were found again and again. "I was never afraid. Whenever a low point came, it was immediately followed by a high point," he says thankfully. Today, INVENT is not only a sought-after supplier for aviation but for aerospace as well, with the majority of orders coming from this sector now. "From the outset, we always had at least one flagship project. Today, we have five running simultaneously." He attributes this to, among other things, one of his previous flagship projects: producing the core module for the ExoMars probe in 2014. One of the current projects is the entire production of a helicopter cabin for edm aerotec GmbH.

When he is not working, Wichmann enjoys being on the tennis court or out at sea. His wife and two daughters go with him because family is just as important to him as INVENT. When asked where he sees his company and himself in 10 years, he says confidently: "I will be closer to retirement, and INVENT will be one of the leading companies in the construction of CFRP structures for satellites."

More information about INVENT:
www.invent-gmbh.de/en/

INTO THE FUTURE WITH COPERNICUS

DLR supports major science initiative for the Energy Transition

By Denise Nüssle

In the sixteenth century, when mathematician and astronomer Nicolaus Copernicus discovered that the Sun, not Earth, is the centre of the Solar System, profound scientific and social changes were set in motion. Fast forward to today, the largest ever German research initiative to contribute to the Energy Transition has been named after the scholar, reflecting the same spirit of progressive change. Over a period of 10 years, participants from science, industry and society will be developing solutions for the sustainable transition of the energy system across four Copernicus projects. The aim of the initiative by the German Federal Ministry of Education and Research (BMBF) is to transfer research results into applications that, from the outset, address economic, social, political and technological issues. The four key areas include: the development of power grids; the storage of excess energy from renewable sources through its conversion into other energy sources; the realignment of industrial processes to a fluctuating power supply network; and optimisation of the interplay of all the sectors in the energy system of the future.

Energy research at DLR is involved in three of the four Copernicus projects. The Institute of Engineering Thermodynamics and the Institute of Combustion Technology mainly contribute their know-how in the areas of energy storage, energy systems analysis, alternative fuels and technical combustion processes. “For over 40 years, DLR has been conducting research into innovative technologies and solutions for a sustainable energy supply – one that is environmentally friendly and at the same time reliable and affordable. We are looking forward to bringing our know-how and experience to the Copernicus projects in the coming years and to, together with partners, work on important issues for the future of the energy sector,” said Pascale Ehrenfreud, Chair of the DLR Executive Board, during the launch of the initiative.

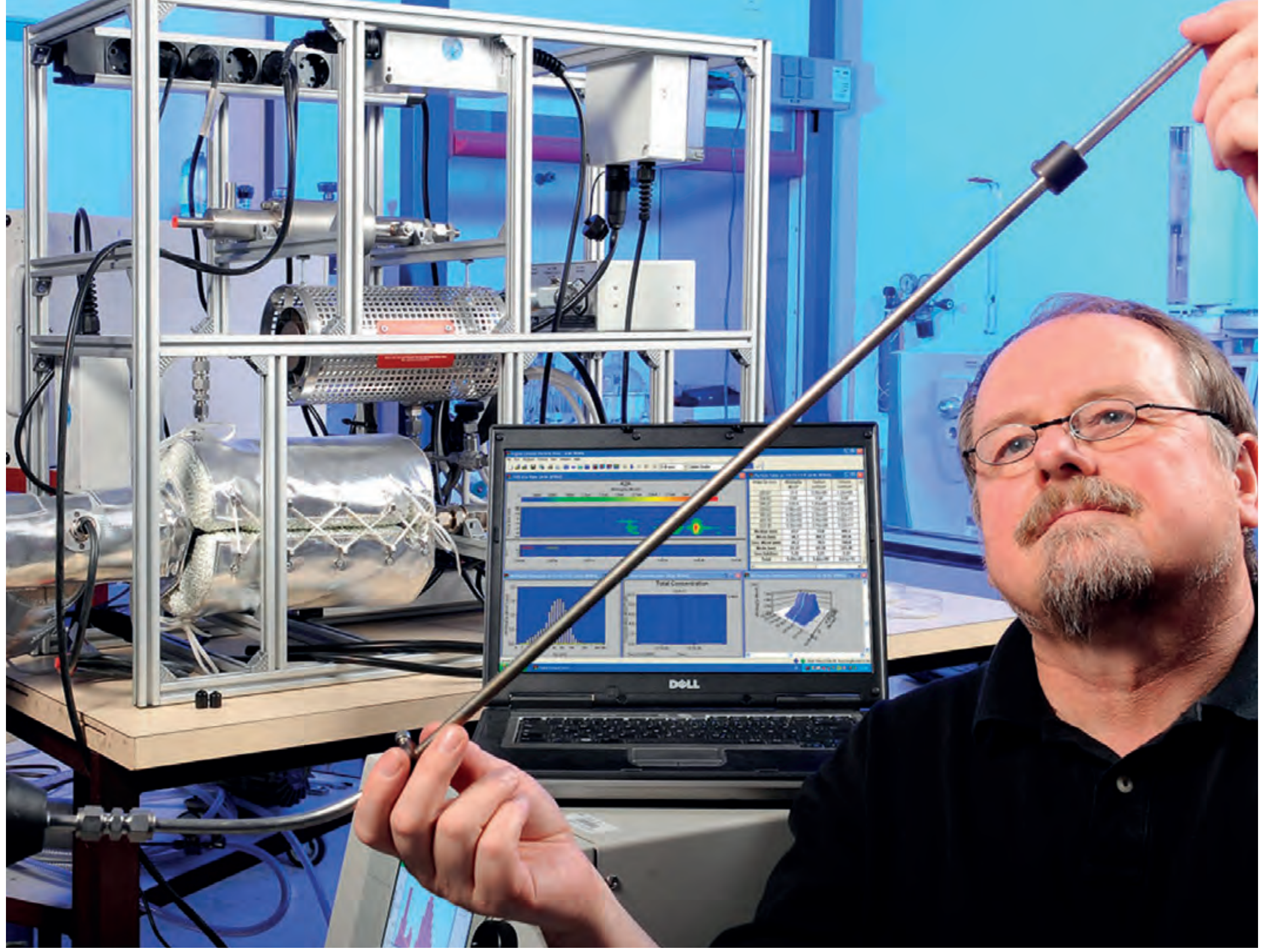
P2X: Storing renewable energy

Even today, energy supply from renewable sources such as solar and wind is increasing in disproportion to demand. In other words, more energy than is needed is being produced. Previous options for storing this energy, such as batteries, have been limited. One promising technological alternative is to use power to generate gaseous substances such as hydrogen or methane (power-to-gas), or liquids for use in the chemical industry or as fuels used for mobility (power-to-liquid).

Within the Copernicus P2X project, the Department of Electrochemical Energy Technology at the DLR Institute of Engineering Thermodynamics is investigating how electrolysis can be used to generate a synthesis gas from water vapour and carbon dioxide. Of importance are the materials needed for this special electrolysis at high pressures and temperatures. Meanwhile, the focus of research activities at the DLR Institute of Combustion Technology is at the end of the P2X process chain. Scientists are investigating liquid energy storage mediums produced by the power-to-liquid process and are coordinating activities with regard to fuel quality. They are mainly focusing on the possible use of such fuels in aviation. To do so, they are analysing the properties and exact chemical composition of fuels. In this way, using experimental analyses and model-based methods, conclusions on further potential for optimisation will be drawn.

SynErgy – For more flexible industrial processes

In Germany, more than 40 percent of the net energy consumed and 25 percent of heat demand goes into industrial processes. This is both a starting point and main challenge of the Energy Transition. On the one hand, there is an energy system with an ever increasing share of fluctuating energy generation from renewable resources; on the other are industrial consumers with a constant demand for energy, heat and gas. There is a need to temporally align the production and consumption of energy. In addition to storage solutions, the ability to increase the flexibility of industrial processes plays a critical role here. Highly energy-intensive processes, in particular, must be designed according to different principles than in the past. The potential is huge: by 2020, industry’s energy supply costs could drop by more than 10 billion euro, and carbon dioxide emissions could be significantly reduced.



Analysis of new fuels: Through experiments and model-based methods, scientists at the DLR Institute of Combustion Technology are optimising the properties of new fuels for aviation applications.

For this reason, the Department of Thermal Process Technology at the DLR Institute of Engineering Thermodynamics is involved in the Copernicus SynErgy project. The Institute is investigating the potential for greater flexibility in the highly energy-intensive primary industry, which produces steel, aluminium, glass, building materials and basic chemical materials. The processes involved in this sector are very complex and must be carried out under tightly restricted operating conditions. Manufactured products are subject to consistent quality requirements. The aim of the researchers, as a first step, is to develop a method to evaluate cross-sectoral flexibility options. On this basis, example processes can then be designed and simulated in a potential analysis.

