Magazine of DLR, the German Aerospace Center · DLR.de/en · No. 144/145 · April 2015

DLR magazine

Into the flame
Researching combustion processes

Fit for space?
How experiments are selected for the ISS

An icy affair
When aircraft encounter the cold

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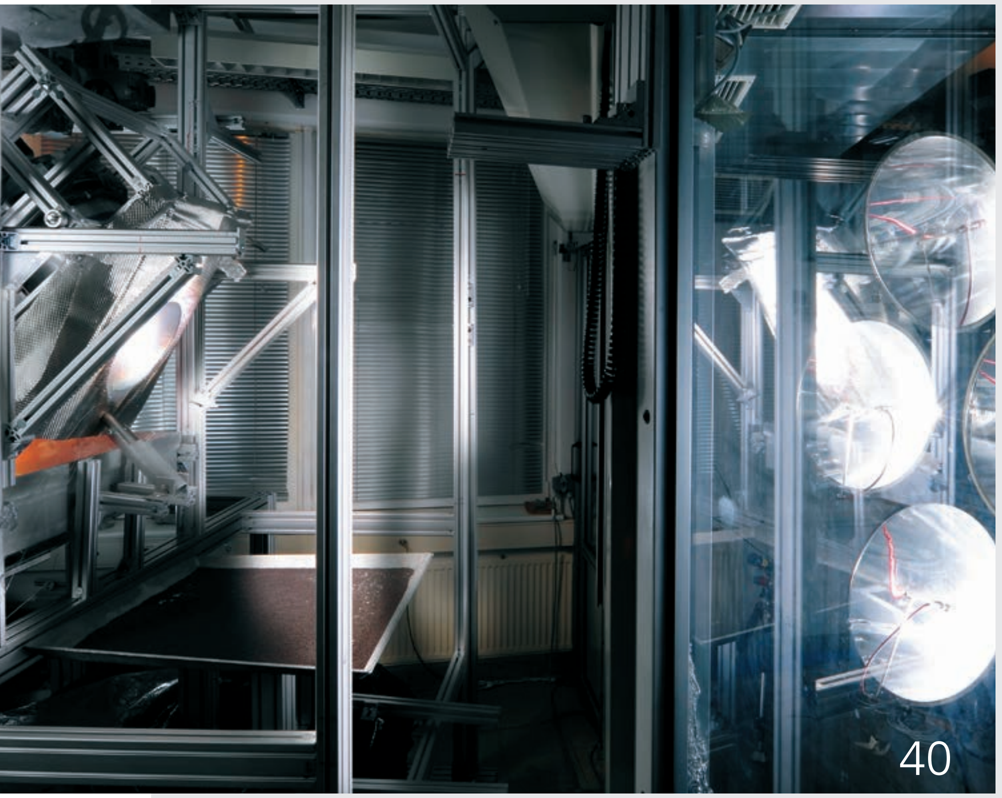
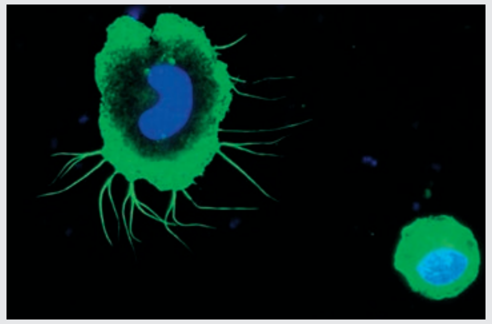
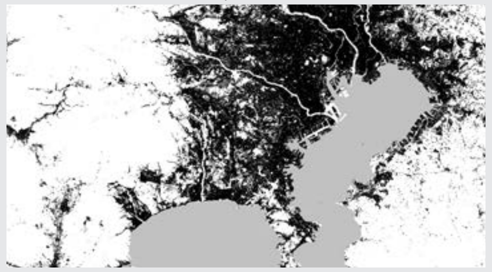
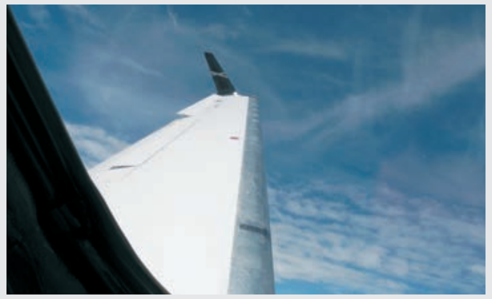


Tumbling particles at the Hanover Trade Fair

When the drum (left in the image) turns, DLR solar researchers are working on a new concept that combines a solar receiver and thermal storage. Inside the receiver, granular ceramic particles are free to move. The focusing mirrors of a future solar power plant will direct sunlight to heat the drum and the material it contains. At the end of the heating process, the ceramic particles are delivered into insulated boxes that can be removed and used to generate electricity or heat for industrial processes. The advantage is that the ceramic granules have very good thermal storage properties and are inexpensive. This and other examples of DLR Energy Research will be presented at this year's Hanover Trade Fair.







Dear readers,

Panta rhei – 'everything flows' – said Heraclitus, and DLR has not been resting on its laurels in recent months either. After Alexander Gerst's much-followed Blue Dot mission, Rosetta's successful flight with the Philae lander on board, and the latter's landing on Comet 67P/Churyumov-Gerasimenko in an incredible feat of space engineering, a new lander developed and built by DLR is already on its way. MASCOT is flying into the depths of space on board the Japanese Hayabusa-2 spacecraft. In 2019, it is due to land on asteroid 1993 JU_3. 2019! Such a mission requires competence and patience – as well as a vision.

DLR researchers demonstrate patience time and again – in combustion research, for example, where using basic research tools, they are trying to understand flames to eventually design more fuel-efficient aircraft engines. DLR has also played a visionary role in setting up transport systems as well as finding methods to determine the carbon footprint of freight transport.

Looking beyond the narrow technical environment at the larger picture is another of the skills we encourage at DLR. Our energy researchers will be at this year's Hanover Trade Fair, demonstrating the results of such a basic research to applications approach, be it in the fields of solar or wind power generators, fuel cells or thermal storage systems.

Such virtues also clearly need a working environment that provides the space to bring them to life and within which they are embedded as part of an overall strategy. In this regard, a great deal has changed at DLR in the more than seven years that Johann-Dietrich Wörner has been Chairman of the Executive Board. The overall strategy and guidelines – developed with the participation of all – provide clear orientation in terms of 'One DLR'. The articles in this magazine not only indicate great diversity, they also demonstrate how successful DLR is when the 'One DLR' way of thinking is brought to life.

Indeed – and here I quote Greek philosopher Heraclitus of Ephesus, whose insights from the fifth century BC are as relevant as ever: "Nothing is as constant as change." The DLR Chairman, who also has a predilection for aphorisms, and who has now been appointed the next Director General of the European Space Agency, spoke of his impending move by quoting Georg Christoph Lichtenberg: "I cannot say for sure if things will get better if we change; what I can say is that they must change if they are to get better."

DLR has not yet reached its goal. But the foundations laid in recent years are sturdy. We have good reason to look forward to the changes ahead.

Sabine Hoffmann
Head, DLR Corporate Communications Department

Perspective

Catching a glimpse of distant light

As its roof slides open at the Paranal Observatory, work begins for the 12 telescopes of the European Southern Observatory Next-Generation Transit Survey. They are looking for evidence of extrasolar planets, which can be detected as they transit their parent star, blocking out part of its light. DLR is contributing eight extremely sensitive cameras to this astronomical detective work.

This image was created using a time exposure. The Moon looks almost like a giant meteor. You can read more about the Next-Generation Transit Survey (NGTS) telescope on page 38.

Image: ESO/G.Lambert

Building on a solid foundation

By Johann-Dietrich Wörner

Johann-Dietrich Wörner,
DLR Chairman

DLR.de/blogs/en/janwoerner

I started in my role as Chairman of the German Aerospace Center, DLR, on 1 March 2007. Since then, DLR has continued to evolve – not only thanks to my fellow board members, but each and every colleague as well. Now that I have been appointed as the next Director General of the European Space Agency by the ESA Council, only a few months remain until I officially leave DLR. Is this the right time to take stock and begin moving on to the new task? From my perspective, no – even though someone who clearly has my best interests at heart has recommended that I now focus entirely on the new job.

Depending on how long it takes to appoint my successor at DLR, I will remain in office for several months. And – as I have done over the last eight years – I intend to use this time to drive forward developments of benefit to DLR. In fact, there are a number of issues and challenges that need to be worked on and that can be pursued in the coming months.

First and foremost, this involves strategy. It is not about leaving my mark on DLR at the last minute, but rather about consolidating the many fruitful internal and external conversations and discussions, as it is these that define the desired direction – regardless of the identity of the Chairman. The overall strategy, which was formally confirmed by the Executive Board before my appointment as Director General of ESA, indicates the primary focus. The area or programme strategies are in line with the overall strategy and focus on the relevant areas – whether they are the aeronautics, spaceflight, energy, transport or safety programmes, the Space Administration and Project Management sectors, or the support areas.

Another issue that needs to be prioritised in the coming months – in my view – is securing the financial situation. This concerns, for example, the difficult problem of sales tax. Now that the tax assessment has been submitted, we need to both continue to push for an appropriate solution at the political level and make arrangements within DLR. In this context, issues such as power saving and a wide-ranging examination of large-scale facilities are of significance.

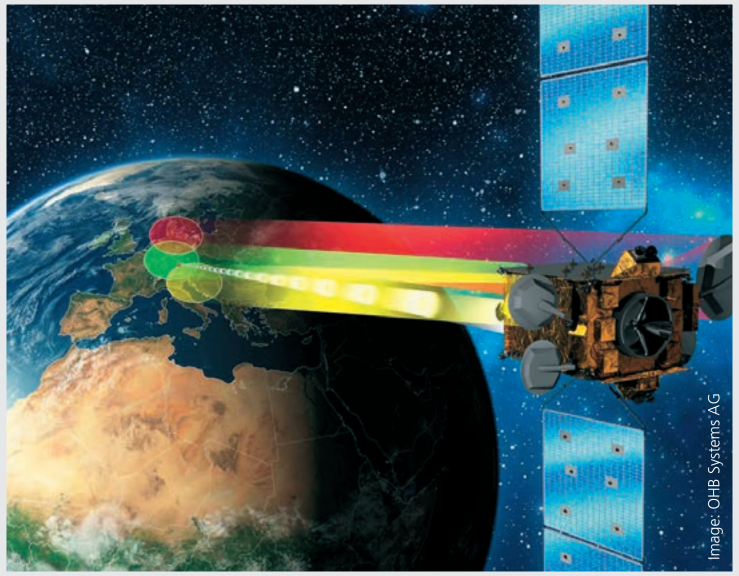
The third area for consideration in the coming period – in my opinion – is the continuation of efforts to establish institutional ties with other facilities, including universities. With DLR@UNI, we have a flexible mechanism with both national and international potential that is worth exploiting. This includes the establishment of DLR_School_Labs in cooperation with universities – as is happening in Dortmund, Dresden and Aachen.

But in addition to these very specific topics, I also see continued importance in ongoing tasks, such as DLR's position in science, industry, politics and society, maintaining a balance between work and private life, international collaborations, and the encouragement of new talent. In this regard, I shall be advocating particularly for the perpetuation of 'One DLR' – with its various areas and subjects – and the synergistic interconnectivity between them. Because I am firmly convinced that this unity – even if it is still not visible everywhere and every day – is the most important foundation for the success of DLR. ●

In brief

Milestone in the Heinrich Hertz satellite project

The German satellite mission Heinrich Hertz has moved a big step closer to its launch in 2019. The DLR Space Administration is leading this satellite mission on behalf of the German Federal Ministry for Economic Affairs and Energy (BMWi) and the German Federal Ministry of Defence (BMVg). The assignment of duties takes place under the Act on Space Science and Technology Mandating (RAÜG). An agreement has now been signed to define the terms of cooperation with BMVg. The two ministries are jointly deciding on the payload. Besides BMWi's interests in science and engineering, BMVg will use the mission to further the cause of satellite communication.



The German communications satellite Heinrich Hertz is scheduled for launch in 2019. It will circle Earth in geostationary orbit for approximately 15 years.

There would be no live shows on television without communication satellites like Heinrich Hertz, no live images from World Cup football matches and no inexpensive telephone calls abroad. These satellites are of assistance to relief services in the event of natural disasters such as floods and tsunamis, and are indispensable for the German army to communicate with soldiers that have been deployed.

In geostationary orbit, at an altitude of 36,000 kilometres, it is almost as if they are 'standing still', looking down at a fixed point on the surface of Earth. This enables a continuous flow of data, unlike low-flying satellites used for Earth observation, which are dependent on short contact times as they fly over a particular ground station. The design and manufacturing phase in the construction of the 3.4-ton communication satellite is scheduled to start this year. The principal objective is to test new technologies for satellite communication in space. The science and engineering payload is designed precisely for this purpose. Once the components have passed this 'field test' – known as in-orbit verification – the risk of a system failure decreases.

The idea is for the satellite – named after the German physicist Heinrich Hertz – to carry 20 experiments for communication, antenna and satellite technology when it sets off on its mission. These experiments are being developed and built by research institutes and industry. Heinrich Hertz will be the first communications satellite designed and constructed exclusively in Germany to be launched to space in 17 years; DFS Kopernikus 3, a German communications satellite, successfully completed its mission in 2002.

Mars Express extended until the end of 2018

Mars Express, the first and longest-serving planetary mission by the European Space Agency ESA, has now been extended until the end of 2018. The spacecraft has been orbiting our planetary neighbour for 11 years now. This additional phase will allow the DLR-operated High-Resolution Stereo Camera (HRSC) on board the orbiter to continue mapping the planet in high resolution, colour and – above all – in three dimensions.

The camera is one of seven experiments on board the spacecraft. Its purpose is to compute the first global, topographical image map of Mars. The HRSC uses nine channels (one nadir channel aimed straight down at the surface, as well as four colour and four stereo channels) to acquire images with a resolution down to 10 metres per pixel, depending on the distance to the planet's surface. Over 90 percent of the Martian surface has been mapped since 2004 – approximately two-thirds at the highest possible resolution.

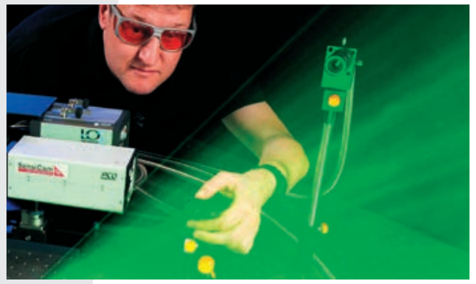
s.DLR.de/0bdc

The section of the ice cap covering the north pole of Mars shown here resembles a beach flanked by sand dunes. The craters are covered by ice or dust. A dark field of dunes stands out in the centre of the picture, most likely consisting of volcanic deposits.

Looking into jet engine combustion chambers

A method designed to provide optical measurements of reactions occurring in the combustion chambers of jet engines was tested for the first time under the quasi-realistic conditions reflecting flight operations. It was developed by DLR researchers. Image-guided endoscopic probes lay bare what happens inside a jet engine.

It will not be possible to develop durable and eco-friendly aircraft engines unless insight can be gained into the processes that happen in the combustion chambers of turbine engines. This endoscopic measurement technology will now enable researchers to acquire a better understanding of flow fields at important positions in the engine inaccessible to optical measurement technologies until now.



DLR.de/at/en/

The measurement technology in a laboratory setting: A crystal fibre introduces a laser beam into the exhaust plane of the combustion chamber. An image guide is then used to observe the scattered light as if through a keyhole.

An app to help the visually impaired in road traffic

DLR researchers, together with partners, have developed InMoBS – an app that helps the visually impaired move safely through road traffic. Users only need a standard smartphone. The app delivers information on current location or on traffic lights that are close by and provides instructions on how to get there.

The app is not intended to replace trustworthy tools such as white canes or guide dogs, but it can be a useful addition. It uses voice and vibration features to provide users with information. The app communicates with the traffic lights via Wi-Fi, and is therefore always able to determine the location of the next crossing and provide information on whether the lights installed there have an acoustic signal for the visually impaired, and whether there is a central traffic island or a ramp on the pavement. The smartphone emits an audio signal when the lights turn green, which makes the app extremely helpful at crossings without acoustic aids. It continues to provide information, for instance on transport hubs, bus stops or museums, for the entire time that the user is out and about.


The new app for the visually impaired has voice and vibration features that provide users with information on the traffic situation

MAPPING AN ASTEROID

bit.ly/1Fq09Sd

After a long journey, the Dawn spacecraft is now in orbit around dwarf planet Ceres. Why not help out researchers analyse the images acquired during the mission? Your journey to space starts here.

INTERNET TV

www.magine.com

Compatible with smartphones and tablets, Magine TV is an online television app to watch up to 70 different programmes at home or while out and about. Besides German national broadcasters, the TV app streams private stations such as ProSieben, Sat.1 and RTL, most of them free of charge. There is also a record function to catch up on TV shows broadcast earlier.

A HEALTHY LIFESTYLE – FINALLY SMOKE-FREE

bit.ly/1wU5nij

Around the world, someone dies of a smoking-related illness every eight seconds. In Germany it is over 300 every day. Smoking is also expensive, turns the skin grey and smells unpleasant. The smartphone app 'Smoke FREE' offers a way out for smokers looking to quit. The producer, a former smoker, promises that his specially designed motivational concept will help users become smoke-free and acquire a healthier lifestyle.

INTERACTIVE MEMORY

bit.ly/1B5Bp1s

The manufacturer of KIDS match'em uses humorous graphics and sound effects to offer young users more than just a memory training game on topics such as food, animals or vehicles. The child-friendly Android app comes with two difficulty settings, asking users to play a game of memory with 12 or 28 cards.

SOUNDS FROM SPACE

soundcloud.com/nasa

For years now, the United States space agency NASA has released its audio recordings from space on the music platform Soundcloud. The various recordings, from Neil Armstrong's legendary proclamation to cosmic beeps, can all be downloaded to a smartphone.

PARKING BY SMARTPHONE

bit.ly/1s5Xo1Y

This is a free app, usable in Germany, designed to step in when people find themselves without small change; it is used to pay parking fees by mobile phone. Users simply park and open the app to find the nearest machine. Parking fees are paid by direct debit. The app lets users know where they have parked their car in the past, comes with a handy 'Where is my car now?' feature, and can even manage several vehicles.

International Space Station on 10 July 2011

Fit for space?

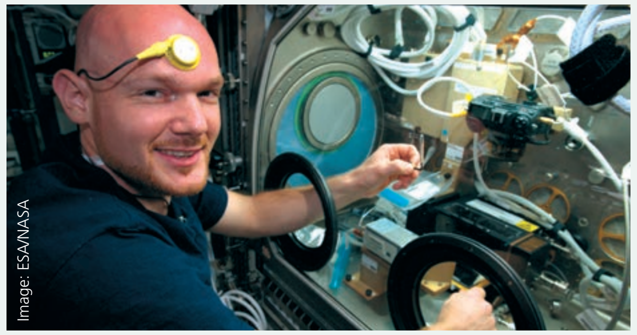
More than 1500 experiments by approximately 1700 scientists from 69 countries have been conducted on the International Space Station, ISS, since the year 2000 – 90 of them from Germany. But how does an experiment actually get onto the Space Station? What must it offer to be selected for a flight to mankind's outpost in space? What route must it take to get into orbit 400 kilometres above Earth? DLR Magazine follows four experiments on their unique journeys to the ISS, telling their story – from idea through to deployment in space.

How experiments are selected for the ISS

By Günter Ruyters, Hans-Ulrich Hoffmann, Maria Roth, Rainer Forke and Markus Braun

Giving an accurate description of the research activities on the ISS is no easy task. It could be referred to as the highest science laboratory in the world, but that would be incorrect on several counts – it is not located high on anything, and it is not on Earth. Also, its scope reaches beyond just the physical sciences; it is also a material science, physics, biology and human physiology laboratory, as well as a perfect test bed for technological developments. It would be much better just to call it the most unusual and, indeed, most international laboratory ever built by humans.

The international way – Alexander Gerst was equipped with sensors to measure his body temperature during the Circadian Rhythm experiment. The German astronaut continued the thermal experiment conducted between 2009 and 2012 during his 2014 Blue Dot Mission.



The German-US way – NASA astronaut Reid Wiseman in the United States Destiny Laboratory, working on the hardware for the fluid experiment. The equipment was transported into space in 2014, and is housed in the Microgravity Science Glovebox (MSG).

The German-Russian way – cosmonaut Valery Ivanovich Tokarev operated the PK-3-Plus apparatus in the Russian Zvezda Module on board the ISS, researching the emergence of complex plasma in a microgravity environment.

The new, commercial way – human macrophage cells and thyroid cancer cells were initially propagated in a laboratory setting for their use in space. Only the best cultures flew with NanoRacks on board the International Space Station, where their behaviour was analysed in a microgravity environment.

The thermal sensor, developed at Charité Berlin.

The ThermoLab experiment – an international journey

How can a person's core body temperature be measured without using a thermometer? This is an important issue for firefighters, for example, as they need to know if their bodies are overheating while at work putting out a fire. At the start of the millennium, researchers at the Charité Hospital in Berlin working with Hanns-Christian Gunga came up with an idea that would find its way onto the Space Station – internal body temperatures can be calculated using two double sensors that measure the heat flux in two different places – the head and the sternum. Following an official, worldwide research announcement by the International Space Life Sciences Working Group (ISLSWG), their ThermoLab project was submitted for peer review in 2004.

The Berlin-based researchers generated great interest among the international assessors and experts from various space agencies – NASA, ESA, CSA, JAXA, ASI, CNES and DLR – who were all represented in the working group. In a sense, what applies to firefighters also applies to astronauts when they are outside the Space Station. In this circumstance, they are exposed to extreme environmental conditions ranging from 200 degrees Celsius when exposed to sunlight to minus 180 degrees in shadow. Wearing spacesuits, the strenuous work they conduct can cause their core body temperature to climb to over 39 degrees very quickly. In this respect, it would be helpful for astronauts to be aware of their body temperature at all times.

However, the commonly used methods were unsuitable for use in space, for technical and hygiene reasons. ThermoLab was intended to change that – but a good idea is not enough for an experiment to be conducted in space. One milestone on the route there was parabolic flights. At the beginning, these were used to expose the sensor to microgravity for short periods of time. In total, ThermoLab flew 186 parabolas and was in microgravity conditions for over one hour in total – a good basis for deployment to the Space Station. In 2005, following a positive peer review and the consent of the ESA Programme Board, the project proposal was approved for the definition phase. This confirmed the technical feasibility of the experiment.

Once ThermoLab had overcome this hurdle, it was a matter of building the flight hardware. Usually, ESA is responsible for this; however, DLR took responsibility for ThermoLab in 2008, to drive the project ahead and enable the application potential on Earth to be put to use more rapidly. Then followed a period of testing, as an experiment must meet very strict safety standards before it can be conducted on the Space Station. Every single component in the sensor and the small electronic device was examined in microscopic detail at ESA's European Space Research and Technology Centre (ESTEC), in Noordwijk, the Netherlands. None of the materials used could be flammable, and the complete absence of bacteria was imperative. The safety conditions for the ISS are strict.

Once the test phase was complete, the flight hardware could be transferred for transportation. ThermoLab reached this stage in December 2008, when the responsible space agency – in this case Roskosmos in Russia – tested the hardware once again for transport to the ISS. When their chief engineer gave green light, it was certain – the measurement device would be flying to the Space Station.

In February 2009, it was launched on board the Progress spacecraft. The double sensor was used on the ISS for the experiment 'Thermo', and provided data from October 2009 to October 2012. Immediately after gravity is lost, more than half a litre of blood rises from the legs towards the head. Heat radiation – approximately 30 percent of which is through the head on Earth – increases significantly in microgravity conditions. On the ISS, the ThermoLab experiment was combined with other physiological performance experiments conducted by NASA and DLR to jointly acquire detailed information regarding the regulation of the cardiovascular system and heat management. The results indicate that, with the same effort, higher core body temperatures occur in microgravity than on Earth and that the core body temperature at rest after work remains higher for significantly longer. These results are important for better estimating the workloads and required rest phases for astronauts.

The ThermoLab experiment demonstrates the benefits of international collaboration and coordination for better use of the ISS, as it has been driven for years by ISLSWG. The follow-up 'Circadian Rhythm' experiment has been running on the ISS since April 2012 to continue investigating the mechanisms of cardiovascular adjustment to thermal stress, especially during physical training and extravehicular activities.

"What is exciting for a space research scientist is that you can run experiments on the ISS in which it is not clear – sometimes not even a bit – what the outcome will be. On Earth, 'switching off' gravity is not a possibility. That is why we do not know how important this factor is for the human body. The ThermoLab data acquired on the ISS thus far indicates that the core body temperature in humans clearly increases during lengthy stays in space. So far, the reason for this remains unclear."

Hanns-Christian Gunga is spokesman for the Center of Space Medicine at the Charité Hospital in Berlin and was the scientific project leader of the ThermoLab experiment.

Image: NASA

Thermal experiment being conducted on board the ISS in 2009 – two sensors attached to the skin (yellow patches on the head and chest) provided continuous measurements of core body temperature as the US NASA astronaut Jeffrey Williams completed a physiological performance test.

Image: ESA/NASA

NASA astronaut Scott Kelly in the Destiny Laboratory, working on the CCF hardware installed in the Microgravity Science Glovebox (MSG).

"We have decided to bring CCF to the Space Station because the results will have a direct influence on spaceflight. They will immediately improve the design of tanks and pipes on spacecraft, thus making space travel more efficient."

Julie Robinson, NASA chief scientist

The Capillary Channel Flow Experiment – a German-US journey

Pumping fuel without generating bubbles – no problem at the filling station around the corner, but certainly one in space where there is no gravity. In a car, the remaining fuel always gathers at the bottom of the tank, so it can be fed to the engine by the fuel pump. But how do you guarantee transporting the propellant from a partially filled tank to spacecraft thrusters in microgravity, and how can the fuel lines be kept free of bubbles? Furthermore, what maximum flow speeds can be reached without the liquid flow breaking down?

Currently, this problem is solved by simply making the tanks larger and filling them with more propellant than is actually needed. By doing this, however, the weight and volume of the space vehicle is increased and – as a consequence – the launch costs rise as well. Another option is to install special structures in the tanks to convey the fuel to the outlet as a result of capillary action, where it can then be pumped out. A design for tanks and lines improved in this way would make spaceflight more efficient. This idea has resulted in the Capillary Channel Flow, CCF, experiment, which has been delivered to the ISS. Every system on board space vehicles that contain liquids – tanks of drinking water, toilets and fuel tanks – has the problem of transporting liquid and the generation of bubbles.

Scientists at the Center of Applied Space Technology and Microgravity (Zentrum für angewandte Raumfahrttechnologie und Mikrogravitation; ZARM) in Bremen have been collaborating with Portland State University in the United States to develop a CCF apparatus that will investigate the flow behaviour of liquids in microgravity conditions. It consists of a pump that sucks a model liquid out of a tank via lines that are open at the side – the capillary channels. The scientists are investigating how fuel channel shapes behave differently and how high the pump speed can be without air bubbles being sucked into the flow.

CCF made it to the ISS as part of a collaboration between NASA and DLR. But its story differs from that of ThermoLab. That is because CCF has a long history as well; it all began in 1994, when Michael Dreyer from ZARM had the idea of investigating the behaviour of liquids in microgravity, which he submitted to NASA. The idea became more concrete in April 2002 – ZARM and NASA jointly conducted a science concept review. However, the review was immediately followed by disillusionment – NASA temporarily put its microgravity programme on hold. But the CCF story continued in Germany and Sweden – from 2000 to 2008, the experiment was flown on four TEXUS campaigns. The flights on sounding rockets launched from the European spaceport in Kiruna in northern Sweden were a 'baptism of fire' for deployment on the ISS. During this period, a great deal of testing was also carried out at the ZARM drop tower in Bremen. Here, the experiment was installed in a capsule and dropped numerous times from a height of 100 metres into a deceleration chamber. On its way to the ground, the experiment was in microgravity conditions for 4.7 seconds.

During this time, the scientists worked with EADS Astrium (today Airbus Defence and Space) under contract to the DLR Space Administration on the hardware for possible deployment on the ISS. In February 2007, nothing stood in the way: DLR and NASA signed a joint collaboration agreement for the CCF research programme on the Space Station. DLR was responsible for the development of the flight hardware, NASA for transporting it to the ISS, for the astronauts' crew time, for the power and for installing it into the Microgravity Science Glovebox (MSG) in the Destiny module. The hardware was ready in 2009. But before its trip to the ISS and installation in the MSG, the apparatus had to undergo numerous tests again at the NASA site in Huntsville, Alabama. On 5 April 2010, CCF was launched to the ISS on the Space Shuttle Discovery. The sequence of experiments then ran from February 2011 to September 2014 almost in real time, fully remotely controlled from ground stations at the two university institutes. All the measurement data was transmitted to the ground and is being used to acquire knowledge for spaceflight technology, as well as for applications on Earth – in biomedicine, for example.

When unobstructed, liquids will flow constantly up to a certain speed under microgravity conditions. If the pump suction pressure is increased until the flow velocity exceeds a threshold value, bubbles form at the boundaries of the apparatus and the flow stops abruptly.

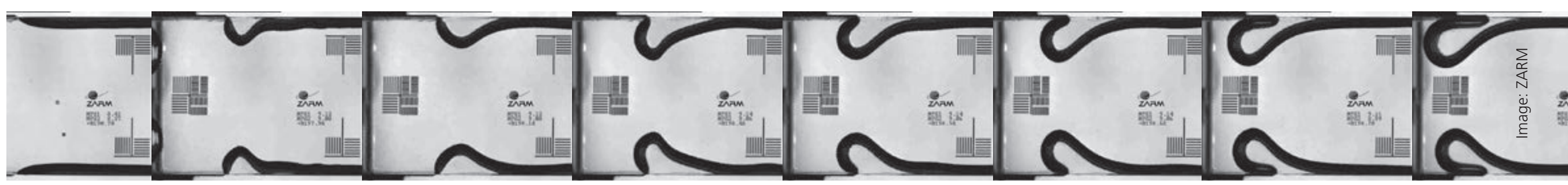


Image: ZARM

The Plasma Crystal experiment – a German-Russian journey

Plasma crystal research in microgravity has a long German-Russian tradition that began back when the ISS was still being built. In April 1998, the Russian High Energy Density Research Center (HEDRC, now the JIHT – Joint Institute for High Temperatures) signed a cooperative agreement with the Max Planck Institute for Extraterrestrial Physics (MPE) to investigate complex plasmas in microgravity.

Plasmas are electrically-charged gases with free electrons and ions and are the least orderly state of matter. Around 99 percent of the visible matter in the Universe consists of it, including the Sun, lightning and the Northern Lights. Besides their significance in astronomy, plasmas are important in many areas such as lighting technology, surface technology, tools processing, hygiene and medicine. A complex plasma, such as occurs in the rings of Saturn or in comets' tails consists (like the fluorescent in a fluorescent light) of a low temperature plasma and small particles (dust) up to 20 microns in size. However, a complex plasma reacts very sensitively to gravity because of the mass of the microparticles it contains, which is 100 billion times greater compared to electrons and ions. The particles fall and compress the complex plasma in the direction of gravity. Hence, large 3D structures can only form without distortion and be studied in zero gravity. Scientists are interested in the physical properties of complex plasmas.

While the Russian side was responsible for transportation into space (initially to the MIR space station), conducting the experiments, transferring the data, returning video tapes and cosmonaut training, the MPE on the German side was expected to secure financing for the experimental equipment. The MPE subsequently contacted the DLR Space Administration – at the time still the German Agency for Space Affairs (Deutsche Agentur für Raumfahrt Angelegenheiten; DARA). However, a similar MPE experiment was already on the programme at DARA in Bonn – and was due to be run in the NASA Getaway Special (GAS) programme in the payload bay of the Space Shuttle. Two experiments would have been too expensive. In Bonn, the decision on the German Russian Plasma Crystal Experiment (Plasma-Kristall-Experiment; PKE) got lucky, as NASA stopped the GAS programme shortly afterwards. PKE officially made it onto the list, agreed between the space agencies DARA and Roskosmos, of potential German-Russian cooperations. After MIR ceased operations, PKE was adopted into the experimental programme for the newly planned International Space Station in October 1999, which initially consisted of just the Russian Zarya module.