ENavi: Power, heat and mobility system integration

The transformation of the energy supply chain linked to the Energy Transition affects numerous closely interconnected systems. The power, heat and mobility sectors are especially interrelated. The Copernicus ENavi project therefore adopts a holistic perspective. The aim is to acquire a better understanding of the complex network of tomorrow’s energy systems and to demonstrate potential courses of action. At the focus are the interactions and interfaces between the sectors, as well as the technological, economic, political and social demands on the entire system. These include issues regarding grid construction, production and storage capacities, the development of suitable management tools and social acceptance. The Department of Systems Analysis and Technology Assessment at the DLR Institute of Engineering Thermodynamics is, among other things, further developing existing simulation models in the project. They can, for example, make statements on the future development of the energy market or model potential future energy systems with high temporal and spatial resolution. In addition, scenarios and models from transport research within DLR enable closer examination of the connection between the energy and transport sectors.

Industry is dependent on energy being constantly available. How this can be reconciled with fluctuating energy generation from renewable resources is one of the questions scientists are looking to find an answer to in the context of the Copernicus Initiative.

Image: Thinkstock/ozgursengelli

The unique facility in the Center for Lightweight Production (Zentrum für Leichtbauproduktionstechnologie; ZLP) in Augsburg combines two production processes into one: when producing rocket boosters made of CFRP, rovings can be wound onto the core (see image) and wider tapes can be laid.

… trois-deux-un-top-allumage des moteurs! When a rocket is launched into space, auxiliary rockets called boosters provide additional thrust. In the process, they are exposed to high thermal and mechanical loads – so they need to be stable and, at the same time, as light as possible. Engineers at the DLR site in Augsburg, together with MT Aerospace AG, have developed an automated production process for a rocket engine casing made of carbon fibre reinforced plastic (CFRP). The aim of the collaboration is to significantly reduce both the weight of the rocket and the production costs for the booster, thereby lowering the launch costs of future rockets, such as the Ariane 6. At the Center for Lightweight Production Technology (ZLP) in Augsburg, a demonstrator has been built that is expected to demonstrate its qualities and, thus, its technological maturity in a burst test.

100 SECONDS OF ADDITIONAL THRUST

DLR and MT Aerospace develop a production process for rocket boosters made of carbon fibre reinforced plastic

By Nicole Waibel

Carbon fibre and plastic, instead of steel

The gallery of the technology hall in the DLR Center for Lightweight Production Technology (ZLP) offers a good overview of the activity. A great deal has been done here since the opening of the new building in May 2013. In the meantime, more than 50 employees work here. In the Multifunctional Cell, intense activity is the order of the day – six robots work collaboratively from the ceiling and can be used flexibly for various projects. Scientists and technicians from DLR and MT Aerospace have been working together for months on the development of a CFRP booster and the respective production process. "Our aim is to take an efficient and stable production process through to industrial maturity," says Michael Kupke, head of the ZLP. "The costs for launching a rocket are critical to surviving the international competition in the sector of civilian launcher systems," he says. And continues: "If the steel boosters – such as those used in the Ariane 5 launcher – are replaced with CFRP boosters, the unladen mass is reduced and the payload can be increased. With the right technology, we can simultaneously lower the costs," explaining the benefits of using carbon fibre reinforced plastic.

Two processes in one facility

The booster that has now been developed is a solid rocket engine. The fuel exists in solid form, and the interior of the auxiliary rocket acts as a combustion chamber. "To prevent the booster from burning up, a layer must first be applied to the core to provide thermal insulation between the fuel and the CFRP casing. At the moment, this is still done manually," says Kupke, describing the preparations required to automate the process.

In the next step, the carbon fibre is applied and fixed. This process – called preforming – takes place in a single facility. It consists of a rotating core on a rotary device and two robots. "A key innovation is that we are merging two fundamentally different technologies in one system," Kupke says. Two processes are combined: dry fibre winding and dry fibre placement. As the name suggests, the used fibres are dry, as opposed to in conventional pre-preg processes, where the material is pre-impregnated with resin and draped over a release coated mould.

The booster consists of three parts: the pressure vessel and the so-called skirts – wide rings at the ends of the pressure vessel that protrude slightly at that point and are used to attach the booster to the launcher. They have to transfer all of the thrust from the booster to the carrier rocket. The pressure vessel is made by winding fibre bundles (rovings) onto the rotating, six-metre-long core. The robot moves steadily from left to right along the core and back again, to and fro, continually winding row upon row of black carbon-fibre rovings. The angles at which the winding occurs are variable and determined by the loads affecting the booster.

Pressing, heating and cutting

During a rocket launch, the booster is subjected to very high forces and very high pressures occur inside as the fuel is combusted. "The important thing is to get the dimensions exactly right and not to make the walls too thick and therefore too heavy, but to still ensure the necessary stability," Kupke says, explaining the art of lightweight construction. The skirts are made by laying 50-millimetre-wide carbon-fibre tapes and are additionally reinforced by individual winding layers. These are fixed using a thermoplastic binder surface, a pressure roller and infrared heating, and are automatically cut.

"Once the preform has been produced, a vacuum is generated – mostly manually at the moment," says Kupke, describing the next stage. The resin is infiltrated in the oven using an infusion process. The rovings have also been modified to ensure that the entire unit is properly impregnated with the resin specially selected for the process. The rotation of the rotary mechanism prevents the low-viscosity resin from accumulating in the lower part of the structure due to gravity during the infiltration. Because of the rotation, the available flow paths for the resin are optimally used until the resin system congeals and hardens.

This new process not only provides a high level of stability, but also offers great potential for lowering costs. These can be reduced by 30 percent compared with the conventional pre-preg process, in which fibres that have already been pre-impregnated with resin are used. Dry fibres have advantages in terms of the material costs and logistics, as no freezing rooms are needed, as is required with pre-pregs. In the infusion process used here, both the infiltration of the resin and the hardening take place inside a special furnace. The process is completed without the need for a cost-intensive autoclave, in which components are hardened under high pressure. This also reduces investment costs.

Non-destructive testing and burst tests

Once these components have been manufactured, they have to be extensively tested. "We use air-coupled ultrasound. The process is designed in such a way that access is possible from just one side – the exterior. If the ultrasound source and the sensor are obliquely positioned, so-called Lamb waves are stimulated in the component from the outside. These demonstrate high sensitivity to damage and can also be detected from the exterior. This is a contactless method, which also does not require any additional coupling media, such as water or gel, which are generally used in medical ultrasounds," Kupke explains.

The components are tested in an automated fashion. Robots guide the test sensors, moving quickly as they do so – at speeds of up to 230 millimetres per second. The resulting ultrasound maps depict the tested component in two and three dimensions with geometric accuracy. The entire test concept is designed for flexibility, high speed and reproducibility, and can meet the ever-increasing requirements for quality assurance and digitalisation in industry. "We are using air-coupled ultrasound here in areas where the process has not been deemed reliable until recently," Kupke says.

THE ARIANE 6 LAUNCHER

The construction of the Ariane 6 was agreed upon at the European Space Agency (ESA) Council Meeting at Ministerial Level in Luxembourg in December 2014. More flexible than its predecessor, the Ariane 5, the Ariane 6 is expected to carry payloads of between five and 10 tons into space. Two versions are planned, which are produced according to the modular principle: The smaller, lighter Ariane 62 with two boosters for launching individual satellites (for the institutional sector), and the larger, heavier Ariane 64 with four boosters for launching two satellites at the same time (for the commercial sector).

The Ariane 6 is expected to make Europe more competitive and flexible in the civilian launcher system sector and to ensure that Europe has independent access to space. It is expected to launch for the first time in 2020.

Artist's impression of the Ariane 6 with four boosters (A64)

Image: ESA – David Ducros, 2016

The pressure vessel was successfully completed in May 2016, and the skirts followed in August 2016. The components are produced and assembled at MT Aerospace AG. The component is then subjected to a further structural and burst test by MT Aerospace AG.

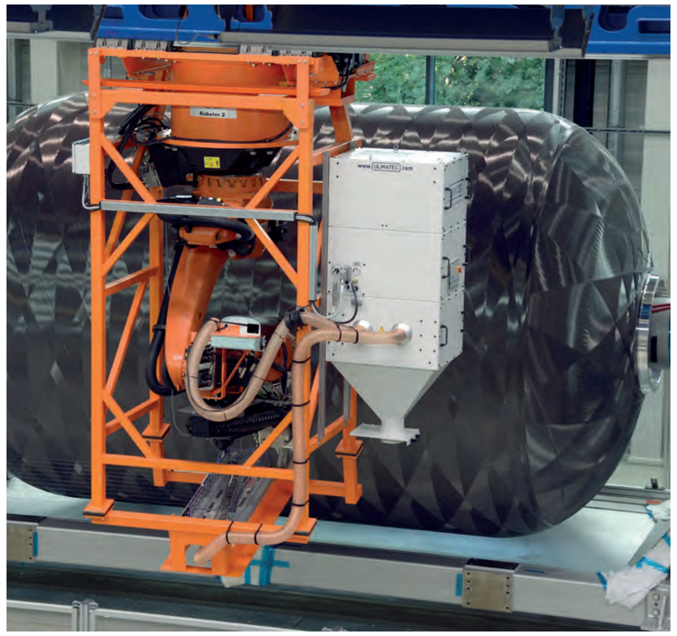
Boosters representative of Ariane 6

The finished demonstrator component has a 3.5-metre diameter and is six metres long. Hence it is representative of future boosters for the Ariane 6. "Its boosters will be almost twice as long, but due to the comparable load flows and appropriate technological challenges we can leave out part of the middle section," Kupke explains. "This means we save time and money in development but still have a representative component to cover technological risks."