As a result, within a half year, an ISS experiment was born from a Space Shuttle experiment and a no future MIR experiment. In November, the financing was secured on the German side. The construction of the ISS plasma apparatus at the MPE, supported by the German aerospace industry, could begin. In February 2001, the PK-3 apparatus was launched to the ISS, and the first ever cycle of physics experiments on the Space Station started in March. Nowadays, it is impossible to think of there being no plasma research on the ISS. In early 2006, the successor PK-3 Plus followed and, in October 2014, the new PK-4 unit, which took shape after the transfer of the MPE work to the new complex plasmas working group at the DLR site in Oberpfaffenhofen. The experiments using PK-3 and PK-3 Plus were made possible on the ISS because the 'right' institutes had concluded a collaborative agreement. The basis of the collaboration was 'no exchange of funds' – all parties involved contribute their own resources. The schedule was extremely ambitious and was only able to be implemented because of the outstanding collaboration. It took less than three years from the decision for launch to its arrival at the ISS.

In the new PK-4 experimental system on board the ISS, complex plasma crystals can be created with an 800-volt discharge in a cylinder filled with an inert gas – similar in principle to using a neon tube as an experimental reactor.

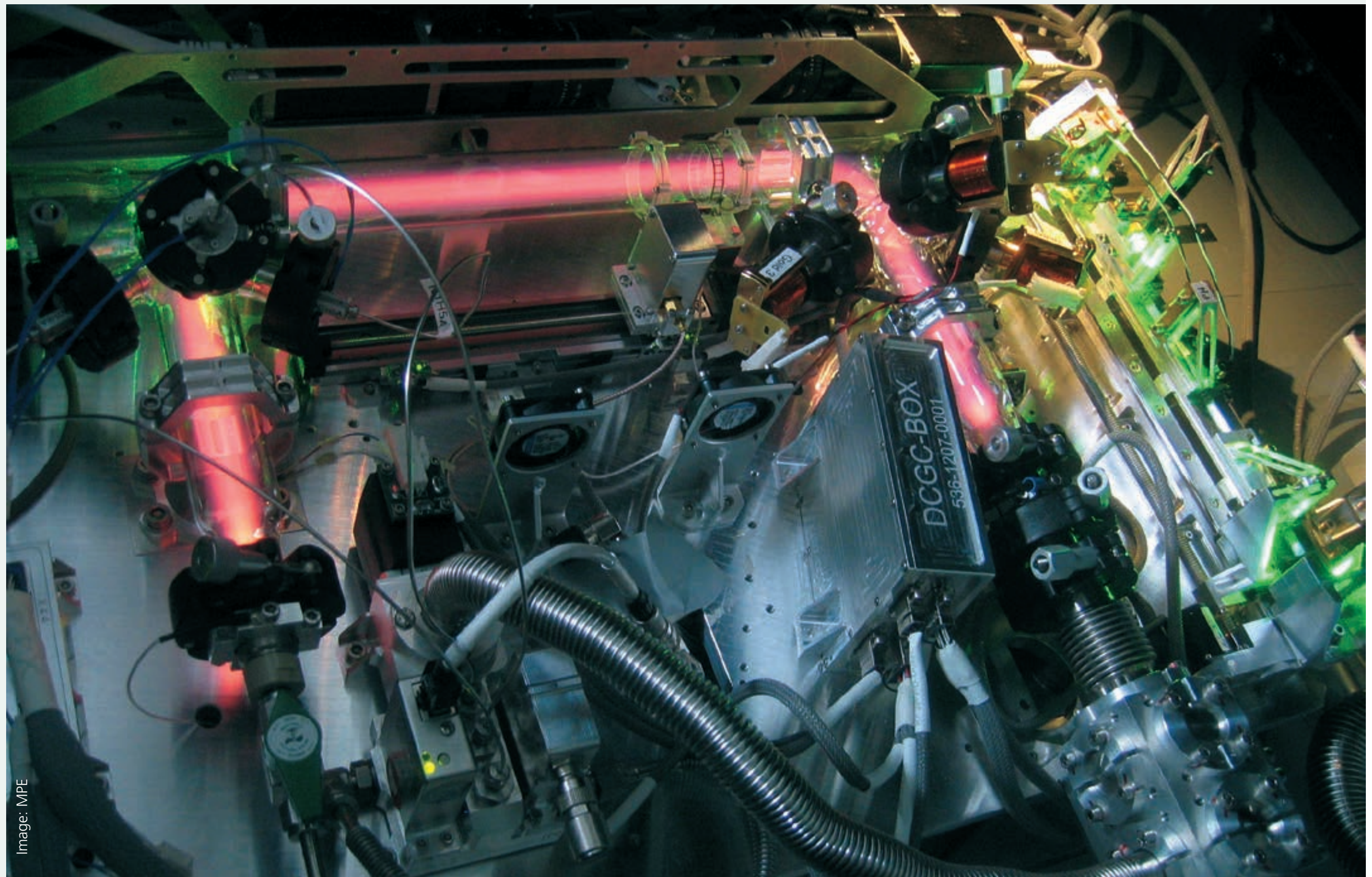


Image: MPE

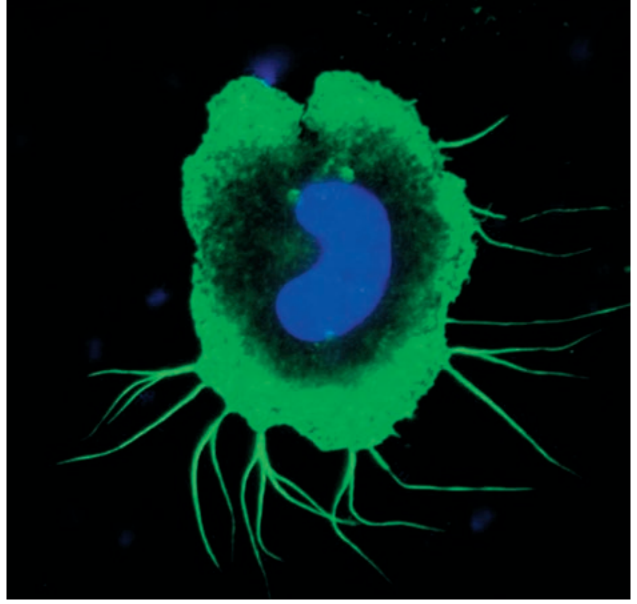


Image: Svantje Tauber/AG Ulrich/Universität Magdeburg

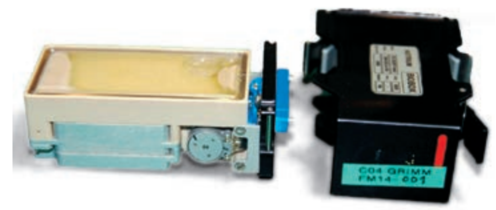
In the second CellBox experiment, millions of macrophages were exposed to microgravity on the ISS. The 'phagocytes' of the immune system travel through the body and destroy invading microorganisms and other foreign substances. Preliminary tests on DLR parabolic flights indicated that the activity of macrophages is influenced by altered gravity conditions. This could be one of the causes of the impaired immune function experienced by humans in space.

The CellBox Experiment – a new journey

DLR was presented with a slightly different opportunity for getting German experiments to the Space Station through US commercial companies that have been offering research facilities for scientific use on the ISS for several years. With the CellBox Project, German industry was commissioned to support two biomedical experiments. Transport to the ISS and conducting the experiments in space was under responsibility of a commercial service provider for the first time. The company NanoRacks was founded in 2008 to commercialise the use of the ISS and open it up to more users in the US. Today, about one quarter of the company's revenue comes from NASA, but the vast majority is from customers worldwide. With the CellBox missions, the DLR Space Administration is testing a new way to offer German scientists comparatively fast and inexpensive options for carrying out experiments in space. To this end, two science teams at the University of Magdeburg are working hand-in-hand with representatives from German industry and from NanoRacks.

Two cell cultures were launched to the ISS on board a Dragon spacecraft, operated by US company SpaceX, from the space centre at Cape Canaveral in Florida on 18 April 2014. Two different types of cell are used in the CellBox experiment: firstly, a macrophage – the immune system's 'scavenger cells' – and secondly human thyroid cancer cells. Before the launch, the cells were prepared in the laboratory and placed into sample chambers. Macrophages move through the human body and digest microorganisms and other foreign substances that have entered it. One focus of the experiment was the analysis of specific surface molecules responsible for the detection of foreign bodies and the communication between cells in microgravity and similar conditions. Furthermore, the cytoskeleton and certain secretion products such as cytokines, which regulate cell growth and differentiation among other things, will be studied. This can be used to determine the condition of the cells and to precisely measure any changes. Therapy or medication can only be developed if the cellular causes for immunodeficiency in microgravity are understood. Preliminary tests conducted during DLR parabolic flights have indicated that macrophage activity is influenced by changes in gravity. This could be a cause for the immune deficiency experienced by humans in space.

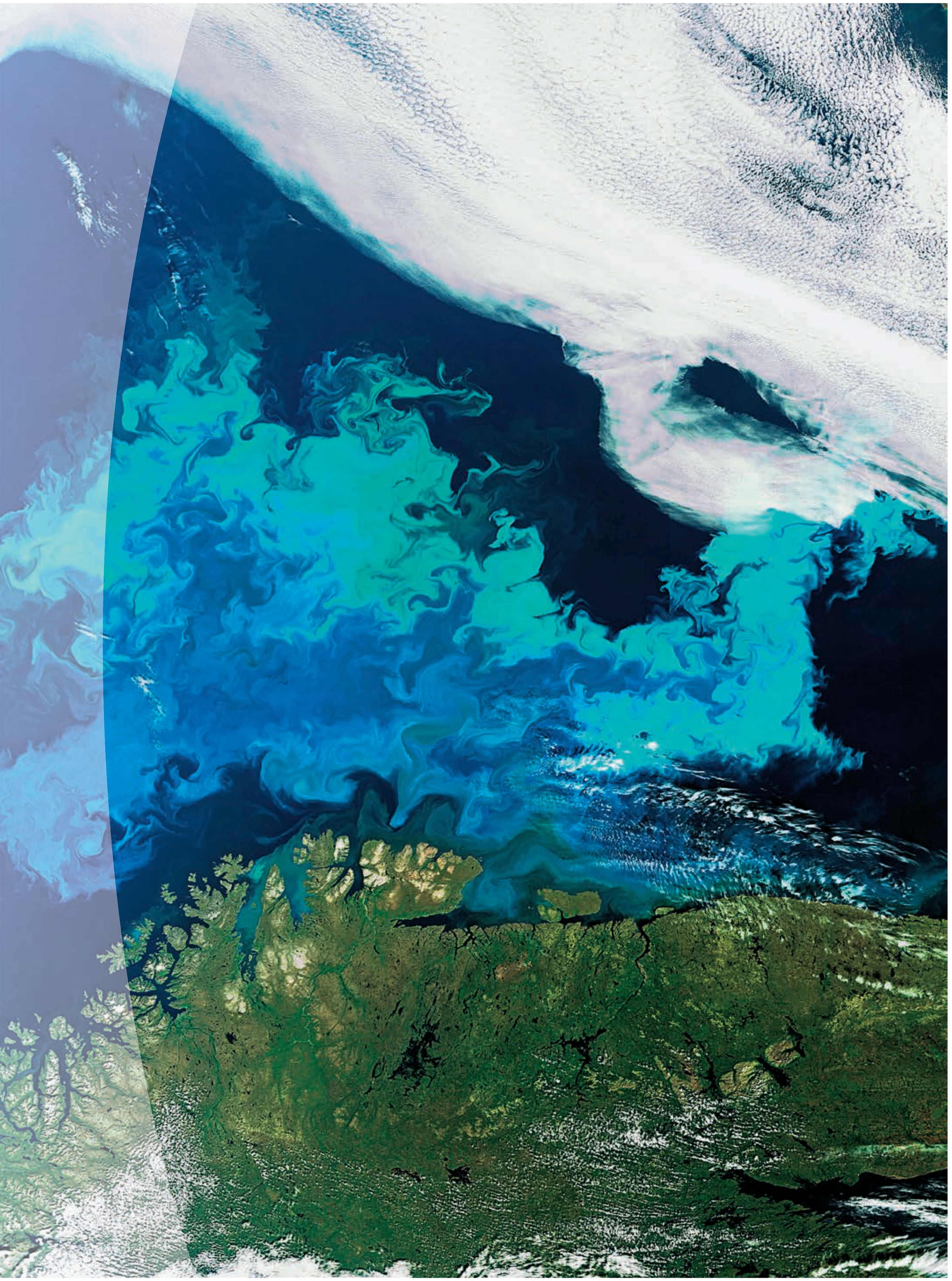
The second CellBox experiment focuses on thyroid cancer cells. It involves studying cellular and molecular changes in the way these cells function as a result of the absence of gravity. The cellular biologists at the University of Magdeburg want to use this knowledge to find new therapeutic methods for combating tumours. In microgravity, cancer cells form spherical agglomerations – spheroids – consisting of thousands of tumour cells similar to the original tumour. Following experiments in space such as the German-Chinese SIMBOX Project, the researchers know that thyroid cancer cells in microgravity change the way they produce a wide range of proteins as a result of various physiological processes. Cancer cell reproduction and metastasis is influenced in precisely the same way as cell death, cellular movement and stimulus processing. These results are now expected to be confirmed and expanded upon in the CellBox experiment. The tendency of cells to grow in spherical agglomerations in microgravity is also of interest in another regard – tissue engineering involves generating three-dimensional tissues. Scientists have previously managed to cultivate vessel-like structures in microgravity. Now, the researchers intend to continue this work as part of the CellBox experiment for use in medical advancement. ●



On the ISS, the cell cultures prepared by scientists from the University of Magdeburg were subjected to microgravity conditions. Their 'habitat' was the CellBox experiment chamber, which is roughly the size of a smartphone. The image shows the chamber, equipped with a pump and tanks for supplying nutrients and fixing the cells. After 30 days in space, the cell cultures and the small experiment chambers were returned to Earth in the Dragon capsule, where they were analysed by the scientists.

About the authors:
The authors work at the DLR Space Administration.
Günter Ruyters was head of the Biosciences Programme in the department of Research under Space Conditions until August 2014; Hans-Ulrich Hoffmann was responsible for the ThermoLab project. Maria Roth is responsible for the Plasma Crystal Experiment, Rainer Forke for the CCF experiment and Markus Braun for the CellBox experiment.

More information:
DLR.de/ISS/en



Algal blooms at North Cape: the environmental satellite Envisat peered down through its MERIS instrument as the phytoplankton bloomed in the Barents Sea, close to Europe's northernmost outcrop.

Monitoring the environment from space

Satellites observe Earth, providing round-the-clock weather, mapping and environment data to help explore, measure and better understand our planet. Modern life and societies demand far greater knowledge than just one generation ago. Global climate change, sustainable development of our environment, prudent consumption of resources and safeguarding mobility are just a few of the catchphrases in this age.

Earth observers from 70 countries come together in Berlin

By Helmut Staudenrausch and Gunter Schreier

During the 36th International Symposium on Remote Sensing of Environment, ISRSE, around 1000 experts will gather in Berlin from 11 to 15 May 2015 to share their knowledge about the latest developments and technologies across all the technical disciplines of Earth observation. The recently launched European Copernicus Programme, national undertakings such as the German radar satellite mission TanDEM-X, preparations for EnMAP and new Earth observation technologies are just a few of the items on the extensive Berlin agenda.

Earth observation from satellites is now an indispensable part of daily life – and this is by no means restricted to increasingly precise daily weather forecasts. For instance, it is possible to monitor maritime traffic from space, draw conclusions regarding the causes of oil slicks and even determine optimum shipping routes. Satellite data can be used to identify ideal and safe locations for new housing estates and farming. Changes or threats to forests and farmland, the air and water resources are best observed from outside the atmosphere. The consequences of severe natural catastrophes such as floods and earthquakes are most easily surveyed by satellites.