So what happens to the boosters after launch? Once they have burned out after about 100 seconds, they separate from the rocket and fall into the sea. They can be salvaged and examined, but there are no firm plans to reuse them.

"This means that, compared with the development and production timescale, the booster will put on a very short, but all the more powerful, performance," summarises Kupke.

Nicole Waibel is responsible for public relations at the Center for Lightweight Production Technology (ZLP) in Augsburg.



With a diameter of 3.5 metres, the component is representative of boosters for the future Ariane 6.

A robot winds the dry fibres onto the pressure vessel. In the development phase, people still check that the process is running smoothly.

Two colleagues from MT Aerospace discuss the measurement results. They can see via monitors at any time how the winding process for the innovative procedure for producing boosters is going.

Kupke (right) in conversation with Mona Eckardt and Roland Glück. The carbon fibres are cut with the help of a blade (centre of image) – one of the many technical challenges in automated booster production.

Heinz Voggenreiter, Director of the DLR Institute of Materials Research in Cologne and the DLR Institute of Structures and Design in Stuttgart and Augsburg.

FROM AUGSBURG INTO SPACE

In conversation with Professor Heinz Voggenreiter, DLR institute director, on the specialties of the DLR Center for Lightweight Production Technology (ZLP), the collaboration with industry and the CFRP expertise at the Augsburg site.

Premium AEROTEC GmbH, MT Aerospace AG, Airbus Group – Mr. Voggenreiter, what makes the DLR ZLP an attractive cooperation partner for so many renowned companies in the aerospace sector?

: The path from innovation to industrial implementation is time- and cost-intensive and often risky. Our task is to help our partners in industry to reduce the time, costs and risks on the way to production maturity. At the ZLP, they find a development environment perfectly adapted for series production, where every process step can be examined and validated. Using cooperative robots in a unique facility, we jointly develop and test needs-based production processes. As a result, innovations find their way into industrial applications more easily.

Together with MT Aerospace, scientists at the ZLP are developing an automated production process for rocket boosters made of CFRP. How does the collaboration actually work?

: We have been working with MT Aerospace AG and other partners for many years on the development of fibre composite technologies for the production of spaceflight structures. A small-scale, step-by-step development and test programme began in 2013. At the time, we compared established, innovative manufacturing technologies, using technical and commercial criteria in the context of process analysis. In 2014, we produced demonstrators in a 1:4 scale. We have been using full-scale demonstrators since 2015. The important thing is that MT Aerospace is ultimately able to build and operate a production line in Augsburg. To tighten up the schedule and minimise risk, there is a division of labour with MT Aerospace for this. They are taking on the engineering and manufacturing of the demonstrators and test components under contract to the European Space Agency (ESA), while DLR is developing the automated production process as well as the production resources on behalf of the Bavarian Ministry of Economic Affairs, Media, Energy and Technology, and incorporates both into the technological development process. The large demonstrators and test bodies were and are produced jointly with MT Aerospace at DLR. In May 2016, the MT Aerospace pressure vessel, which weighs several tons, was successfully produced at DLR Augsburg, followed by the respective skirts in August 2016.

How important is this for the Ariane 6 and for Augsburg?

: We have developed an automated production process that offers great potential for lowering costs, guarantees high stability and, at the same time, enables an efficient design. In this way, we are making a substantial contribution to the development of the future Ariane 6. Together, we have set ourselves the goal of demonstrating the technological maturity and industrialisation capability of automated fibre composite technology and, as such, bring the production of CFRP boosters to Augsburg. With this Bavarian stake in the construction of the Ariane 6, the leading role of the Augsburg site in CFRP technology is being further enhanced. It also makes the region attractive for future technical talents.

MEET DLR AT ...

HANNOVER MESSE
24 to 28 April 2017
The Hannover industrial trade fair is considered to be the leading Industry 4.0 and energy trade show. As part of the energy meta-theme, DLR is showcasing examples of its current research and development work. DLR's personnel team will also be present. Ten leading international trade shows from various industrial sectors gather under the HANNOVER MESSE umbrella. Current issues are discussed in cross-sector forums and directly at the exhibitor stands.
bit.ly/2luFCr9

INTERNATIONAL SYMPOSIUM ON REMOTE SENSING OF ENVIRONMENT
8 to 12 May 2017
The 37th International Symposium on Remote Sensing of Environment (ISRSE 37) will take place in Tshwane (Pretoria), South Africa. The overarching theme is 'Earth Observation for Development and Adaptation to a Changing World'. ISRSE 37 will be hosted by the South African National Space Agency (SANSA). This will be the second time in this millennium that the African continent will host ISRSE and coincides with the implementation of the recently adopted African Space Policy and Strategy.
isrse37.org/

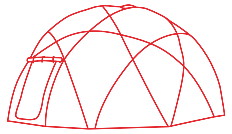
YOUNG RESEARCHERS SEMINAR 2017
16 to 18 May 2017
The 8th Young Researchers' Seminar will be held in Berlin, Germany and will be hosted by DLR. The Young Researchers' Seminar is organised every two years in a different European country. The common vision for the Seminar is the preparation of a new generation of transport scientists and science professionals in the area of transport. Since 2007, thanks to the Memorandum of Understanding between European Conference of Transport Research Institutes (ECTRI) and the Transportation Research Board from the United States, participation to the Seminar is now open to young researchers and tutors from US Universities.
ectri.org/YRS17/

PARIS AIR SHOW 2017
19 to 25 June 2017
The 52nd International Paris Air Show will take place at the Le Bourget Parc des Expositions. Once again, the biggest European event in this sector will bring together all the players in this global industry around the latest technological innovations. The first four days of the Show will be reserved for trade visitors, followed by three days open to the general public. DLR will present itself as a part of the German Aerospace industry at its joint stand in Hall 2C.
siae.fr/en/

4SMARTS® – SYMPOSIUM FOR SMART STRUCTURES AND SYSTEMS
21 to 22 June 2017
The focus of 4SMARTS® is the interdisciplinary topic of active, intelligent and adaptive – in short smart – structures and systems. The symposium covers all the relevant technological fields, from materials, to designing components and integrating functions, through to ensuring the reliability of complex systems. Topics include applications such as Structural Health Monitoring (SHM) and Energy Harvesting, as well as the traditional applications of active vibration, sound and shape control. The second 4SMARTS® aims to continue to drive the transfer of new ideas from research to industrial applications in the mechatronics and adaptive systems sector, and grow as a nucleus for cooperation and innovation in the area of smart structures and systems.
4smarts2017.inventum.de/en/home/

INTERNATIONAL AVIATION AND SPACE SALON (MAKS)
18 to 23 July 2017
The International Aviation and Space salon MAKS is one of the major world aviation forums. Once again, DLR will be present with a stand of its own. MAKS is held in the town of aircraft science and technology – Zhukovsky – at the airfield of the major national testing facility – Gromov Flight Research Institute. The MAKS agenda includes scientific conferences and symposia held under the auspices of the Russian national research centre TSAGI.
aviasalon.com/en/

TRACKS IN THE SNOW



Measuring the impact of black carbon on the climate at Union Glacier, shovel and crowbar in hand

By Bernadette Jung

POLAR RESEARCH AT THE EOC

Polar research at the Earth Observation Center (EOC) is consolidated in the Polar Working Group. Its profile at the German Remote Sensing Data Center (DFD) was recently further boosted by the founding of the 'Polar and Cold Regions' team in the Land Surface Department.

It is hard to believe that today, in the 21st century, small pockets of our Earth have yet to be fully explored. With scientifically reliable data in great demand, data obtained 'in situ' is highly sought after. Acquiring such data for polar regions is even more valuable, considering the adverse conditions. This is especially the case in the South Pole. People and technologies are unable to advance at will into the Antarctic continent, due to its remoteness and extreme weather. Its snow-covered, icy surface still holds many secrets. But despite this seemingly pristine exterior, our ecological footprint is already beginning to show. How much and with what consequences are questions polar explorers are tackling with growing commitment – for there is hardly a region on Earth as sensitive and thereby as crucial for the global climate and ecosystem as the Antarctic.

The Transantarctic Mountains divide the ice continent into two uneven halves along a curved line. East Antarctica is an almost infinite plane, much like a polar ice shield where record-low temperatures are the norm. In the western hemisphere, the Antarctic Peninsula extends far into the Antarctic Ocean. This half is characterised by a milder coastal climate and jagged mountain ranges. At the southern end of the Peninsula – in the midst of the immense Ellsworth Mountains – the backdrop of the Union Glacier amazes both researchers and adventurers alike. Here, between the rugged mountain peaks, more than half a dozen glaciers come together to form an extensive glacier that merges into the mighty Filchner-Ronne Ice Shelf after some 65 kilometres.

At the wide outlet of the glacier, there are small signs of civilisation: a private base camp and a Chilean research camp have been set up at 79.76 degrees South and 82.87 degrees West. These are important arrival and departure points for expeditions of both researchers and explorers, as it marks the entry point to the highest peak of the Antarctic, the almost 5000-metre-high Mount Vinson, to Mount Sidley, the tallest volcano in the Antarctic, and to the 'empire' of the emperor penguins. For many adventurers, Union Glacier is also an interim step on the journey to the South Pole, another 1100 kilometres or so away.

In his doctoral thesis, qualified geographer Paul Wachter investigates the connection between temperature trends and atmospheric circulation in the area around the Antarctic peninsula.

Black on white

During the summer months in Antarctica, the camps open their gates, and there is once again hustle and bustle in the otherwise completely deserted region. Paul Wachter from DLR's 'Antarctic' Junior Scientists group at the German Remote Sensing Data Center (DFD) was able to witness this in November 2016. The scientist supported a measurement campaign by the Universidad de Santiago de Chile (USACH) at Union Glacier – a rare, polar mission that came about through an invitation extended by USACH and supported on-site by other Chilean partners. Contact with colleagues at USACH had been funded in recent years with resources from DLR's Project Fund International Cooperation (PIZ).

An 11-day research visit to the Antarctic involves obtaining a wealth of data for many years of research. To date, specific on site datasets to answer particular questions are available to a very limited degree. The logistical effort is so great that – compared to the Arctic – only a few research stations can be operated in Antarctica and very few measurement campaigns conducted. The aim of the long-term project at Union Glacier is to more precisely investigate the influence of soot, known as 'black carbon,' on the optical properties of snow, and thus on the climate.

Black carbon is emitted by industry and transport into the atmosphere and is 'scattered to the four winds' – all the way to the seemingly untouched Antarctic. The contamination is not visible to the naked eye. But even in small concentrations, the dark particles can result in the snow absorbing sunlight more strongly, thus reflecting it to a lesser degree. With a total surface area of around 13.5 million square kilometres, the Antarctic continent is around one and a half times the size of Europe. Thus, a lot of white material is perhaps blacker than meets the eye. The polar regions with their high reflectivity are an important factor in Earth's radiation budget. Through targeted measurements and snow samples, the scientists at Union Glacier want to find out how the man-made change to Antarctica's snow and ice sheet are affecting the world's climate.

Landing on sheer ice

A long journey lies ahead of Paul Wachter. Starting in Munich, his first stop is the partner university in Santiago de Chile. At USACH, he makes the final preparations with his South American colleagues, including briefings on the individual measuring instruments and calibrating the systems. There is no room for mistakes in the glacial cold of the Antarctic. "Our aim is to carry out our own Antarctic measurement campaigns in the future. The collaboration with Chile allows us to get acquainted with the special on-site logistical requirements and expand our international research network," explains Kathrin Höppner, head of the 'Polar and Cold Regions' team in the Land Surface Department at DFD. Wachter's participation in the Chilean measurement campaign is now also giving polar experts from Oberpfaffenhofen insights into activities at Union Glacier. The journey continues for the junior scientists eight days later – to Punta Arenas, the gateway to the Antarctic and last stop on the way to the glacier.

In the world's southernmost city, scientists at the Chilean Antarctic Research Institute (Instituto Antártico Chileno; INACH) are awaiting key instructions and commands for a safe and responsible stay in the Antarctic. Nothing can be left behind on the white continent. Any contamination of the environment – even if this is simply emptying a water bottle – should be carefully avoided. The final items of equipment required are also lent out at the INACH and handed over for transportation to the Chilean military, camp operators and hosts on site. After four more days of waiting, the time has finally come: transport aircraft bring the research team of four, together with 20 members of the Chilean military, from Punta Arenas to the white south. Five-and-a-half hours later, the C-130 Hercules starts its descent to the blue ice runway at Union Glacier, an area of sheer ice approximately three kilometres long and 100 metres wide – frozen water in its purest form. "When I saw the ice blue surface through the window while being jolted back and forth on the bench of this propeller aircraft, I knew I was in an entirely different place," says the 31-year-old.

No time to freeze

Following the bumpy landing, it was time for everyone to get to work, leaving no time to acclimatise. The camp operated by the Chilean military had been closed over the past winter months, so the entrance had to be dug free from under a one-metre-thick layer of snow. And so the first two days at Union Glacier were spent shovelling snow and building the additional work tent at bitterly cold temperatures of -20 degrees Celsius. "When I now imagine

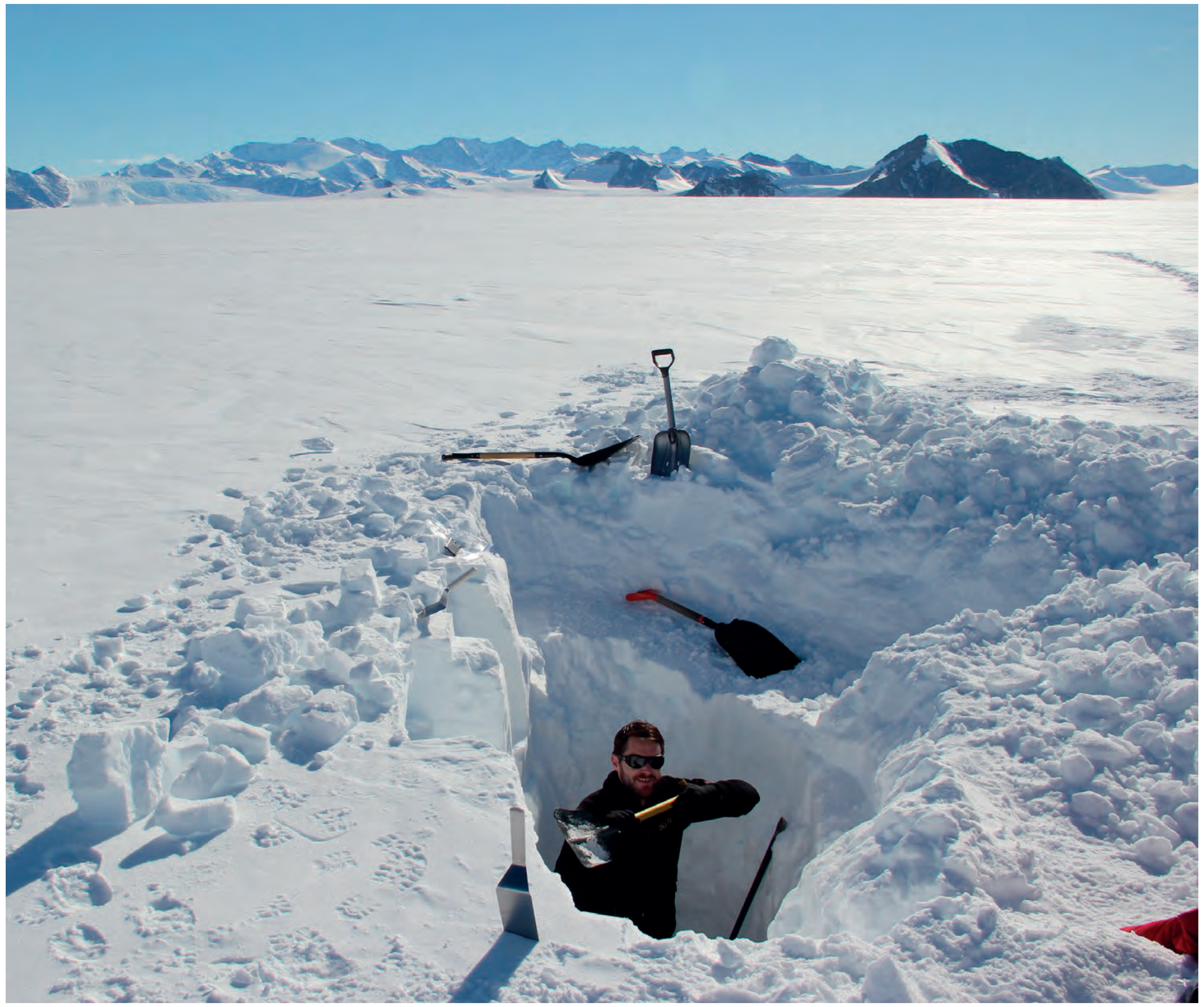
DLR'S ANTARCTIC STATION

DLR operates its own Antarctic station, the German Antarctic Receiving Station (GARS) O'Higgins on the Antarctic Peninsula. Its main purpose is to receive satellite-based Earth observation data and is fitted with a nine-metre antenna system correspondingly suited to Antarctic conditions. In November 2016, the station celebrated its 25th anniversary (DLR Magazine 152 dated November 2016).

Even long after midnight, the Sun is still shining brightly above the white measuring tent at the Union Glacier camp in Chile.

The colourful tents serve as the scientists' sleeping quarters. The red containers in the background, which are mounted on sleds, have already been used to carry out a scientific expedition trip from Union Glacier to as far as the South Pole.