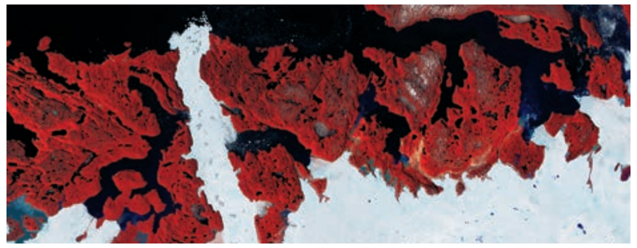
Germany and DLR are involved in many of these Earth observation tasks – not alone, but hand-in-hand with various international partners. DLR and other German researchers will participate in the ISRSE Symposium to take stock of the current situation, discuss upcoming goals and explore the path to achieving them. As part of the Living Planet Programme, Germany contributes to Earth and climate science research satellites developed by the European Space Agency (ESA). A number of these satellites are already orbiting Earth, observing the melting of polar ice caps and the changing thickness of sea ice (CryoSat-2), the soil moisture content over land and the salinity of our oceans (SMOS), as well as the structure of Earth's magnetic field (Swarm), among other things. Coming years will see the launch of additional satellites, designed to observe the dynamics of Earth's wind fields (ADM-Aeolus) and the behaviour of clouds and aerosols (EarthCARE) – to name just a few.

EUMETSAT, the European Organisation for the Exploitation of Meteorological Satellites, operates weather satellites like the Meteosat family. The Copernicus Programme, part of the European Union's space activities, is one building block in the endeavour to provide reliable and sustained Earth observation in cooperation with ESA. This involves the production and operation of various satellite series – the Sentinels – to ensure that each point on Earth can be observed with enough frequency and without interruption. The first satellite, Sentinel-1A, has been in orbit since April 2014. Its next sibling, Sentinel-2A, is scheduled for launch immediately after the ISRSE Symposium. In addition, Germany is actively involved in international networks and initiatives. Coordinated across the globe, these networks provide data to, for instance, model and monitor climate change, to provide assistance in the wake of natural catastrophes or to assist in the protection of tropical forests.

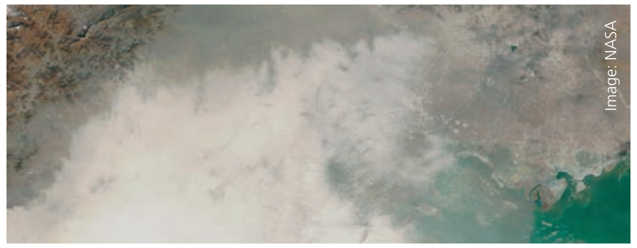
Experts from international bodies such as the Group on Earth Observations (GEO), the Committee on Earth Observation Satellites (CEOS), the International Society of Photogrammetry and Remote Sensing (ISPRS), together with numerous other specialists from space agencies and the aerospace industry, will meet in Berlin to discuss these and many other topics and look into the future of Earth observation. ●

About the authors:
Helmut Staudenrausch works in the Earth Observation Department at the DLR Space Administration and chairs the Organisation Committee for the 36th ISRSE. Gunter Schreier, from the German Remote Sensing Data Center at DLR, chairs the symposium's Technical Programme Committee.

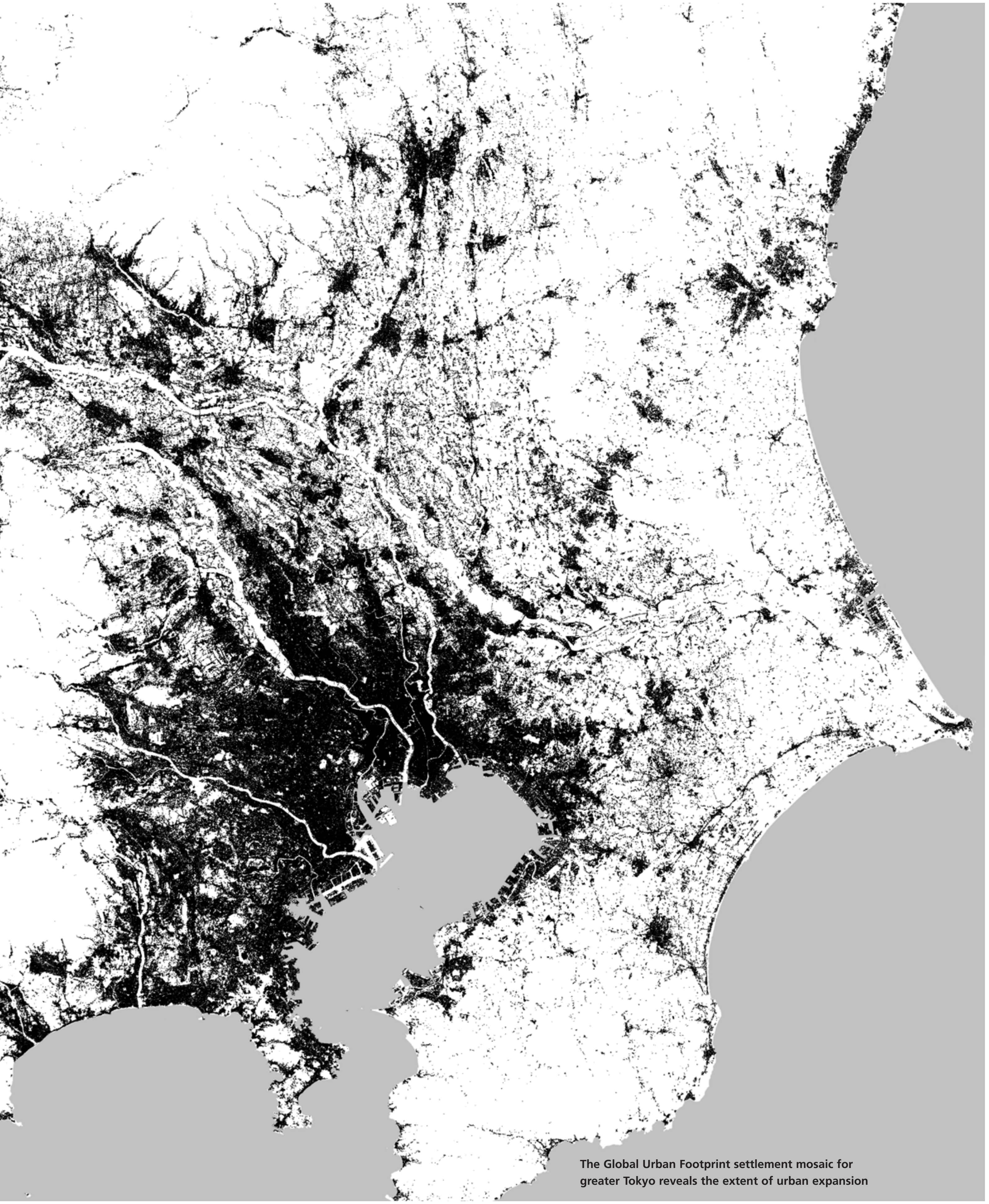
More information:
www.isrse36.org



Greenland's Jakobshavn Glacier



Smog over Beijing, China.


The Global Urban Footprint settlement mosaic for greater Tokyo reveals the extent of urban expansion

Footprints of humankind on the Blue Planet

A large-scale transformation has occurred on Earth, largely ignored in headline stories on the topic of global change – for some years now, the number of people living in urban areas has exceeded that of those living in rural regions. The trend towards urbanisation shows no sign of abating. In particular, cities in Asia and Africa are expanding at a staggering pace. Megacities are springing up in a matter of years and urban sprawls are emerging, spreading across extensive swathes of landscapes that, until recently, had been untouched by development. How can the opportunities that urbanisation presents be put to good use? How can the negative effects of such rapid city growth be mitigated or avoided? This is one of the central challenges that society will face over the coming decades. DLR is using Earth observation data to help create sustainable urban development.

Radar data documents urbanisation with hitherto unseen precision

By Thomas Esch

The future is urban. Today, approximately 7.2 billion people inhabit Earth. By 2050, this number will have risen to nine billion, 70 percent of which will be living in cities. In future, urban areas will account for 90 percent of population growth, 80 percent of increased prosperity and around 60 percent of energy consumption. Urban conurbations will occupy a key role as centres of political, economic and cultural life. They will exemplify the future, defining how the coming generations will live and work.

Managed urban development requires knowledge about how dynamic urban systems interact with the natural and man-made landscape that surrounds them. To what extent do cities damage the environment by consuming land and resources, polluting the air and the water, or by reducing biodiversity? To what extent are cities threatened by natural hazards and climate change? How have urban regions developed in the past, and how should they do so in future?

Urbanisation playing out across the world has regional roots, but it also comes with common drivers and causes. A global view is required to identify what they are. It is here that Earth observation can make a valuable contribution. It helps differentiate between urban and rural settlement forms and to introduce systems of categorisation and delineation. Satellite-based geo-information delivers a current image of progressive urban sprawl, while at the same time documenting its changes over time.

Satellites record settlement areas

Satellites enable continuous mapping of Earth's surface. They allow researchers to record the expanses of cleared forests, lost agricultural land and constructed settlements. But until now, the perception of inhabited areas has lacked a spatially detailed global view; populated areas and those used for infrastructure are frequently hard to distinguish in optical satellite images. Now, scientists at the German Remote Sensing Data Center (DFD), part of the DLR Earth Observation Center (EOC), have succeeded in using a newly developed method to map the world's cities at an unprecedented spatial resolution. A fully automatic image analysis system has used radar data to create a global settlement mosaic at a resolution of 12 metres – the 'Global Urban Footprint'.

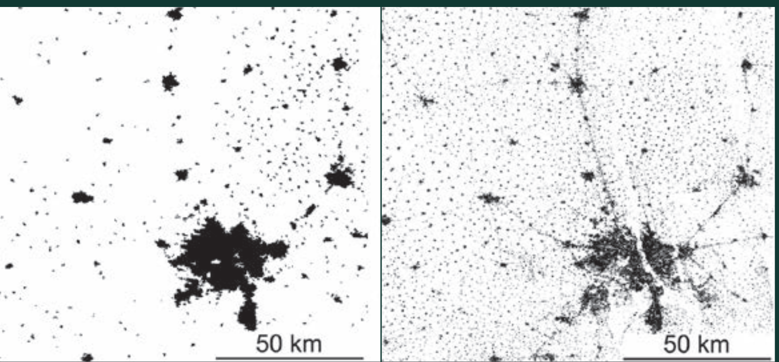
Over 180,000 images acquired by the German radar satellites TerraSAR-X and TanDEM-X between 2010 and 2013 were processed – together with additional data such as digital terrain models – to produce the Global Urban Footprint. In total, the researchers processed over 20 million datasets with a combined volume of 308 terabytes, equivalent to the information contained on roughly 440,000 compact discs. The team applied sophisticated algorithms in a complex decision-making process to assign each of the roughly 50 billion pixels to one of three coverage types: settlements in black; land surface in white; water in grey. This focus on three categories clearly highlights the settlement patterns, improving the ability to analyse and compare them with other built-up areas across the world. Unlike previous approaches, this fully automatic evaluation procedure detects the characteristic vertical structures of human habitations – primarily buildings. In contrast, areas used for infrastructure purposes are not mapped. This is why broad urban canyons or expanses of greenery within the cities are shown as white corridors and patches.

Accurate maps of urban sprawl

The Global Urban Footprint delivers unparalleled precision. Until now, global analyses have been unable to identify small villages. The single-set satellite systems used offered a maximum resolution of 300 metres, but it is particularly important to consider smaller scale settlements in addition to metropolitan areas. In many cases, villages are symptomatic of a gradual spread in urban development. Disorganised, small-scale settlement is increasingly destroying arable farmland in rural regions and leading to the fragmentation of important natural environments. Biodiversity is reduced and, as the separated areas grow smaller, the environment gradually loses its robustness and capabilities.

Recent estimates have shown that settlements cover between one and three percent of Earth's landmass. The DFD Global Urban Footprint paints a different picture. The proportion

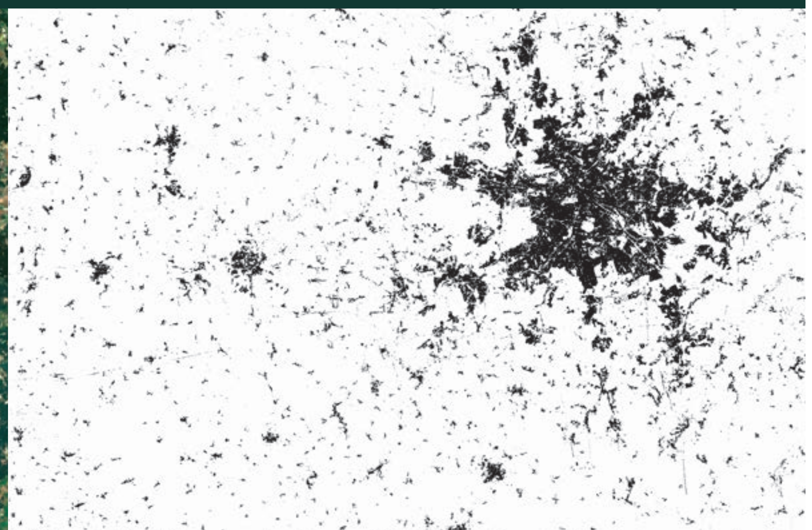
European settlement mosaic derived from the Global Urban Footprint dataset



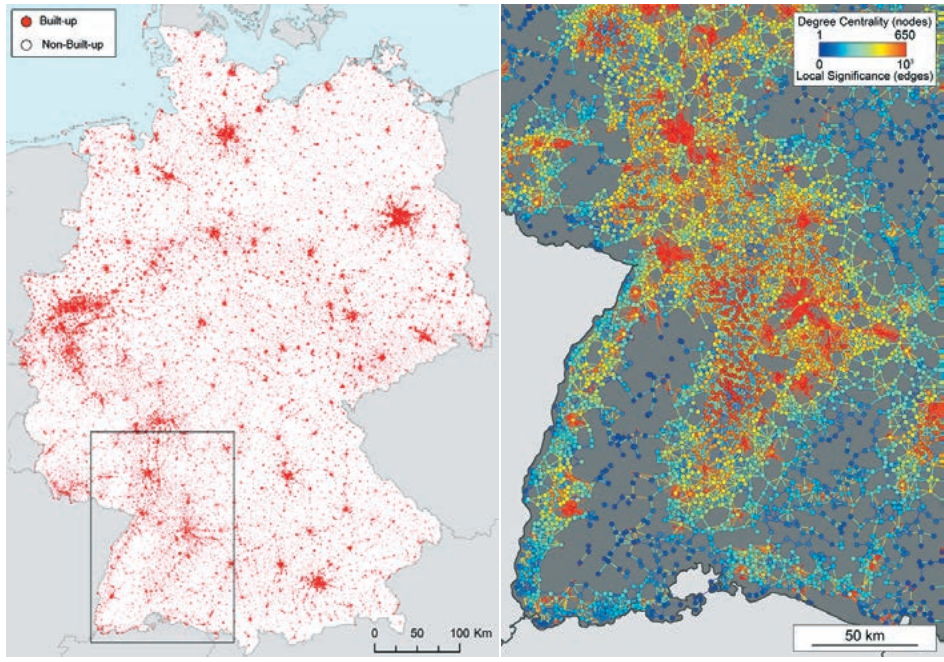
A comparison of the spatial detail between previous global settlement maps (left) and the new Global Urban Footprint data (right) using the example of the Indian megacity Delhi

Settlement mosaic showing the northeastern seaboard of the United States with the prominent 'BosWash' conurbation snaking its way from Boston to New York and on to Washington

Comparison – an optical satellite image of Berlin …



… versus the settlement mosaic compiled using Global Urban Footprint data



Settlement mosaic of Germany and an excerpt from a spatial network produced on this basis to characterise the density of all recorded settlements. Here, the red areas indicate a high density of primarily larger settlements, while more remote, smaller localities are shown in blue.

of developed areas has been underestimated in many instances, especially in rural regions. While the percentage differences may be slight, they nevertheless have substantial relevance. Life and work in even the smallest village influences the immediately adjacent environment. A network of small settlements can change the character and ecology of entire areas.

Global diversity of settlement patterns

Settlements reflect the landscape and society. In many cases, they emerged centuries ago in locations offering favourable natural resources or geopolitical advantages – on fertile plains, beside the junctions between important trade routes or along coastlines and rivers. Some of them developed to become growing economic centres, expanding into every available space and precipitating the emergence of satellite cities. In other cases, the burgeoning structures have been more rural in character – a network of hamlets stretching along rice paddies and canals in China, a pattern of villages dotted through cleared forests in southern Germany or the farmyards strung out at regular intervals in the more industrialised agricultural sector of the United States. Hence, settlement patterns and development structures provide a unique and exciting insight into the origins of and cultural history leading to human urbanisation and farmed landscapes. They also show the economic and social trends of more recent times.

It has taken just a few decades for densely packed urban landscapes to emerge in many locations – among them numerous megacities with more than 10 million inhabitants and surrounding regions occupying expanses several hundred kilometres across. Many conurbations blend and merge in these regions, among them Tokyo-Yokohama – with over 37 million inhabitants – and the 'BosWash' belt – a sprawl of cities home to roughly 45 million people, spread across Boston, New York City, Philadelphia, Baltimore and Washington DC.

Precise data and new evaluation methods

The Global Urban Footprint is currently undergoing validation. DFD will make its results available to other researchers in 2015. Examples of its use will include the first comprehensive description of global urbanisation, improved modelling of how cities affect the climate, more precise risk analyses for earthquake and tsunami regions, and assessments of human impact on ecosystems. In addition, DFD has developed a method to quantitatively and qualitatively analyse and compare settlement patterns on a continental and even global scale. Here, all connected settlement areas indicated in the Global Urban Footprint are joined to produce merged objects. Then, for each of these objects, the researchers compute several underlying properties based on size and shape and also compactness, within the overarching settlement structure. The final stage involves connecting all developed areas to produce one spatial network, which is then used as a foundation to efficiently and effectively describe the relationships between the different localities in terms of their centrality and connectivity.

The new dataset from the Global Urban Footprint and the newly developed evaluation method help to acquire a better understanding of the urbanisation phenomenon and hence, in future, to respond appropriately to the immense social challenges of mushrooming cities, population explosion, climate change and the erosion of biodiversity. By improving the quality of spatial analysis and modelling, scientists benefit from the increase in the precision of data relating to settlement structures. Planning agencies and development banks are also important users of these new data and technologies. For instance, uniform data – applicable worldwide – on the location of settlements and including important parameters on their sizes and shapes, as well as their compactness, help with the derivation of important information of a kind urgently needed in infrastructure planning. This is a crucial advantage, especially in remote and underdeveloped regions of Earth, where suitable geographical data are frequently scarce. ●

More information:
DLR.de/guf/en

The Global Urban Footprint Initiative – GUF

Participants: Thomas Esch, Wieke Heldens, Andreas Felbier, Mattia Marconcini, Achim Roth und Julian Zeidler

In the wake of the leading bird

About a century ago, natural scientists unravelled a secret about flocks of birds. They recognised the advantages of flying in formation – the upwash generated by the bird flying ahead reduces the air resistance for the one behind, so it therefore expends less energy. The outcome is that birds flying in formation significantly extend their range. Could this also be an option for aviation? Researchers from the DLR Institute of Air Transportation Systems in Hamburg are pursuing this question.

More economical travel by following nature's example?

By Tobias Marks

Researchers and engineers are striving to transfer the formation flight of birds to commercial aircraft. Analogous to the natural example, they hope to save fuel and, as a consequence, reduce emissions and operating costs. Similar to the birds, aircraft in formation could fly in the upwash field generated by the wake vortices of the aircraft flying ahead. This changes the direction of the airflow at the trailing aircraft and alters the drag. Encouraged by the promising results achieved from various studies, several formation flight tests have been carried out over the years. These have shown that, in practice, worthwhile fuel savings of up to 10 percent can be achieved.

In view of ever increasingly stringent regulations with regard to the reduction of carbon dioxide emissions, it is logical to determine whether such a new procedure is feasible in today's air transportation system. Therefore, researchers and industry are addressing this topic, and the different aspects of formation flight are being considered. In addition to the aerodynamic issues and questions of flight control and flight mechanics, the primary challenge is the operational integration of this procedure into the overall system. While the savings theoretically achievable in formations are already quite well understood, the potential system-wide operational savings achievable have not yet been sufficiently researched. However, it is the latter that essentially determines the feasibility of such a novel concept and could provide an incentive for the aviation industry to invest in the necessary systems and infrastructure.

In addition to the technical challenges, there are of course operational issues concerning the actual execution of formation flight. Which aircraft should join together in formations? How will they be arranged within the formation? Where do they meet and where do they separate again? In addition, the aircraft flying together causes inefficiencies since the aircraft participating in a formation cannot all fly in their ideal operating point – at optimal cruising altitude and speed. This is particularly relevant for different types of aircraft. If the aircraft do not take off from the same airport, they must also accept detours to reach the place where the formation will be created, which further qualifies the savings. The location of these rendezvous points, as well as the assignment of the formation partners are therefore critical to achieving the maximum potential of the procedure. In addition, flying the aircraft together requires precise synchronisation in timing and planning to ensure that the aircraft arrive at the rendezvous points at the required time.

The DLR Institute of Air Transportation Systems in Hamburg is therefore concerned mainly with the integration of formation flight into the air transportation system, in addition to its evaluation. To this end, the savings achievable for formations are calculated using simulations, while optimal formation routes including the location of rendezvous and separation points, as well as the positional assignment of the formation participants, are identified for predefined aviation scenarios using proprietary optimisation algorithms. An estimate of the potential system-wide fuel savings is then made on this basis. Early studies have already demonstrated that the expected savings of a formation can be estimated through simplified procedures, and that they are well suited for optimising the overall system. ●

About the author:
Tobias Marks is a research associate at the DLR Institute of Air Transportation Systems and is pursuing a doctorate degree on the subject of formation flight.

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DLR.de/LK/en

What happens when large drops of water caught in a cold front attach themselves to an aircraft and freeze? Hopefully, the test flights with a Phenom 300 by the Brazilian aircraft manufacturer Embraer will find the answer.

An icy affair

It is warm in Gavião Peixoto, approaching 30 degrees Celsius. December in Brazil, 280 kilometres northwest of São Paulo, is quite different to Germany. But the flight tests that DLR is conducting with the Brazilian aircraft manufacturer Embraer have a 'cool' topic – SLD. These three letters stand for 'Supercooled Large Droplets', a very unusual aircraft icing phenomenon.

Image: TU Braunschweig

Analysing the phenomenon of large supercooled droplets on aircraft wings in the ice wind tunnel at TU Braunschweig

In the heat of Brazil, DLR researchers began a measurement campaign on aircraft icing

By Jasmin Begli

Today's aircraft are already prepared for 'normal' icing. Anti-icing systems on the leading edges of the wings prevent large-scale deposits of ice. The aviation industry knows what must be done here. Anti-icing systems have been part of the certification process for years – no larger aircraft is approved without it. "Things are different with SLD," explains Per Ohme, from the DLR Institute of Flight Systems. "In unfavourable weather conditions, ice can accumulate in places where conventional anti-icing systems are not installed; for example, on the upper and lower surfaces of the wings directly behind the anti-icing system."

Water can exist in liquid form even at sub-zero temperatures. It then turns to ice when it encounters a cold surface. It needs a 'crystallisation seed' to freeze. "This can even be a dust particle," says Ohme. "Supercooled water occurs in clouds. When an aircraft flies through them, the water crystallises on the surfaces, leading to icing. The conventional anti-icing systems turned on melt off the ice and the problem is solved." SLD icing conditions – on the other hand – can occur as a result of water droplets that are larger in diameter. Snowflakes from a high altitude layer of cold air fall through a layer of warm air, where they melt and are then supercooled in a lower cold air zone. If an aircraft encounters them, the droplets dissolve or break up, then accumulate and freeze. They can be thawed off in places where the anti-icing systems are installed, but ice can still form behind the systems. This disrupts the sensitive aerodynamics: "SLD icing drastically degrades the aerodynamic properties of the aircraft. If the wings and tail section ice up in this way, the drag greatly increases. The lift characteristics are significantly changed as well," explains Ohme.

Since November 2014, there has been a new certification regulation for aircraft that also targets icing caused by SLD. It initially applies only to smaller aircraft, but larger aircraft may also be affected by this in the future. As this is of great interest to

Glance into the cockpit of the Brazilian machine for conducting research into aircraft icing – the Phenom 300.

DLR researchers tested a system with which aerodynamic parameters can be recorded directly on board the aircraft

The Embraer Phenom 300 shortly before its test flight

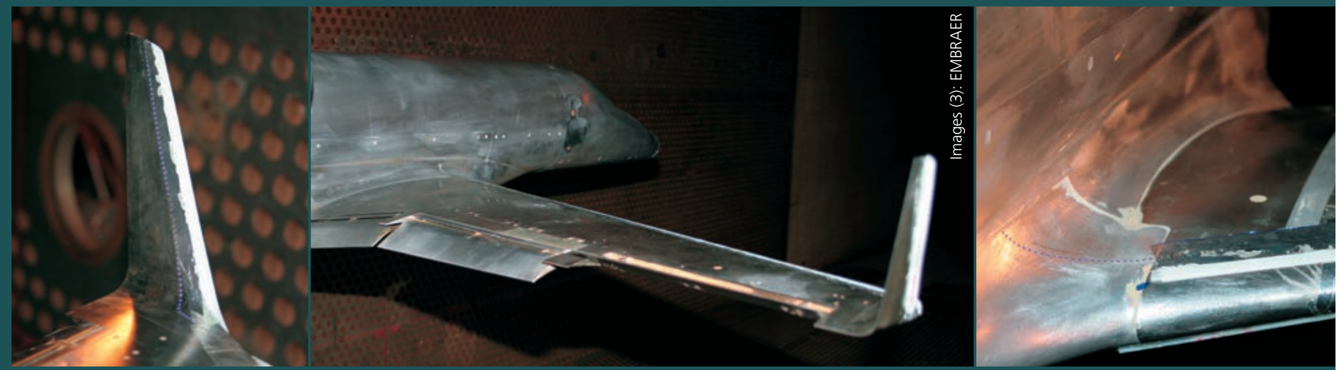
aircraft manufacturers, a solution is needed. The problem is the current lack of calculation methods, test facilities and, ultimately, flight data on the phenomenon of SLD.

The plan – flight tests using artificial ice shapes

Back to Gavião Peixoto. Here, between huge sugar cane and orange plantations, is the flight test centre of the Brazilian aircraft manufacturer Embraer. Also here is a need to acquire flight data under SLD conditions; this aircraft manufacturer is, of course, affected by the new certification regulations. “We have been in contact with Embraer for more than 10 years. So it was obvious that we should pool our knowledge and capabilities,” says Ohme.

No sooner said than done; in December 2014, a three-person DLR team flew to Brazil, firstly to collect flight data under normal conditions – without icing. Ohme and his colleagues tested a system that can be used for real-time calculation of aerodynamic parameters directly on board the aircraft. “This is particularly helpful for checking the manoeuvres being carried out and for monitoring flight stability and controllability during icing flights – and for responding accordingly,” says Ohme, making the importance of real-time analysis clear. On board the test aircraft, an Embraer Phenom 300, and with the assistance of a team from the manufacturer, the DLR researchers were able to connect their software, which was installed on two laptops, directly to the system. After just half a day, all of the test equipment had been installed in the Phenom 300 and the aircraft was flight-ready.

What next? “Further flights will follow using the same aircraft this summer,” says Ohme, looking ahead. “Until then, Embraer will be producing precalculated ice shapes made of plastic that will be applied to the aircraft prior to the next tests. In this way, we can simulate an SLD icing flight and acquire the relevant data.” In addition, the real-time analysis processes will be prepared for this specialist use. The database acquired will be used in a later stage of the project to develop simulation models to be implemented on the DLR AVES Simulator. An icing flight can then be realistically reconstructed in the motion simulator and worked on to improve aircraft designs. Ohme and his team are already excited: “When we make a start on our flight tests in the summer, we will probably be the first to fly with SLD ice shapes on the aircraft.” ●



Images (3): EMBRAER

Phenom 300 wind tunnel tests with artificial ice shapes in the Russian Central AeroHydrodynamic Institute TsAGI

Contending with the cold

Project SuLaDI, Supercooled Large Droplets Icing, sponsored by the Helmholtz Association, is the leading project of the DLR@Uni initiative at Braunschweig. The principal subject of the project is basic research into aircraft icing, with a special focus on the processes of contamination by Supercooled Large Droplets, SLD.

Research into aircraft icing in Braunschweig – SuLaDI

By Per Ohme

SuLaDI is considering the problem of aircraft icing from various angles, and so is split into a number of areas in which four institutes from the Technical University of Braunschweig and four from DLR are collaborating. At the foundation of Project SuLaDI is the network of the Aeronautics Research Centre of Lower Saxony (Niedersächsisches Forschungszentrum für Luftfahrt; NFL). The project consists of four work packages in total: aerodynamic analyses, detection of contamination, structural integration of ice detection and de-icing, and changes to the aircraft configuration caused by icing.

Aerodynamic analyses

Icing on aircraft wings can significantly degrade aerodynamic performance. Firstly, drag is significantly increased and must be compensated for with greater thrust. This leads to increased fuel consumption. Secondly, the airflow is separated at lower angles of attack, changing the operating limitations for safe flight conditions.

Theoretical and experimental aerothermodynamic methods are being used to enable a better understanding of the ice accretion caused by SLD. TU Braunschweig is providing an ice wind tunnel for this, the only one of its type in Germany. In it, experimental results relating to wing profile icing can be compared to corresponding computational models.

Detecting contamination

Icing still cannot currently be detected on sensors and aerodynamically important surfaces – this is one of the reasons for ice-related accidents. To enable pilots to respond better under such unusual flight circumstances, they need to have a better understanding of the situation.

If sensors are no longer providing reliable measurements, the contamination must be detected to prevent the failure of one or more aircraft systems, which in turn can give rise to dangerous flight conditions. For example, that is the case when the allowable range for the angle of attack is exceeded but this is not registered. With the help of reliable systems, icing and restrictions of system capabilities are expected to be detected in good time to prevent system failures.

Structural integration of ice detection and de-icing

Conventional anti-icing systems generally rely on the use of thermal energy. Firstly, warm air can be channelled from the engines to the inside of the wing leading edges. Secondly, it is possible for electrically heated mats, for example, to be integrated into the parts of the structure in danger of being iced up. But this requires a lot of energy. Mechanical systems that create deformations in the structure and so break up the ice are more efficient. Currently pneumatic de-icing systems called ‘boots’ are used, in which inflatable rubber mats deform and so displace ice deposits.