The snow profile, which is 2.4 metres deep, will be excavated and then packed for transport to Chile. Whether the soot residue is present in such high concentrations that they can permanently impact the reflection behaviour of the snow, and thus affect the climate, will be shown by the laboratory tests of the samples.



the conditions of early day expeditions, what the first polar researchers achieved is unbelievable," says Wachter. In his newly built 'office,' the newcomer to the Antarctic can immediately enjoy an indoor temperature of 15 degrees Celsius. As early as the second day, a generator delivers power and the scientists can start setting up the measuring instruments.

A pyranometer and a spectrometer are installed one metre above the snowy surface. Their sensors continuously measure the incident and reflected solar radiation. From the ratio of these two values, scientists measure the albedo of the Antarctic snow. Earth's white polar caps reflect solar radiation back into space extremely effectively and also play an important role in regulating the global climate system. The on site measurements provide essential datasets to describe the albedo during the course of the day and under different meteorological conditions. The results provide important input variables for global climate modelling. However, this is not enough for scientists. In a next step, snow samples are also taken and their content analysed in the laboratory. This meant shovelling snow once again. Every year, approximately 80 centimetres of fresh snow falls on Union Glacier. To monitor development over several years, field researchers have to dig to a correspondingly deep level. For two whole days, Wachter and his colleagues took turns digging through the blanket of snow on Union Glacier, until a hollow around 2.4 metres deep and 3 x 3 metres wide, including steps was ready. "We were all absolute beginners, but we quickly figured out that we had to make a snow staircase," laughs the postgraduate as he thinks back. The team took a sample every 40 centimetres. In parts, the snow was so compact that the researchers had to break through it using a crowbar – strenuous work requiring just a fleece at times for protection against the cold.

Daily camp life and a prestigious duel

Summer in the Antarctic Peninsula delivers what it promises – with temperatures that reach the single-digit sub-zero range and weather conditions largely suitable for measurements. Only the relentlessly shining Sun during the polar day knocks Wachter off his rhythm: "There, you are awake in a completely different way and prone to work non-stop." Eleven days without having to switch on a light. The glacier and the surrounding Ellsworth Mountains offer their spectacular panorama without fail. Time at camp is kept predominantly through shared meals – a simple breakfast followed by two calorie-rich main meals. A full-time cook from the Chilean Marine does an excellent job using just a small folding worktop and a gas stove. Between meals, the camp dwellers also eat chocolate and other sweets; when conducting polar research, one can never consume enough calories!

The Chilean research camp has a friendly relationship with the neighbouring Antarctic Logistics and Expeditions (ALE) camp. In inimical locations, such as the Antarctic, mutual support is crucial. Yet on a cloudy Thursday during the Advent season, all friendships and favour seem to fall out for a period of 60 minutes. The football game of the year is on the agenda: ALE against EPCCGU (Estación Polar Científica Conjunta Glaciar Unión) – the Antarctic derby per se. A prestigious duel! Where 'English lawns' and 'floodlit atmospheres' are usually commonplace, it is a Pistenbully that levels the playing field here. Floodlights? Not necessary during the polar day. A heated but largely fair game ends with a score of 8:2 to the Chilean team. Sporting supremacy on the glacier has once again been settled for the next 12 months. The triumph and defence of the Union Glacier Cup is accompanied by a fervent "Chi-Chi-Chi, le-le-le: Viva Chile" as the Cup is held up in the Antarctic sky. Chilled limbs and old friendships begin to thaw again over mulled wine and fresh empanadas.

Not much time then remained – at the beginning of December, the 11-day campaign on Union Glacier came to an end. With the completion of the measurement series, Wachter and his colleagues ultimately have more than just their sporting success to be happy about. The new data and snow samples will help polar researchers unlock the secret behind black carbon in the Antarctic and more accurately determine its impact on the global climate. For researchers from Santiago to Oberpfaffenhofen, work will continue in brick-built laboratories and warm offices. But first they must dismantle the tents and measuring instruments brought with them, protect them for the bumpy journey back, and secure the camp that was home for the next Antarctic winter – without leaving a trace.

Coveted trophy: While soccer takes its winter break in Germany, at the Antarctic station the game is on. Welded together from steel cables, nuts and washers, the Union Glacier Cup is fiercely contested by the inhabitants of both glacier camps. The wooden plinth is adorned with the names of previous victorious teams.

MEASUREMENT TECHNOLOGY

Extremely precise measurements of the snow's albedo were carried out with a pyranometer and spectrometer installation. This makes it possible to investigate the spectral and integrated reflectivity in relation to different cause variables such as cloud cover, position of the Sun and temperature. The proportion of reflected sunlight – and hence the albedo – determine how much energy is available on the surface to increase its temperature.

After an 11-day field trip, material and instruments are again shared between two C-130 'Hercules' transport aircraft. They will fly their cargo, together with the expedition members, back to Punta Arenas.

The white surface of the Union Glacier glistens dazzlingly bright on a sunny day – in fact, the Antarctic functions like a highly effective solar mirror in the global climate system.

MORE GREEN, LESS GREY

Information system based on remote sensing data supports roof greening

By Elisabeth Schreier

It has long been clear that green spaces in cities play an important role. For urban dwellers, they are a haven from the hustle and bustle of the city and a place for numerous leisure activities. They have also become an essential part of a city's environmental balance as they provide ecological niches, filter air, retain water and have a positive effect on the climate. But in especially dense cities, there is barely enough room left for green spaces. So, where are such green spaces supposed to be created? Roofs are a possibility. Many cities and municipalities have a large number of existing buildings with flat roofs – yet they are only used sporadically. How many flat roofs are there in the world and in German cities in particular, and how many of them are already 'green' or could become so? The German Roof Gardeners' Association (Deutsche Dachgärtner Verband e.V.; DDV) has been working for years on answering these questions and on turning the untapped potential of German roofs into green lungs of cities. Together with DLR, the DDV has now developed a method to map roofs with existing greenery, as well as those with a potential for greening.

The idea for a joint project emerged at a conference, where staff from DLR's German Remote Sensing Data Center (DFD) presented remote sensing images that included urban vegetation. The images captured not only normal green areas but also green roof tops. This information is of great importance to many municipalities because the exact number of green roofs is unknown in most of them. DLR scientists Thomas Esch and Julian Zeidler have been able to bridge a knowledge gap with their geo-information products. In close collaboration with the German Roof Gardeners' Association, and under the project 'Fernerkundliche Inventarisierung und Potenzialanalyse von Dachbegrünung' (Remote Sensing Inventory and Analysis of Potential for Green Roofs), they developed a software solution to map existing green roofs and to identify areas suitable for greening.

Green roof pioneer award

The project was funded by the German Federal Environmental Foundation (Deutsche Bundesstiftung Umwelt; DBU) as one of its innovative research projects for resource-conserving and energy-efficient construction, and was also presented during 'Environment Week 2016' at the Schloss Bellevue park. As early as 2014, the project was awarded the Green Roof Leadership Award in the Green Roof Pioneers category at the 4th International Green Roof Congress in Istanbul. Other partners include the cities of Hamburg, Karlsruhe, Stuttgart, Munich and Nürtingen as well as the HafenCity University of Hamburg, the company ZinCo GmbH, the German Municipal Gardens and Parks Heads Conference (Deutsche Gartenamtsleiterkonferenz) and the geo-information company EFTAS.

To develop the procedure, the partner cities provided aerial photographs as well as geodata for existing buildings. Esch and Zeidler decided to use a combination of infrared aerial photographs, building cadastral data and digital building models for their purpose. This information is available to municipalities and does not have to be procured at high cost. The infrared region of the spectrum, which is not visible to humans, makes it possible to better distinguish vegetation from similarly coloured surfaces. Scientists use the red and infrared channels of the aerial photographs to calculate Normalized Differenced Vegetation Index (NDVI). In the images, living vegetation stands out in colour from the lifeless subsoil.

The information system developed by the two DLR scientists identifies green roof surfaces on the basis of aerial and cadastral data and provides quality control. At the same time, the exact NDVI values can be used to infer the type and intensity of roof planting.