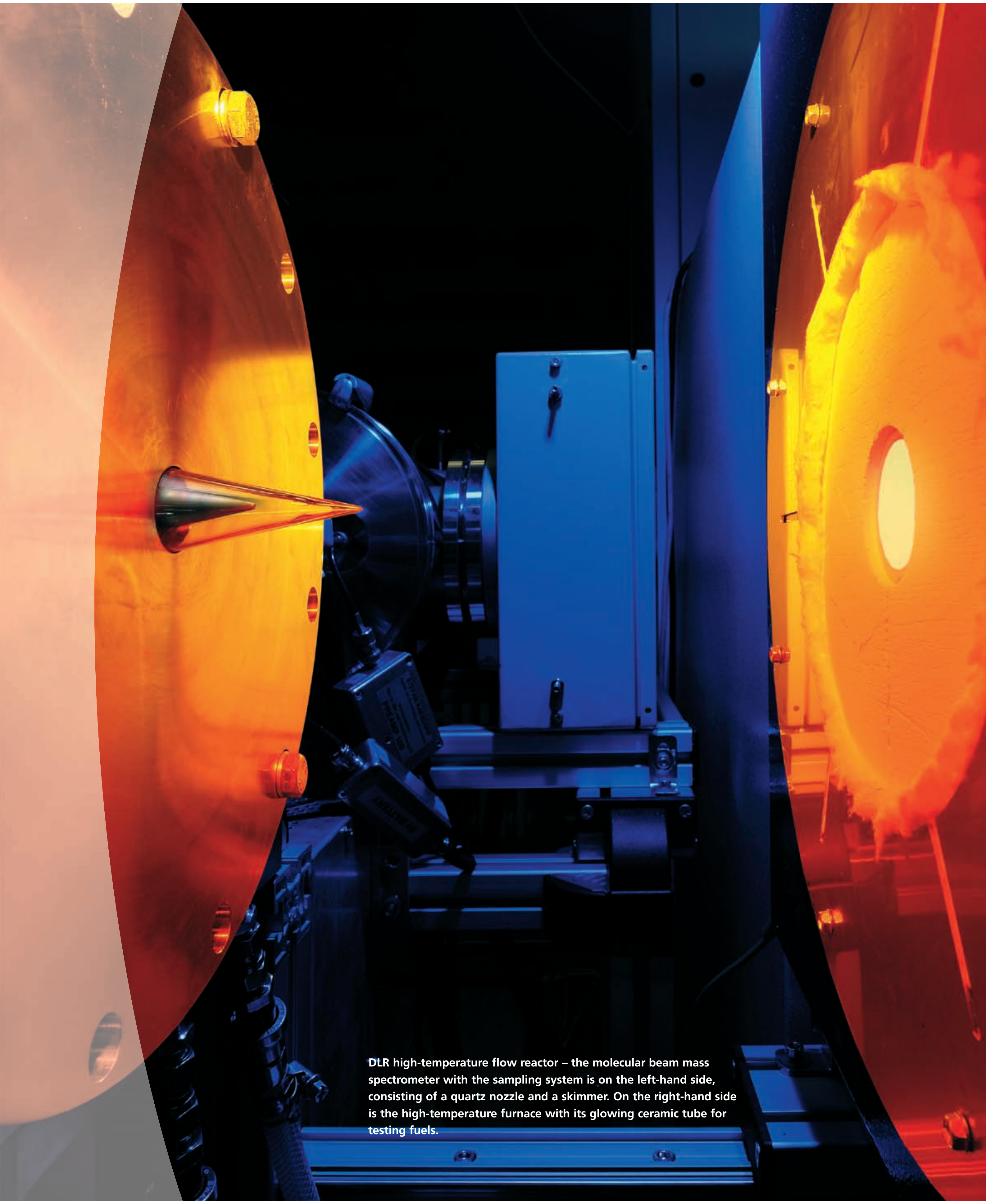
Active measures for de-icing the leading edges of wings are being investigated in project SuLaDI. This involves developing new de-icing concepts and integrating them into the leading edges of the wings of a commercial airliner. A new de-icing wind tunnel is being used for the experiments.

Degenerated aircraft configuration

Because of the major effects of icing on the aerodynamic properties and flight performance, this is termed a ‘degenerated aircraft configuration’. Understanding the behaviour of degenerated aircraft under different types of icing is important for increasing pilots’ situational awareness and thus preventing accidents. The data acquired by the project will be used to develop new flight dynamics models. These will then be applied in a flight simulator. The aim is to incorporate the appropriate icing scenarios into pilot training. Also new is that the effects of icing are not only taken into consideration in relation to the individual aircraft, but also with regard to the surrounding air traffic. ●

About the author:
Per Ohme works at the DLR Institute of Flight Systems and is responsible for project SuLaDI, cooperation with Embraer and is Team Leader of Modeling and Simulation at the DLR Institute.

More information:
s.DLR.de/043h



DLR high-temperature flow reactor – the molecular beam mass spectrometer with the sampling system is on the left-hand side, consisting of a quartz nozzle and a skimmer. On the right-hand side is the high-temperature furnace with its glowing ceramic tube for testing fuels.

Into the flame

Combustion processes are complex and not yet fully understood. Scientists at the DLR Institute of Combustion Technology in Stuttgart have adapted an analysis technique in such a way that they can directly see the intermediate products in a flame without affecting the combustion itself. Such sensitive tools are important to be able to develop more efficient combustion processes or alternative fuels.

Molecular beam mass spectrometry addresses questions that have previously been difficult to explore

By Michael Vogel

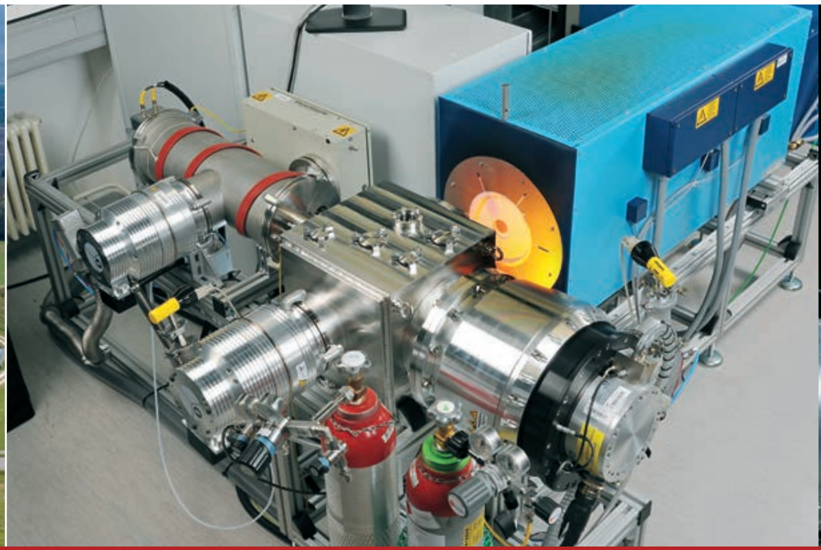
Observing without disturbing is not so simple. Quite often, the behaviour of others is already affected by our mere presence. Markus Köhler and Patrick Osswald have a story to tell about this, even when they are observing combustion processes rather than people. The two postdoctoral chemists work at the DLR Institute of Combustion Technology in Stuttgart and have invested a lot of research time over the past three years on being able to observe without interfering. Using molecular beam mass spectrometry, they can observe combustion processes in such a way that they can directly record the processes and obtain an overview of the chemical reactions at play. The researchers are core members of the mass spectrometry group, which is an intersection between the Combustion Diagnostics and Chemical Kinetics departments at the Stuttgart Institute. "The group emerged as the focus of the Institute was turning to researching a range of fuel topics, such as energy storage using liquid hydrocarbons and the development of alternative fuels," explains Köhler. "For this, suitable measurement tools are necessary."

Storing energy using liquid hydrocarbons, also known as 'Power-to-Liquid', is key to solving a basic problem with renewable energy sources – the amount of wind and solar power produced fluctuates and does not always match the energy needs of consumers, so a way to store the collected energy is necessary. A possible solution that is being investigated worldwide and also at the DLR Institute of Combustion Technology is the synthesis of liquid hydrocarbons from suitable gases using the excess energy. At the time when the energy needs to be returned to the power supply network, the hydrocarbons can be burnt like petrol in a small gas turbine, thus generating power again. The search for alternative fuels should not just aim to simply replace fuels like kerosene with an alternative fuel, but to design new fuels in such a way that they can be used more efficiently and with lower emissions.

Of course, the world of combustion is a complicated one. The processes involved can be conducted at various temperatures, pressures and flow rates. "Depending on the application, the temperature can be anywhere between 500 and 1500 degrees Celsius, and the process may run at atmospheric pressure or at 30 to 40 times higher," says Köhler. "The fuel and oxygen required for combustion can either flow quickly or very slowly into the combustion chamber." If any of these

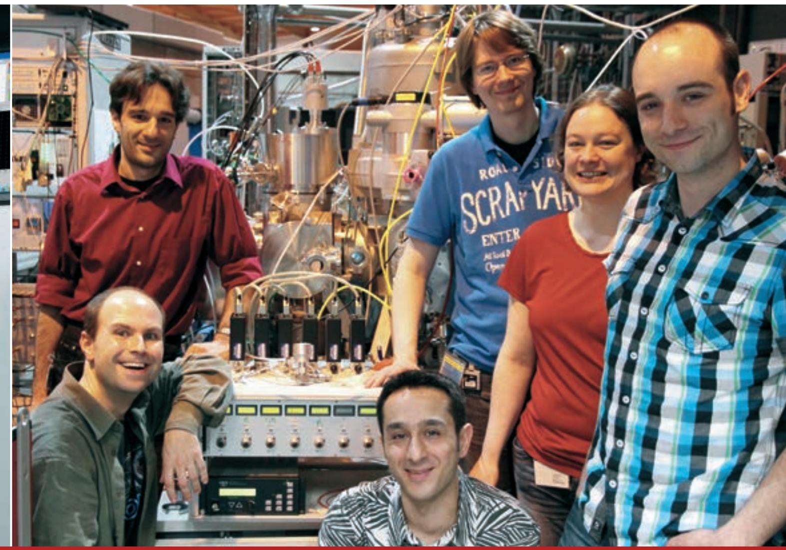
The mobile mass spectrometer – developed by DLR for exhaust measurements and analysis of both gases and nanoparticles.

The Swiss Light Source (SLS) particle accelerator. The first iPEPICO flame experiment was carried out here. The building has a diameter of almost 140 metres.



DLR high-temperature flow reactor, consisting of a high-temperature furnace (blue housing) and the molecular beam mass spectrometer

The DLR high-temperature flow reactor is a 'powerful tool' for Markus Köhler from the DLR Institute of Combustion Technology in Stuttgart to understand the working of flames



The iPEPICO team (from right): Patrick Hemberger (Paul Scherrer Institute), Tina Kasper with her PhD students Thomas Bierkandt and Erdal Akyildiz (University of Duisburg-Essen), Patrick Osswald and Markus Köhler (DLR).

Mass spectrometry

Complicated murder cases in TV series are solved by means of sophisticated laboratory procedures, yet only a few viewers know that many of these tests are only possible with a mass spectrometer; it allows the investigation of the chemical elements and bonds within a material. Although there are many and different modern mass spectrometers, they are all based on the same principle – the material to be examined is first converted into a gas, which is then ionised. These ions can then be separated from each other based on their mass using electric and magnetic fields, as the mass-to-charge ratio is different for each ion.

The idea of mass spectrometry has its roots in the 19th century, when the basic knowledge of atomic and molecular mass was developed. In the second half of the century, scientists discovered that the motion of electrically charged particles is influenced by magnetic and electric fields. Finally, in 1913, the British physicist Joseph John Thomson published the first mass spectrometry investigation on gases. The first functioning mass spectrometer was built five years later by the British chemist and physicist Francis William Aston, one of Thomson's co-workers. In the same year, the Canadian physicist Arthur Jeffrey Dempster developed and built the first modern mass spectrometer, which worked much more accurately. It was not until the 1950s that mass spectrometry experienced its ultimate breakthrough. Since then, it has been used in various fields, such as archaeology, biology, chemistry, climate research, medicine or engineering. There are many designs, each of which work for a specific parameter space and is particularly suitable for specific questions and conditions. The molecular beam mass spectrometer, like the one used at the DLR Institute of Combustion Technology, is also one of the many mass spectrometer variations.

parameters change, the process becomes different from a chemical and physical perspective. This is a huge parameter space for the researchers and must be understood if engineers want to further improve combustion processes.

"Even the combustion of the supposedly simple methane, whose molecules consist solely of one carbon atom and four hydrogen atoms is so chemically complex at high temperatures and under fuel-rich conditions that the process is still not fully understood," says Köhler. This has only recently been discovered. Things become much more difficult for fuels like petrol or kerosene that are made up of a cocktail of various long-chained hydrocarbons. "In a typical combustion process, several thousand chemical reactions occur simultaneously," clarifies Köhler. "In present-day fuels, the combustion of the pure components is chemically quite well understood, but when the physics is addressed – changing temperatures, pressures and flow rates – it becomes quite complicated."

Some parameters in the experiments can be adjusted to match real-life situations, so that they are more or less easily transferable to technical applications; others, however, can only be approximated, such as the very high pressures that occur in the combustion chambers of an aircraft. In parallel, the scientists also use simulations for further exploration. A combustion process is rendered on a computer as realistically as possible after which a step-by-step observation is possible. "Complex flames must be simulated in more detail. To calculate a full technical combustion process, it may take the computer months to arrive at the correct result," says Köhler, clarifying the enormous effort involved. When carrying out simulations it is imperative to obtain as much and as detailed information as possible from the experimenters because of the several thousand chemical reactions involved. This makes it possible to check the calculations and avoid inaccuracies.

This is where Köhler and his colleague, Patrick Osswald, come into the picture. Combustion processes can be recorded more precisely and directly using molecular beam mass spectrometry. To do so, molecules produced by the combustion process are extracted from the combustion chamber into a high-vacuum chamber using a tiny nozzle with an opening of only 50 microns. In the vacuum chamber, the molecules are isolated in such a way that they can no longer interact with each other. "We are thus 'freezing' the reaction products in their current state," Köhler explains. After that, the mass spectrometer ionises the molecules and sends them to the analyser, where they are sorted according to their mass on the basis of their time-of-flight (TOF) – small molecules are faster than large ones and, therefore, have a shorter TOF. "This is how we can determine which substances arise during a certain phase of combustion," says Köhler. Even radicals, which are molecules that have a free electron and are produced during combustion, can be recorded in this manner. Due to their free electron, radicals generally react very rapidly with other substances and are therefore only detectable for a very short time. "Although radicals greatly affect the reaction chemistry, only molecular beam mass spectrometry is able to examine most of them properly," explains Köhler.

Molecular beam mass spectrometry is not only suited for the analysis of the actual combustion process, but also for studying the resultant pollutants. Köhler and Osswald have been able to measure nanoparticles and soot precursors – found in the exhaust gas of experimental combustion chambers and engines – using a mobile molecular beam mass spectrometer. "In the theoretical model of soot formation, the processes in the gas phase, the agglomeration and surface growth of solid particles are quite well understood," clarifies Köhler, "but the knowledge about nanoparticles between the gas phase and soot particles – in other words, how exactly the transition from gas to solid occurs – is currently being investigated. Our measurements can help to close the gaps in our knowledge." ●

About the author:
Michael Vogel writes as a freelance journalist about topics ranging from astronomy to physics and technology.

More information:
DLR.de/VT/en

When the last veil is lifted

The complex chemical reactions in a combustion process and the short-lived intermediate products are important research topics. Understanding the reaction networks helps with improving the fuel quality and efficiency. Markus Köhler and Patrick Osswald from the DLR Institute of Combustion Technology cooperated with Tina Kasper's group at the University of Duisburg-Essen (UDE) to combine molecular beam mass spectrometry with a further analysis technique and were thus able to study the reaction processes in a flame in detail.

The researchers observed a flame at low pressure and extracted the resulting short-lived molecules using the spectrometer. They ionised the molecules with light provided by the particle accelerator SLS (Swiss Light Source) at the Paul Scherrer Institute in Switzerland. "In addition to the mass of the ionised particle, we measured the energy of the electron that was released on ionisation," Köhler elaborates. "In this way, we could clearly identify the ionised species." A unique identification is not always possible, for instance in the case of isomers – molecules that have identical masses, and therefore cannot be differentiated by a normal mass spectrometer. However, isomers do not have identical structures and thus their chemical and physical behaviour is different. For combustion processes, this means that isomeric molecules can still clearly be identified by this technique as the method measures both the ionic mass and the electronic energy. This combined technique has been labelled 'Imaging Photoelectron Photoion Coincidence Spectroscopy (iPEPICO).

DLR and UDE researchers have demonstrated the possibilities of iPEPICO over the past year using butyl radicals, which exist as four different isomers during combustion. "That was a pioneering experiment," exclaims Köhler proudly. "It shows what a powerful tool molecular beam mass spectrometry is in this combination."

The Andøya Rocket Range in northern Norway is a launch pad for scientists from around the world. From here, DLR sent SHEFEX-II on a 10-minute test flight into space in June 2012. DLR Magazine 134-135 reported on it.

In space, all countries are small!

By Bo Andersen, Norwegian Space Centre

Image: Trude Eng

Bo Andersen, Director General of the Norwegian Space Centre

There are several areas of natural sciences – theoretical or observational science, nationally or internationally oriented science, 'big' or 'small' science. In all of these fields we can have 'good' or 'bad' science. It is clear that theoretical, nationally-oriented and 'small' science can be very good. But in all cases, 'big' observational science must be carried out internationally to become 'good' science.

Space science is – at least in the dominant and well-evolved fields – clearly 'big' science. ESA is an excellent example of how international collaboration can be conducted quite efficiently. It is essential that the science is defined by international peer review and that responsibility for development of the payload is close to the scientists. The mandatory ESA Science Programme works well in this regard.

Looking at the civilian utilisation of space it is clear that – for all nations – the mantra "In space, all nations are small" is currently valid. This includes the United States and China. No nation has the technical capability or the financial willingness to do everything they need in space on their own. This clearly implies that, for most major endeavours in space, international collaboration is essential. On single missions, the dominant part can be carried out by the major space partners alone. Examples here are both the Hubble Space Telescope and its successor, the James Webb Space Telescope. NASA could have embarked in both undertakings on its own, but found it useful that ESA participate – to lower the cost and create a mutual international dependency. As a principle, it is more difficult to cancel a project with a large cost overrun when a commitment has been made to an international partner. NASA cancelled programmes several times in the 1980s, and this negatively affected the US-ESA relationship. With the ESA BepiColombo mission to Mercury, both ESA and Japan have used the collaboration as a main argument to maintain its development – in spite of severe cost overruns.

Concerning Earth Sciences from space, it is clear that no nation can do everything independently. On that basis, the Group on Earth Observation (GEO) was created with the aim of providing a worldwide scheme of systems to cater to the global needs for measurements. This collaboration is not without problems because the distance to the scientific needs is increasing.

'Mutual need' is the dominant driver in all areas of 'big' science. We see the successes and potential of this in CERN, ESA, EUMETSAT, GEO and ITER. These exist just because each participating nation could not give priority to undertaking it alone, but believe that it must be done. As long as 'big' science is the driver, collaboration is still difficult, but clearly possible. It is also of utmost importance to ensure that competing nations do not gain individual advantages.

When collaborative activities move outside the pure science realm, the cooperation becomes more cumbersome – often impossible – as issues of security come into play. The ISS is very successful, but the reasoning behind its existence is not just based on science or technology. The wish of the western partners to strongly involve the expertise of the collapsed Soviet Union is clear – to gain knowledge and reduce costs, but also to ensure the engagement of engineers that may otherwise have gone to work in places with not so peaceful intentions. At the same time, the total costs were unacceptably high. So ISS, being the most costly international R&D collaboration, had to be done internationally.

Scientific and technological collaboration has a good effect on other international affairs. In the space area, a main goal should be to strongly involve China in the projects. This may be difficult due to export control issues and because the distinctions between science and security aspects are especially difficult in the field of Earth Sciences.

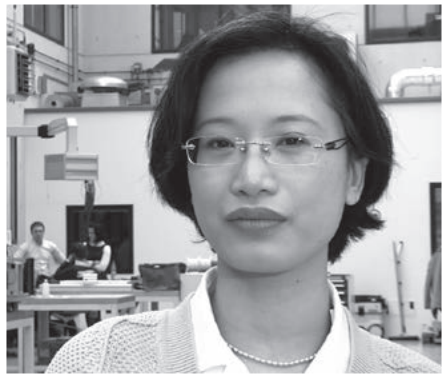
'Big' science requires international collaboration and it will only be successful if the goals are clear, not subject to change and well defined. In this, ESA is the best example. ●

Metamorphosis of an asteroid lander

When the Japanese orbiter Hayabusa-2 was launched on 3 December 2014, it was not alone; accompanying it to asteroid 1999 JU_3 was the Mobile Asteroid Surface Scout. MASCOT is a lander designed to touch down on the asteroid surface, where it will 'hop' to move between different locations. While the Hayabusa-2 spacecraft and its small companion are currently at the beginning of the journey towards their destination, DLR researcher Tra-Mi Ho examines the remarkable history of MASCOT from conception to launch; she describes an unusual slimming cure and almost maternal feelings for a shoebox brimming with cutting-edge technology.

How Marco Polo became the Mobile Asteroid Surface Scout

By Tra-Mi Ho



Researcher Tra-Mi Ho

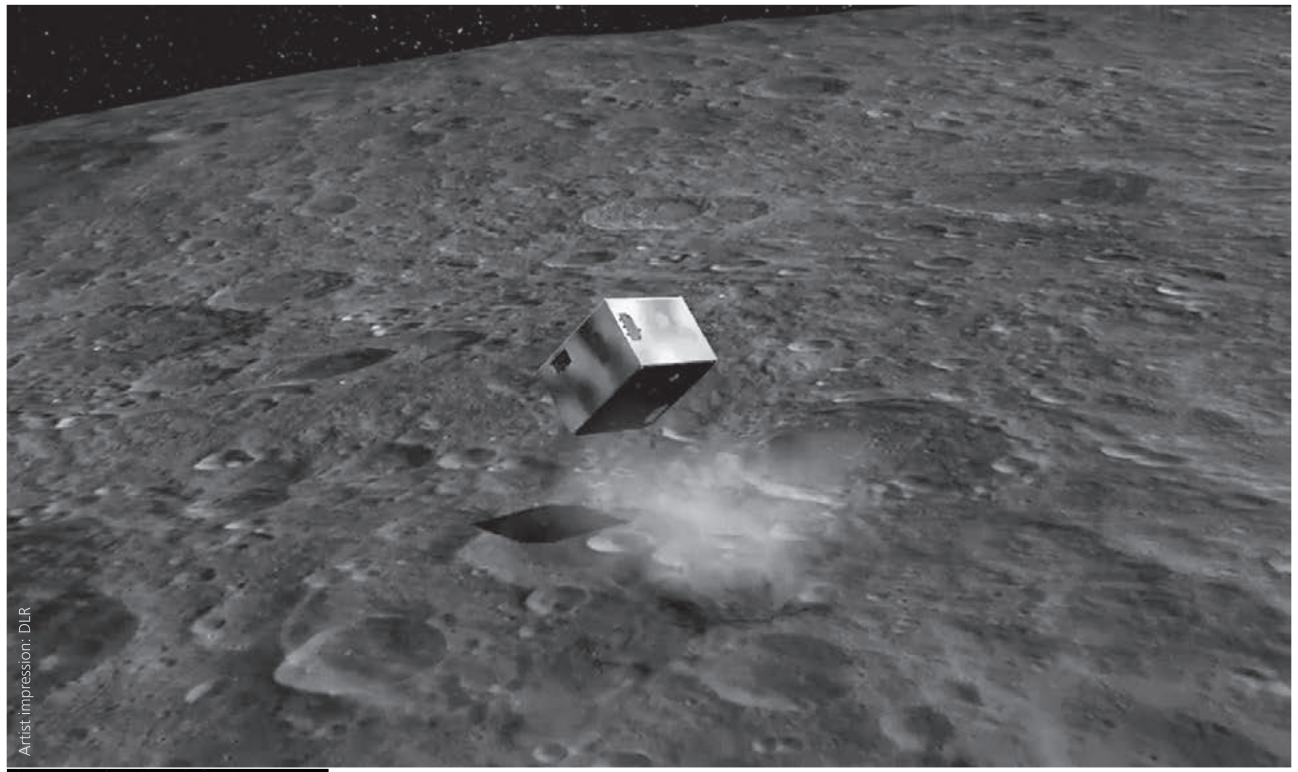
The 41-year-old Chinese-Vietnamese physicist has been working at DLR in Bremen since 2008.

Artist impression of Hayabusa-2, as it approaches asteroid 1999 JU_3.

MASCOT was merely a 'proposal' when I started working at DLR in Bremen six years ago. The idea was to design a lander for the Marco Polo mission within the framework of the ESA Cosmic Vision Programme. At the time, MASCOT stood for 'Marco Polo Surface Scout'. Back then, though, the project involved developing and building a lander that weighed 100 kilograms, comparable in size and features to Philae, the first spacecraft to land on a comet. Marco Polo was not accepted as part of ESA's Cosmic Vision Programme, but a call from the Japanese space agency JAXA would change everything. The Hayabusa-2 mission would make its way to asteroid 1999 JU_3, taking a DLR lander with it.

Hayabusa-2 – we were gripped by excitement. At the time, the first Hayabusa mission was the biggest thing around! The images from asteroid Itokawa – which Japanese scientists thought resembled a sea otter – were the subject of everyone's attention. This comparison taps into the immensely popular Japanese Kawaii culture. In Japan, even people on the street are quite likely to have heard of Hayabusa and JAXA. Each time I visit JAXA, I am impressed at the number of school groups, families and visitor groups that flock to the Sagamihara campus for a tour.

The specifications for MASCOT proved somewhat challenging. The complete lander, including power system, on-board computer, communication system and much more, could weigh no more than 10 kilograms and everything had to be fitted into a space not much larger than a shoebox – our lander would have to lose some weight. So MASCOT was given a rigid, lightweight box structure weighing just one kilogram and the electronics for all the subsystems and instruments were brought together into a central unit.



Artist impression: DLR

Artist impression: DLR

MASCOT's moment will come in 2019, when, together with Hayabusa-2 it arrives at its destination and lands on the asteroid's surface.

Hopping is allowed – unlike the Philae lander, MASCOT has the capacity to move around the asteroid. A flywheel will help the lander hop from one location to the next.

With a reduction in the scientific objectives, only four of the 14 proposed instruments were selected – the DLR Institute of Planetary Research MASCAM and MARA, the French Institut d'Astrophysique Spatiale's MicrOmega microscope and the MASMAG magnetometer from TU Braunschweig. We realised that three of the instruments needed to be in a specific location within the lander to operate properly on the asteroid – MicrOmega's optical window requires ground contact; MASCAM and MARA also need to look down onto the surface. For this to work, MASCOT requires a mechanism to move it into the correct position should it land in the wrong orientation. We devised a swing arm to generate this movement; this also gives it the ability to hop across the surface of the asteroid. Here, assuming an upright position and hopping employ the same principle. We conducted a number of studies in our Concurrent Engineering Facility, and came up with a feasible concept.

JAXA officially confirmed Hayabusa-2 as a project in 2011, which meant that MASCOT would indeed fly. DLR and JAXA then signed a Memorandum of Understanding, establishing their cooperation. Our French partner CNES soon joined as well. And that is how Marco Polo's Surface Scout metamorphosed into Mobile Asteroid Surface Scout.

The period that followed, in which we developed and built MASCOT, was unforgettable. In some of my talks, I illustrate this time with a cartoon showing a couple having a conversation just before going to sleep. The man says: "Let's try getting up every night at 02:00 to feed the cat. If we enjoy doing that, then we can talk about having a baby." And that is just the way it was! Like raising a child: sleepless nights during our thermal tests, for instance; plenty of worries – big and small – when we experienced setbacks; annoyance when MASCOT did not behave as we had predicted. But we never lost sight of our ultimate target: to prepare our little one for its harsh and cold life out in space – in about two and a half years.

Launch day was finally around the corner – 30 November 2014. The weather did not cooperate, and MASCOT finally began its journey on 3 December from Tanegashima Space Center in Japan. A total of 290 tons lifted off, rose into the sky and disappeared into the clouds. Then came a cruise phase of about one hour and a half, another firing of the second stage engine, and then Hayabusa-2 with the lander on board was inserted into an escape trajectory. Following this, preliminary data has shown that MASCOT survived the launch and is in good health. We will not acquire detailed information on its physical wellbeing until mid-2015, when it undergoes commissioning; then, we will find out more about how well each subsystem and the science payload is likely to behave. For now, the news is good and we have hope that our years of hard work and overcoming challenges have culminated in equipping this small asteroid lander with what it needs to survive the long journey ahead. ●

About the author:
Tra-Mi Ho is responsible for the MASCOT project. She has been working at the DLR Institute of Space Systems since 2008.

Into space with Hayabusa – an intercultural experience

Interview with MASCOT systems engineer Christian Ziach

Image: anonymous

DLR systems engineer Christian Ziach

DLR's asteroid lander MASCOT is on its way to asteroid 1999 JU_3 on board the Japanese Hayabusa-2 orbiter. The spacecraft took off from Tanegashima Space Center in Japan on 3 December 2014 at 05:24 CET.

Image: MHI Global

You worked as a systems engineer on the MASCOT mission for two and a half years. Did you believe that it would be possible to develop a lander that will one day touch down and 'hop' around on an asteroid within such a tight timeframe?

When I responded to that question during the job interview for the position of system engineer I think I said that I believed the schedule was a 'sporting challenge', but nevertheless feasible – and that is precisely what happened. Our project team worked long, hard hours over the two and a half years. We did not have much time to iterate and ultimately finalise the design. Also, we had to simultaneously build and test the hardware. At times, the obstacles appeared insurmountable. But thanks to the team's creative potential, we always managed to find a solution and recover quickly from any setbacks. To this day, I remain deeply impressed by the skill sets of the team.

Is creativity a factor in success?

Yes, naturally – and the diversity of our team made a substantial contribution. MASCOT is a German-French-Japanese project, developed jointly by DLR, CNES and JAXA. Its underlying structure is already international. Then there is the fact that the DLR team alone was comprised of colleagues from 13 countries. It also helped that we were rigorously focused on our targets. The launch date in December 2014 was absolutely fixed. This centred our attention on the essentials while fostering a willingness to depart from industry-standard practices.

You spent eight months as liaison engineer with the Japanese space agency JAXA in Sagamihara. What was that time like for you?

I am sure that the eight months I spent in Japan have been among the most exciting periods of my life thus far. We conducted countless tests, putting MASCOT and Hayabusa-2 through their paces, without much time to detect or overcome teething troubles. My wife and our son – who was at the time just six months old – accompanied me to Japan, which firmly anchored the time I spent there as one of my most precious memories. We got to know and love Japanese culture as a family. We were surprised at how well we were able to cope in everyday life with a mix of English and Japanese. My colleagues at JAXA welcomed us into their families, which proved an enormous help in building a network of friends and acquaintances. The team was almost like a family as well. It was certainly based on the Japanese ideals of how families should function, involving a strict hierarchy and clear rules. Whenever problems surfaced, the first step was always to try to find a solution within the family. Problems are not taken outside the immediate group until this attempt has proven unsuccessful. That was my experience of the project work.

You were almost guaranteed a front row seat in the control room of the Sagamihara Space Center when the Hayabusa-2 orbiter launched with the MASCOT asteroid lander on board. Can you try to convey an impression of what the atmosphere in the control room was like?

Astonishingly, the mood was fairly relaxed a few hours before take-off. My Japanese colleagues were joking, laughing – they seemed very relaxed. This surprised me, because there had been a lot more tension in the days leading up to the launch. But it was good to see that our colleagues at JAXA were confident and able to enjoy the fruits of their hard work. Silence fell in the control room a few seconds before launch, with all eyes and ears focused on the Japanese countdown announcer. The only other sound came from the fans running in the many computers and the air conditioning system. You could have heard the proverbial pin drop. It was truly an unforgettable moment.

What can we learn from the Japanese?

First of all, to subordinate our personal needs to the common good; to do everything we can to achieve a shared objective. Secondly, we need a general mood of optimism – one in which giving up is not an option, no matter how difficult the situation might seem. We need to broaden the horizons of how we think – even looking several decades into the future. And we need to be unbiased in our approach to new ideas and technologies. ●

More information:
s.DLR.de/n450

As planets go by

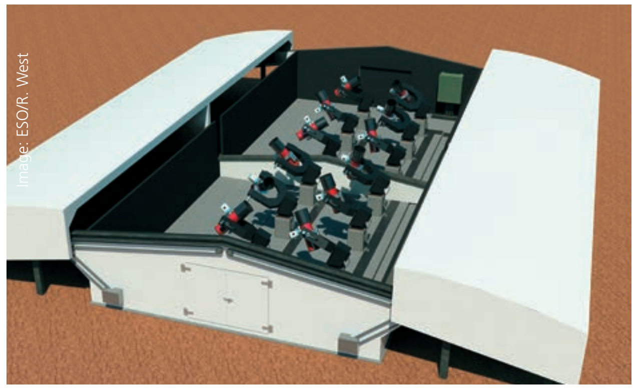
Scarce clouds, scant rain, clean air and no light pollution – the sky above the Atacama Desert in northern Chile is ideal for stargazing. This is precisely why the European Southern Observatory, ESO, has been operating an observatory on Cerro Paranal – roughly 2600 metres above sea level – since the 1990s. Great telescopes at this location, such as the Very Large Telescope, VLT, will soon get a new neighbour. In 2015, the Next-Generation Transit Survey, NGTS, will begin to search for small planets outside the Solar System. Eight of its 12 highly sensitive cameras have been developed by DLR.

New telescopes to search for extrasolar planets

By Ruth Titz-Weider

The Next-Generation Transit Survey has seen 'first light'. The new observation system, an array of 12 robotic telescopes, each of which has an aperture of 20 centimetres, is gradually being built at ESO's Paranal Observatory. Scientists from Germany, Switzerland and the United Kingdom are planning to use it to search for extrasolar planets.