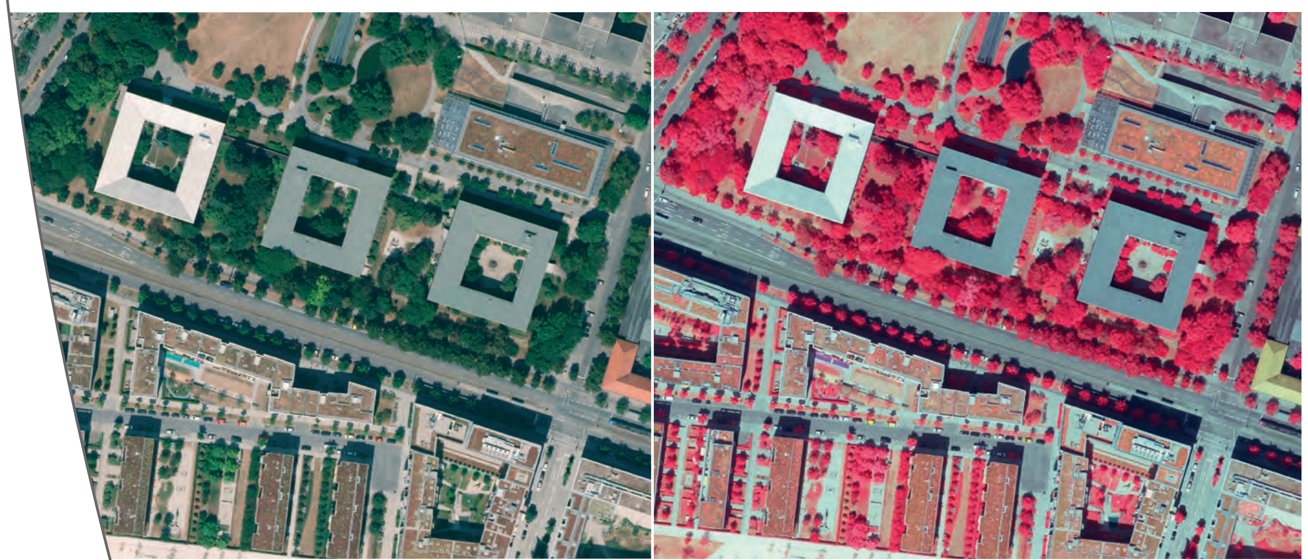
Identifying suitable building areas

Additional elevation data and parameters regarding roof inclination are also used to analyse potential locations for new green roofs. Since planting on inclined roofs is much more complex, mainly buildings with flat or, at most, slightly inclined roofs are considered for the DLR method. In addition, building statics must be observed. In particular, the roofs of factory buildings have only a low load-bearing capacity due to their method of construction. Roofs that are already covered with a gravel layer, on the other hand, have a higher static reserve for greening. Here the gravel can be replaced by a soil cover. However, this method of detection only gives an initial indication of which roofs could be used as a vegetation surface in the future. It does not substitute an accurate examination of building statics.

Numerous cities' active participation in this project clearly demonstrates the importance of green roofs to municipalities. As the first major German city, Hamburg has developed a green-roof strategy with a view to planting a total of 100 hectares of roof surfaces. And rightly so: Green roofs work in many urban ecological areas and are also retreat and recreation areas, not only for people but also for a wide variety of animals, especially birds and insects. The cooperation partner EFTAS has contractually licensed the method and already carried out a comprehensive analysis for the city of Frankfurt in 2016. Other cities have already expressed their interest.

Image: Deutscher Dachgärtner Verband

Residential buildings are increasingly being built with flat roofs. Thus, lost vegetation areas can at least partially be recreated.



Images: Stadt München

True and false colour aerial photographs: Green surfaces are shown in red in the image to the right.

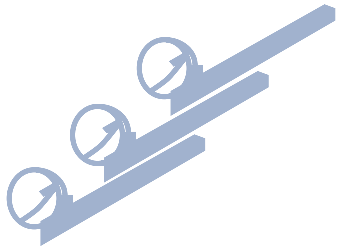
Image: Stadt München/DLR

With the aid of cadastral data, house outlines can be filtered out of aerial photographs. Roof surfaces are thus clearly recognisable.

Image: Deutscher Dachgärtner Verband

Green roofs contribute to a healthy environmental balance among all city dwellers, human and nonhuman.

SUN AT YOUR FINGERTIPS



Part two of the 'Glorious Giants' series – Synlight

By Jana Wiedemeyer

Although Jülich is not necessarily known for its bright weather, sunshine is guaranteed – if only for solar researchers. Even when the sky is full of clouds, conducting solar research is possible. Amid the Jülich Technology Center, between the solar tower and sugar factory, a hall houses the world's largest artificial Sun. 'Synlight' is the name of the research facility that Kai Wieghardt from the DLR Institute of Solar Research and his team have been developing and building since mid-2014. The goal is to provide optimal test conditions for solar thermal and solar chemical research, as well as for the development of components for the aerospace industry – regardless of the weather and time of day. The facility was officially opened on 23 March 2017.

'Bridge' between laboratory and solar tower

There have always been laboratory-scale systems for solar research. The high-flux solar simulator at the DLR site in Cologne, for instance, allows researchers to conduct solar radiation experiments on a small scale, and the weather-dependent solar tower in Jülich accommodates large-scale experiments. And now, there is also a place for solar research projects in between – Synlight. "With Synlight, we have achieved a whole new level of solar test conditions, and the development of the world's largest artificial Sun has bridged the gap between conventional high-flux solar simulators and solar towers," Wieghardt says. "The more than 350 kilowatts of radiative power exceeds that of any of the currently available high-flux solar simulators in the world." There are no systems of a comparable size. The advantages: the test conditions can be very accurately adjusted and the scientists can conduct

Image: DLR/Markus Hauschild

With its flexibly adjustable radiation modules, the Synlight facility offers optimum test conditions to develop production processes for solar fuels – even when the Sun is not shining.

Image: DLR/Markus Hauschild

An equivalent power of 10,000 times the solar radiation focused on one spot: 149 Xenon spotlights can be concentrated on a 20 by 20 centimetre area. This results in temperatures of up to 3000 degrees Celsius.

experiments independently of the weather. This will allow the further promotion of solar energy as a power source as well as boost the development of solar power plants.

Sun at the touch of a button – but how?

The building in which the Sun shines at the touch of a button resembles a two-stage cube. The front area is occupied by the control offices and three radiation chambers, where the tests take place. The frame of the artificial Sun is located in the back. An array of 149 Xenon short-arc lamps arranged in 13 rows is mounted on a 15-metre-tall steel structure. "These lamps are also used in cinemas. Their emission spectrum closely matches that of sunlight," says Wieghardt, explaining the choice of lamps. Each individual seven-kilowatt lamp is surrounded by a one-metre-diameter ellipsoid-shaped aluminium reflector. The structure as a whole is a bit reminiscent of a honeycomb – except that what is collected in the reflectors is not honey, but light.

Each reflector, with its lamp, is mounted on a telescopic arm that can be individually adjusted from a control room. Each radiator module operates independently. "This makes it possible for us to concentrate or spread out the light from all the lamps. The target points are located eight metres away in the radiation chambers. Here, we want to achieve a light concentration corresponding to 10,000 times the solar radiation. This allows us to reach temperatures exceeding 3000 degrees Celsius – which is more than is usually achieved in combustion processes," Wieghardt explains. When all the lamps are switched on, the air in the research facility can heat up to as much as 50

Image: DLR/Markus Hauschild

All lamps are equipped with a mirrored aluminium reflector and can be focused individually onto the samples

Image: DLR/Markus Hauschild

The team behind Synlight: third from the left is Project Manager Kai Wieghardt, to his right is Karl-Heinz Funken, Head of the Department.

degrees Celsius; cooling is therefore essential. This is achieved by using an air system that blows cool air in through the rear wall and releases the heated air via the roof.

Three simultaneous tests in three radiation chambers

The facility receives 3.5 million euro in funding from the Ministry for Climate Protection, Environment, Agriculture, Conservation and Consumer Protection of the State of North Rhine-Westphalia and the German Federal Ministry for Economic Affairs and Energy. It is available to users from research facilities and industry for experimental purposes. The flexibly adjustable radiator modules and three radiation chambers arranged side by side make it possible for up to three users to carry out experiments in the facility at the same time. For this, the light from the lamps is divided into three subsets – one for each of the chambers – either bundled to focus onto one point or distributed over a larger area.

"We have optimised the radiation chambers for different fields of application," Wieghardt continues. "We are now standing in the UV chamber, which means that the lamps facing us emit more UV light than the lamps in the left side of the construction. This can, for example, be of interest to our colleagues in aerospace research, as their components are generally exposed to particularly high levels of UV radiation." The other two chambers are specially designed to meet the requirements that come with solar-chemical process development testing. They are equipped with a stainless steel pipe that is directly connected to an adjacent room in which the exhaust gases are neutralised and washed – a prerequisite for many solar-chemical experiments.

A flat, wheeled trolley with a maximum payload of 2500 kilograms is used to pick up the test objects from the delivery hall on the ground floor. From there, they are pushed on a system of rails into the elevator and then into the radiation chamber, where they are positioned. In the front part of the building, shielded by a massive concrete wall, are the control and measuring rooms for the chambers. From here, the research partners – together with a DLR staff member – control the individual radiator modules. They can also monitor their experiment and evaluate the measurement results on screen.

To operate, Synlight needs energy – a lot of it. In three hours, the system consumes as much electricity as a four-person household in a whole year. However, these kinds of tests are restricted to just a few hours per month. "The aim of the facility is to obtain more energy from the Sun in the future. If we were to increase the efficiency of a solar power plant by one percent, we would be able to supply electricity to an additional 1000 households per year," says Wieghardt.

A way to the fuel of the future

The projects are from different research fields. The focus of Synlight, however, is to produce solar-generated fuels – because in the future it should be possible to 'refuel' with energy from the Sun. Solar fuels are one way of making the transport sector climate-neutral. For instance, hydrogen could be the fuel of the future – either directly in fuel cell vehicles or as an intermediate for the production of liquid fuels, such as kerosene. With solar energy, it is possible to split water into hydrogen and oxygen directly, without electricity and electrolysis. DLR researchers have already tested this successfully on a small scale.

No more than three years have elapsed since the funding agreement and the start of the project through to the festive opening of Synlight. During this time, the building, including its elaborate technical equipment, was designed, approved and built. Things did not always go smoothly because the facility is situated on historical land. A farm from the Roman Empire was located where the facility now stands. "This had to be secured before we could start constructing the building," Wieghardt recalls. In parallel with this, the researchers developed their system, built a module as a prototype and, after its successful test, installed it in their facility mainly using their own resources. "For DLR, it is probably rather unusual that a facility of this size has not been completely constructed by a general contractor," Wieghardt says. "But in this way, we were fully in control of the costs and were even able to equip Synlight with twice the originally planned radiative power without exceeding our budget. And, of course, we know our facility extremely well now."

The first attempt at generating solar hydrogen is currently under way, and the solar experts are hoping to use their facility for many more experiments in the near future. This 'Glorious Giant' in Jülich is therefore boosting solar research and the development of new energy technologies – no matter the weather.

STAR TREK – WHEN FICTION BECOMES REALITY

Fifty years of the Starship Enterprise – Special exhibition at the Dornier Museum in Friedrichshafen

By Elisabeth Mittelbach

Here I am, sitting on the exact replica of the bridge of the most famous television starship of all time – the USS Enterprise NCC 1701. Standing next to me is the not less legendary captain of this spaceship James T. Kirk, alias William Shatner. Admittedly, this Captain Kirk is a life-size cardboard cut-out like those we see in cinemas. So I am not completely spellbound. In the captain's seat right in the centre of the bridge, I put on a virtual reality headset that, unlike the other props around me, is brand new. My imaginary trip to the year 2200 is about to begin: "These are the voyages of the Starship Enterprise. Its five-year mission: to explore strange new worlds, to seek out new life and new civilisations..."

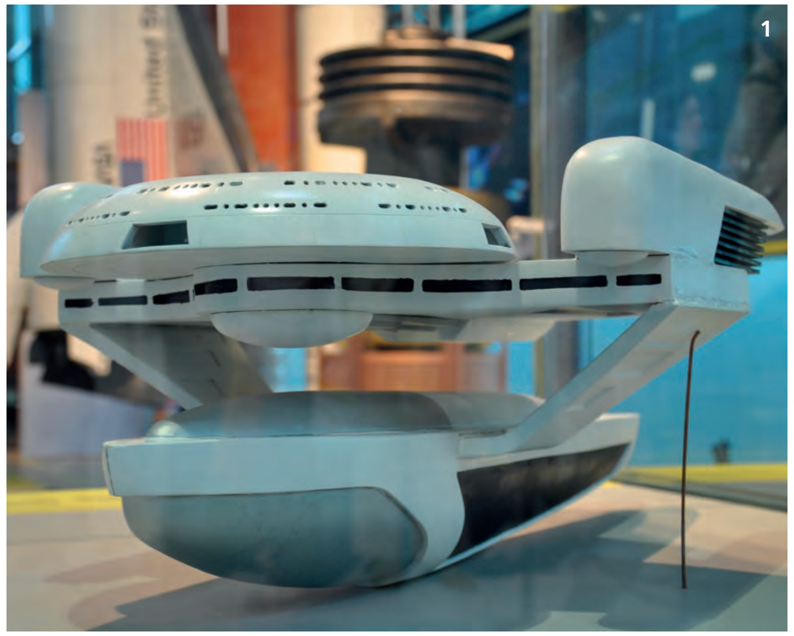
'Science & Fiction – 50 Years of the Starship Enterprise' – with this small but highly engaging exhibition celebrating the anniversary of the United States cult series, exhibition organiser and curator Ingo Weidig of the Dornier Museum in Friedrichshafen has fulfilled a childhood dream. "I myself am a 'Trekkie', a big fan of the complete Star Trek series – from the Original Series created in the 1960s to Star Trek: The Next Generation and Star Trek: Deep Space Nine, and of course, the feature films," the 35-year-old admits, adding: "I grew up in Thuringia, in the border area of former East Germany, so to me, a show about endless expanses and voyages to distant civilisations was, as Mr Spock would say, simply 'fascinating'."

First Officer Mr Spock, the Vulcan – brilliantly portrayed by Leonard Nimoy – is one of the strongest Star Trek characters alongside Captain James T. Kirk and Captain Jean-Luc Picard. Generation after generation of Trekkies have been captivated by his razor-sharp intellect and superior knowledge – as well as his apathy and lack of empathy. For Weidig and his colleague Philipp Lindner, the special exhibition in Friedrichshafen is not just about presenting the characters and the series, but mainly about demonstrating how visions from fiction have evolved through technical progress. "Star Trek was revolutionary in a myriad of ways, and the crew's adventures have had an influence on many people in science and technology, as well as on pop culture and society. We want to demonstrate what has actually come about from such a vision, to show what has become technically and socially possible," explains Weidig.

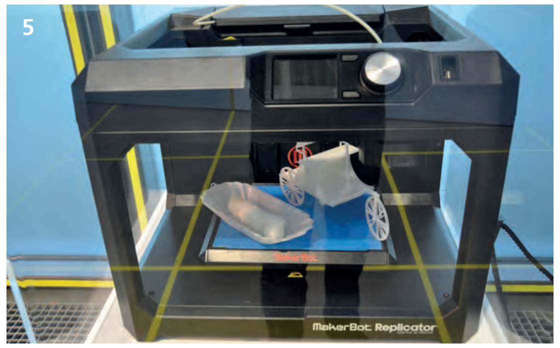
Just two decades after the end of the Second World War, a Japanese and a Russian – Hikaru Sulu and Pavel Chekov – sat on the bridge of the USS Enterprise; today, Europeans, US-Americans, Russians and Japanese astronauts work together on the International Space Station (ISS). The first on-screen kiss between the communication officer Nyota Uhura (played by African American actress Nichelle Nichols) and Kirk (played by William Shatner) followed in 1968 – right at the height of the American Civil Rights Movement. It was Star Trek creator Gene Rodenberry's way of showing that we humans are capable of surpassing borders, coexisting and treating each other with respect.

Rodenberry's personal IBM computer is on display, as are original props from the series that, like the computer, mostly come from Martin Netter's huge collection. The Berliner owns approximately 150,000 pieces from the cult series, which he acquired several years ago at Christie's Auction House in New York. Part of this treasure is being showcased at the special exhibition in Friedrichshafen – original costumes, make-up moulds for the numerous aliens, the Warp Core of the Enterprise, models of the starship from the special effects studio.

The exhibition itself takes the visitor on a 'fascinating' journey – through a wormhole, over the threshold into a new world 'to boldly go where no man has gone before'. Upon entering this Star Trek universe, visitors explore its








1 A model of the Star Trek Oberth starship class **2** The heroes from the original series – Captain James Tiberius Kirk (right) and his first officer Spock. **3** Live long and prosper – the special welcome by the Vulcan Spock is symbolic of the Hebrew character shin. It is also the first character of the word 'Shaddai' (almighty) as well as 'Shalom' (peace); today, Star Trek fans across the world use this sign as a greeting. **4** In addition to original costumes, make-up moulds and masks of many aliens of the series are showcased at the exhibition in the Dornier Museum. **5** What the replicator could do 50 years ago, a 3D printer can today. **6** Exhibition organisers Ingo Weidig (right) and Philipp Lindner on the replica bridge of the USS Enterprise NCC 1701.

origins in science fiction and the beginnings of the series – from the costumes and scenery through to the characters and scripts, and then to the recreated holodeck, located in the main hall of the exhibition, surrounded by photographs and film excerpts from Star Trek: The Next Generation. A 1:10 scale model of the ISS hangs here, as does a model of a space shuttle ready for launch.

Various themed areas explain the origins and history of science fiction – from Jules Verne's From the Earth to the Moon and Isaac Asimov, science fiction author and spiritual father of the Three Laws of Robotics, to Commander Data, an android in Star Trek: The Next Generation series. The next focal point of the exhibition is of particular interest, for this is where reality stems from fiction. Several technologies that only functioned on the Enterprise 50 years ago have now become everyday items. For example, the replicator that materialised food for the crew of the Enterprise is largely a predecessor of today's 3D printers. The communicator in the original series resembles the first Motorola clamshell mobile phone – the StarTAC – and the mini computers used in Star Trek: The Next Generation are comparable with today's tablets and smartphones. The Warp Core from the Enterprise is compared with the original thrust chamber from an Ariane 5 carrier rocket. Original models show how science has also influenced fiction – for example, a Moon base by Wernher von Braun and the Oberth starship class, named after the founder of modern rocket technology Hermann Oberth.

Only beaming is unfortunately still a pipe dream.

The 'Science & Fiction – 50 Years of the Starship Enterprise' special exhibition at the Dornier Museum in Friedrichshafen will remain open until 18 June 2017.

Opening hours:	10:00 to 17:00, Tuesdays through Sundays (9:00 to 17:00 from May on)
Entry fee:	9.50 euro for adults 4.50 euro for children and youths under 16

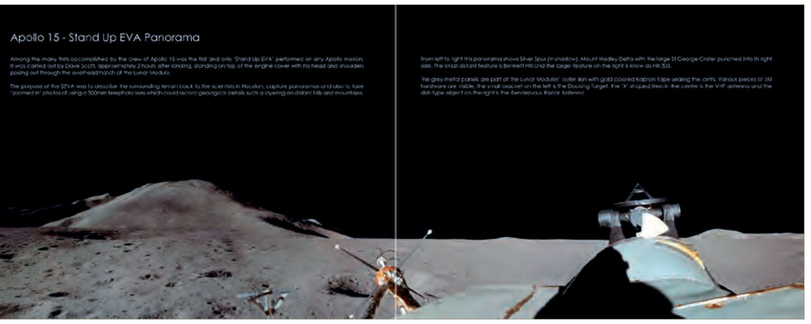
The exhibition is accompanied by a supporting programme of events and workshops. More information at: **www.dorniermuseum.de**

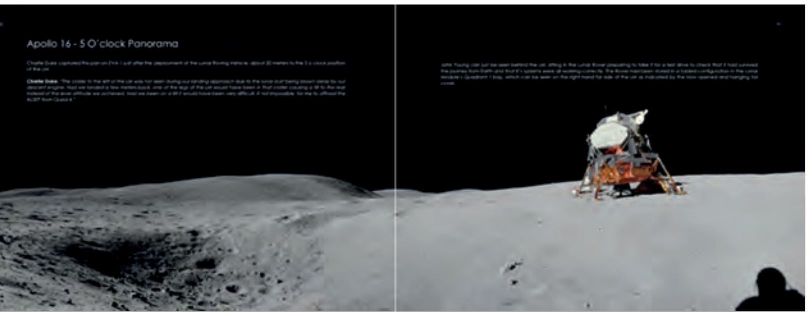
THROUGH THE EYES OF THE APOLLO ASTRONAUTS

As Neil Armstrong and Buzz Aldrin looked out of the windows of their lunar module and let their gazes wander, a ghostly, landscape lay before – grey against the blackness of space. A fascinating sight never before been seen by humans. At this moment, the first panorama of Earth's satellite was taken – from the window on the left side of the module, Armstrong photographed the Lunar landscape piece by piece, while Aldrin did the same through the right window. Had there been an incident requiring the immediate termination of the Apollo 11 mission, at least the landing site of the first ever Moon landing would have been documented.

In his wonderful landscape-format book **Apollo: The Panoramas (moonpans.com)** Mike Constantine has carefully blended, adjusted the exposure and contrast, and seamlessly combined the individual photographs acquired by the two space pioneers. The result: Anyone can now look over the Sea of Silence and, like an Apollo astronaut, enjoy the symphony of the grey gradations without having to place foot on the Moon.

A total of 56 panoramas from the various Apollo missions are presented. Each panorama is the combination of 15 to 25 individual pictures, which were taken by the astronauts during their tightly scheduled timelines at different places. Constantine names the various, sometimes more, sometimes less striking landscape features, such as hills, craters or rocks, as well as the instruments seen and the measurements they were used for, and which astronaut took the photograph. This is complemented by short quotations from the astronauts. Perhaps some more emotional commentary should have been used here that would have reflected their personal impressions better. Finally, a few of the images clearly show how far away the astronauts are from their secure base – seeming to slowly shrink into a tiny point in the panorama. Often even the colleague astronaut is lost within the lonely landscape.

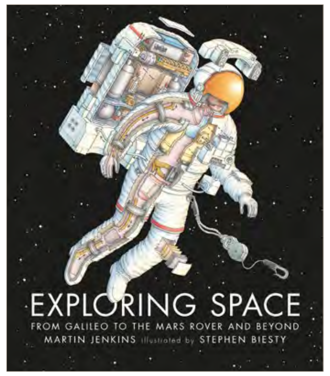




Even though most of the panoramas appear to be black and white shots – the cameras did take colour photographs. "This and similar views of the LM, Rover and our flag was always special. Other than the grey and white of the Moon, this was the only colour," recalls Charles Duke, pilot of the Apollo 16 mission. Much of course remains a monochrome experience, but with each mission, the landing sites became visually more exciting, the distances longer and the objectives of the astronauts more spectacular. The stays on the Moon and the duration of the excursions left more time for photographs. And so, as you browse the book, you can follow the exploration of the Moon as if in fast forward.

Although Constantine's text is succinct, he dedicates two double pages of facts to each mission, a picture of the respective landing site from the Lunar Reconnaissance Orbiter, as well as a schematic drawing of the astronauts' tracks. In this way, the viewer always knows from where he/she is looking across the Moon. That was not as easy for the astronauts: "Many craters look very similar as we drove, so at first we were unsure as to exactly where we were located," recalls Duke. But, he adds: "Can't get lost on the Moon! Just make a U-Turn and follow your tracks home!"

Manuela Braun



SPACE ADVENTURE

FROM GALILEO TO THE MARS ROVER AND BEYOND

Just under 35 years after it was launched in September 1977, Voyager 1 crossed the invisible boundary enveloping the Solar System (the heliopause) and crossed through into interstellar space. How humankind went from stargazing to sending spacecraft to the outer limits of the Solar System is the subject of Martin Jenkins' splendid book **Exploring Space – From Galileo to the Mars Rover and beyond** (Walker Books)**.** The text is accompanied by wonderfully detailed cross-section illustrations by Stephen Biesty.

The story begins with the ancient astronomers who discovered that Earth must be a globe or sphere as early as 300 BC. The invention of the telescope (with lenses, mirrors and later radiowaves) dramatically increased our knowledge of the Universe, and liquid-fuel rockets enabled humankind to set foot on the Moon (where their lunar landers remain to this day). Despite the author's doubt that humankind will settle on Mars in the nearby future, the book includes a great drawing of what such a settlement might look like.

The cross-section illustrations of satellites and spacecraft like the Hubble Space Telescope, Soyuz rockets, the US Space Shuttle, the International Space Station and the Mars Curiosity Rover really bring the narrative to life, triggering the imagination and sparking curiosity in youngsters and adults alike.

Merel Groentjes

CONQUERING THE UNIVERSE

FROM THE PERSPECTIVE OF THE DAY BEFORE YESTERDAY

Resources on Earth are becoming scarce. The crew of a space station is sent on a mission to Mars in search of new sources of raw materials – the theme is timeless. The Science Fiction classic **Conquest of Space (Al!ve film distribution)** from 1955, on the other hand, is markedly aged: The story does not stand up to modern knowledge of Mars. The diameter of the space station, just like 13 years later in Kubrick's '2001: A space odyssey' is much too small to create artificial gravity. And the comedic interludes are quite old-fashioned. From today's perspective, the fact that the filmmakers were inspired by rocket pioneer Wernher von Braun hardly gives any realism to the film. And a strange anxiety before the unknown is inherent to the film – atypical for the space operas of that time, which were often characterised by a naïve space optimism. But, Al!ve treats the classic to a lovingly designed media book with the film in high definition and bilingual in German/English. This is no 'trash gem', but rather a charming testimony.

Philipp Burtscheidt

RECOMMENDED LINKS

FOLLOW ALEXANDER GERST
twitter.com/astro_alex
Follow German European Space Agency astronaut Alexander Gerst on Twitter as he prepares for his next mission to the International Space Station (ISS). He will fulfil the role of commander during the second part of his six-month mission in 2018.

FLYING FIRE BRIGADE
bit.ly/2lHheT2
Global SuperTanker Services in Colorado Springs has implemented the world's biggest fire engine – a converted Boeing 747-400. It supersedes its predecessor, a 747-100, and makes for a spectacular sight as it unloads up to 75,000 litres of extinguisher agent onto large fires from a height of some 60 metres. The extensive conversion of the supertanker's interior is a marvel and can be seen via a virtual tour. There are also videos of firefighting.

POSTER DOWNLOAD
mars.nasa.gov/multimedia/resources/mars-posters-explorers-wanted/
When designing posters for Wanted: Mars Explorers, the comic style was chosen, likely for its adventurous and inspiring tones. Originally commissioned by NASA for an exhibition at the Kennedy Space Center, the print templates can now be downloaded for private use. Whether there will be Mars explorers, teachers or engineers is anyone's guess. Still, the posters are cool.

INFINITE VASTNESS
bit.ly/2kBQToc
How can the dimensions of space be made comprehensible? A virtual, true-to-scale graphic of our Solar System by Josh Worth can help with this. For most of the time, the screen is black; after almost endless scrolling, a coloured spot emerges - a planet...

WHAT HAPPENS IN WEIGHTLESSNESS?
bit.ly/2kO01Zz
What happens to the body when it is in space? The World Economic Forum foundation has explained its take on how the lack of gravity affects circulation, bones and growth. Vivid graphics make the processes understandable.

NASA's EYES
eyes.jpl.nasa.gov/eyes-on-juno.html
Unfamiliar with Juno? With an app/download from NASA, you can familiarise yourself with the Jupiter probe and other missions interactively and in three dimensions.

About DLR

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

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Cover image
The largest artificial Sun shines in Jülich – 149 Xenon short-arc lamps ensure optimal experimental conditions. With the Synlight facility, scientists are working with industry to further develop processes for the production of solar fuels.
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