Direct detection of exoplanets is infrequent, as they are vastly outshined by their parent star. Nevertheless, there are indirect methods to detect them. A star's brightness can be dimmed as the planet passes in front of it – as long as the orbit is in the line of sight between the observer and the star itself. The NGTS will be on the lookout for such periodic – albeit minuscule – changes in brightness caused by the planetary transit. The telescope array will automatically and continuously record the brightness of hundreds of thousands of bright stars in the southern sky. Variations in the brightness of stars will be measured with a precision never before achieved by ground-based observatories – down to one thousandth. Such accuracy will enable planets the size of Neptune or smaller – down to around twice the diameter of Earth – to be discovered.



The Next-Generation Transit Survey 12-telescope array

The cameras were manufactured by Andor Technology Ltd, and the charge-coupled device (CCD) arrays were specially developed for the red wavelength range. They are most sensitive at wavelengths of between 600 and 900 nanometres, which corresponds to the spectral peak of the stars that the scientists are looking to observe. Each array consists of 2048 x 2048 pixels, each with a resolution of 5 arc seconds. Developing cameras of this quality and for this application is challenging; they must undergo extensive testing before being put into service. Their specifications were precisely determined through a collaboration between scientists in the entire consortium and the manufacturer. The analysis software, which automatically looks for transit signals in thousands of light curves, is critical for the success of the measurements. Planetary researchers based in Berlin have already accumulated years of experience in the area of high-precision astronomical photometry, mainly from the COnvection ROtation and planetary Transits, CoRoT, satellite mission, which scientists from DLR participated in and which has discovered 32 exoplanets to date.

The planetary researchers have been on site to supervise the construction of the first telescope. Of course, they will also be present when the completed facility starts operations during 2015. ●

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Ruth Titz-Weider works at the DLR Institute of Planetary Research in Berlin, in the Department of Extrasolar Planets and Atmospheres.

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www.ngtransits.org

This image, taken from the roof of the Chilean telescope site, used a long exposure time. The Milky Way is clearly visible in the background.

Solar receiver in a 'spin cycle' – prototype of a CentRec particle receiver. The particles in the rotating drum of the receiver heat up when exposed to solar radiation.

From problem statement to business idea

From fundamentals to applications – DLR will be presenting its spectrum of energy research at the Hanover Trade Fair (Hannover Messe) in April 2015. The projects presented by DLR at the Trade Fair will demonstrate how quickly and efficiently DLR can drive developments from basic research to industrial application. With many developments, there can be a business model at the end, as can be seen in the example of the CentRec particle receiver developed by DLR.

DLR Energy Research to appear at the Hanover Trade Fair

By Dorothee Bürkle

The development of CentRec began with a question. Can the benefits of the high temperatures reached in a tower power plant be combined with an efficient and affordable energy storage concept? And can this be done with a view towards significant cost savings? It can be done, said scientists at the DLR Institute of Solar Research, before starting on a fundamental analysis. "There are already a number of solar tower power plants that directly heat the salt storage material," explains Lars Amsbeck, CentRec Project Leader at the DLR Institute of Solar Research. "However, salt can only be heated to a temperature of 550 degrees Celsius. Our aim was to combine the high temperatures of up to 1000 degrees Celsius that are reached in air receivers with a storage concept."

The outcome was that the concept of a particle receiver has the most advantages. Here, ceramic granules move in a rotating drum. This drum is also the radiation receiver installed on the solar tower, onto which the mirrors that surround the power plant focus the sunlight. The amount of time the particles spend in the receiver and thus their temperature can be very effectively regulated by changing the rotation speed of the drum. At the end of the process, the heated granulate falls directly into insulated boxes; it can then be taken out and used immediately – or later – for power generation, or as process heat, depending on the requirement.

The advantage of the concept is that the ceramic granules have very good storage properties, can be heated to 1000 degrees Celsius and can be purchased very inexpensively. "The basic idea is not new. During our analysis, we came across a patent from France dated 1954. We have substantially redeveloped this concept for today's applications," says Amsbeck. At that time, developments in solar power plants were largely put on hold due to low energy prices. Once the scientists decided on the concept of a centrifugal receiver, the groundwork started. In drop tests, they conducted research into, for example, whether the granulate turns to dust in a short time due to the continuous abrasion and thus becomes unusable. "This does happen but,

Turbines:
From kinetics to gas turbine design

Batteries:
From molecules to battery systems

Fuel cells:
From electrode coatings to entire systems

System analysis:
From Earth observation to power plant design

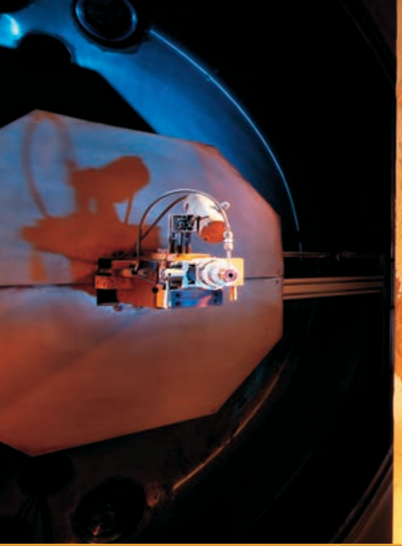
Heat storage:
From chemistry to process heat

Wind energy:
From flow modelling to rotor control

Solar power plants:
From ceramics to the tower design

TEG:
From Skutterudites to waste heat recovery

From basic research to applications is the topic of the DLR Energy Research stand at the Hanover Trade Fair. Exhibits about all eight areas outlined above will be on show. Here, DLR researchers have expertise both in basic research, for example, in chemical tests on new storage materials in the milligram range, to applications such as the development of an entire storage system for factories or solar power plants.



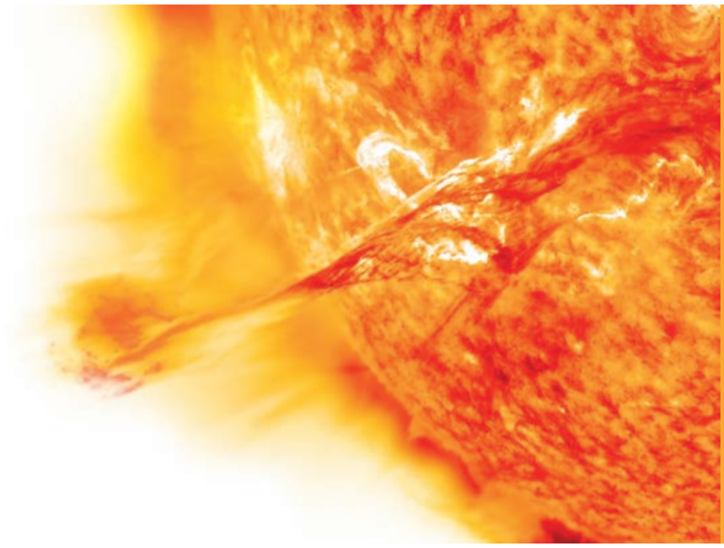
Fuel cells – from the electrode coating to the practicable system

Basic research – in the vacuum plasma spraying system, DLR researchers coat fuel cell components (right). They are developing a new coating process for longer-lasting fuel cells that have less precious metal content.

Application – Antares DLR-H2 is a motorised glider developed by DLR together with Lange Aviation GmbH; it is the world's first aircraft capable of taking off using the electrical power from a fuel cell.

according to our pre-tests, at a relatively low rate, so it is not significant from an economic perspective," observed Amsbeck. The first laboratory-size test receiver was put into operation by the researchers in 2013. The researchers in Stuttgart are currently testing a large receiver for use in industry; this will then be used in the solar tower in Jülich in a complete system for the first time. Travelling along the same path is industry partner Grenzebach Maschinenbau GmbH, which intends to use the generated heat as process heat. The Helmholtz Association also considers this way of using solar energy more effectively to be very promising. The project was selected for the Helmholtz Validation Fund, which aims to drive research results that are close to application through to market maturity. It sponsors projects that have potential for commercial use and a high level of social benefit. In addition, Amsbeck is being sponsored for one year by the Helmholtz Enterprise Fund to develop a business model for the particle receiver.

Amsbeck is sure: "Even though there is surely a long way to go, I firmly believe that the CentRec concept will have commercial success." ●



The DLR booth at the 2015 Hanover Trade Fair will be the first appearance by DLR Energy Research. It is located in

Hall 27
Booth number G31

More information:
s.DLR.de/oma6

Energy stored in hot stone

Be it in the power plant sector or in energy-intensive production processes, heat storage systems are gaining importance. DLR researchers in Stuttgart have therefore developed 'CellFlux' – a thermal energy storage concept. Today, this is the most economical way of storing heat from industrial and power plant processes. The DLR energy researchers presented the concept as a pilot system at the fourth Stuttgart EnergieSpeicherSymposium (Energy Storage Symposium) in January 2015, demonstrating how the complete system can be examined during various test cycles.

Flexible and economical heat for industrial processes – DLR energy researchers present the new storage concept CellFlux

By Wolf-Dieter Steinmann

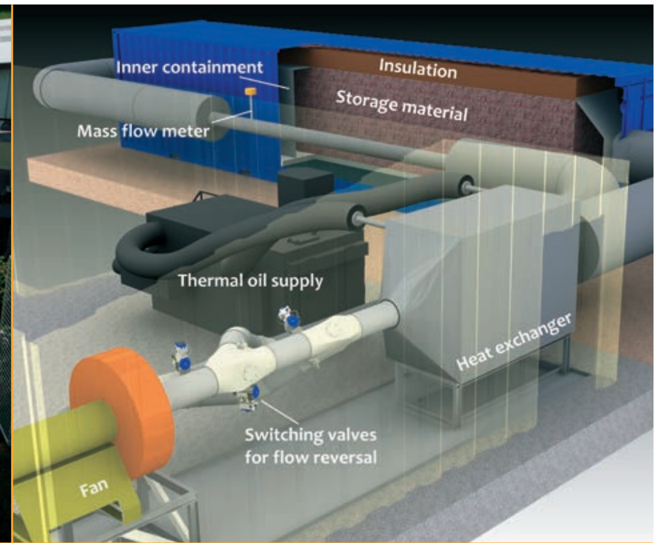
The CellFlux concept has several advantages – on the one hand, the storage system is very flexible in terms of its temperature range. Low temperatures are not a problem for solids, while liquid salt crystallises at temperatures below 230 degrees Celsius and cannot be reused. On the other hand, the storage mediums can be acquired inexpensively. This is due to the use of readily obtainable materials such as bricks, concrete or basalt, which are likely to be found locally, thereby reducing transportation costs and lifting the local share. These cost only a fraction of the liquid salts or thermal oils used until now in thermal storage systems. For liquid salt based stores, the mass of salt required accounts for 50 percent of the investment costs. If solids costing one tenth of these prices are used, the storage costs can be considerably reduced.

The CellFlux concept is based on individual modules – storage cells – and adapts flexibly to the required storage capacity. First, the process heat is emitted to a working medium such as air using a heat exchanger. This working medium is then circulated in a closed circuit by a fan, flows into the individual modules containing the solid storage material and gives up the heat. The modular design of the concept allows larger heat storage capacities to be realised more cost-effectively and optionally to provide heat to other consumers.

Flexible and economical storage solutions for electricity and heat are indispensable for using energy as efficiently as possible. At the same time, they are a key technology for sustainable transformation of our energy supply, as with them, fluctuations in power generation from wind and solar energy can be bridged. With its focus on 'Flexibility through energy storage', the Stuttgart EnergieSpeicherSymposium organised by the DLR Institute of Engineering Thermodynamics brought together more than 100 representatives from science and industry for the fourth time. The focus was on topics such as load sharing, legal framework conditions and application networks, as well as currently available storage technologies. ●

More information:
DLR.de/tt/en

CellFlux pilot plant at the test site at Birkhof in Stuttgart



The CellFlux concept for heat transfer and storage

Image: anonymous

Following unwelcome travel companions

Greenhouse gases – the search for global standards to calculate emissions along entire transport chains

By Verena Charlotte Ehrler

With growing concerns about the environmental impact of our actions, consumption and behaviour, the subject of the sustainability of products and processes is becoming ever more important. Companies and consumers want to understand the carbon dioxide footprint of their products. At the same time, freight companies and logistics providers are striving to make the efficiency of their transport systems transparent, so that they can be further optimised. Although numerous tools, methods, standards, instruments and databases exist for measuring emissions along transport chains, there is no international standard in place that fully covers an entire chain. Today, a comparison of different chains, of different transport modes and different providers is not feasible. As an industry participant said: "We have not even reached the point of being able to compare apples with oranges, as far as the emissions of transport chains are concerned." The EU project COFRET, Carbon Footprint of Freight Transport, provides transparency on existing methodologies, tools and databases relating to the carbon footprinting of freight transport. Within the project, which was coordinated by the DLR Institute of Transport Research, researchers and industry partners jointly analysed over 120 existing emission calculation tools, identified gaps in the most important existing standards and mapped out a way forward toward a global standard for the calculation of emissions along transport chains.

When searching for a standard, people are confronted with a variety of models, instruments and approaches. To date, there are more than 120 different tools for calculating emissions from transport chains. Which calculation method should be applied to measuring the emissions of the T-shirt we are about to buy? Should we use European Standard EN16258, or the standards of the International Organisation for Standardization (ISO), or those of the Green House Gas Protocol? Different results regarding levels of carbon dioxide emissions are obtained from the various methods. Today, there is no binding, internationally applicable and accepted standard for the transport sector – or for industry and trade as consumers of transport services – that takes into consideration every element of transport chains, including logistics nodes and transfer points. Also, questions such as the best allocation of energy consumption to individual unit loads are not yet satisfactorily resolved – is direct routing the best approach or should it be real-life routing? How are the emissions of empty containers to be allocated? Many of these issues can only be solved by agreement of conventions. As a consequence, the topic is often politically charged.

In the COFRET project, the various calculation methods used for international transport chains have been analysed and their shortcomings have been identified. One of the most urgent gaps to be closed is the calculation of emissions at logis-

The DLR COFRET team (from left) – Verena Charlotte Ehrler led the project, Saskia Seidel conducted interviews with partners and stakeholders, and Andreas Lischke coordinated the evaluation.

tics hubs and nodes, for example at ports; the loading, transporting or, where required, cooling of goods is not adequately covered by any of the current standards. Also, dealing with empty journeys is not yet clarified; how can the emissions from return trips be appropriately allocated to successfully completed deliveries? Should the actual route – often burdened with detours – be used for the calculation of emissions of the transport of a product, or should only the emissions that would occur in an ideal, direct route be assumed?

Accurate, simple, flexible – towards a global standard

One of the project's central aims was to offer industry, shippers and logistics providers the opportunity to remove the current uncertainty in calculating the carbon footprint of freight transport. Furthermore – and in line with the industrial partners' requirements – it was an important objective of COFRET to build on existing emission calculation tools to further progress towards an internationally-accepted, harmonised global carbon accounting system for freight transport supply chains, covering all modes and including terminal and warehousing emissions.

To achieve such international acceptance, it is important that the solutions developed are easy to use, flexible enough to adapt to different situations and organisations, yet as accurate as possible and, for the most part, they need to be transparent.

Given the complexity of this challenge, it will not be simple to develop and implement a consensus, thereby closing the current gaps. So, where to start? One way to bring light to the situation is to break the chain of goods transportation down into transport chain elements (TCE). Calculating emissions for each TCE in a transport chain contributes to mastering the complexity of the chain. Adding up the individual TCEs allows subsequent calculation of the emissions of entire transport chains.

Science and industry hand in hand

It quickly became apparent that this would not be achieved just through scientific analysis and the suggestions for action resulting from this. Project participants from the transport and logistics industries and environment stakeholders have decided to continue working on the results from the collaborative project and take them to an international level via the framework of an EU project. Acceptance and use of a standard beyond European boundaries can only be ensured if industry itself controls this process. The forum of the International Workshop Agreement (IWA), under the guidance of the German Institute for Standardisation (DIN), was initiated by the COFRET project to get all stakeholders involved in the topic of international transport chains around one table. As a result, a globally open, neutral platform could be established that facilitated the definition of a framework of requirements for an international standard on calculating emissions of transport chains. The number of participants reflects the level of interest in this topic; a total of almost 70 participants from 15 countries were involved in the IWA process.

The outcome of this work, IWA 16:2015 'International method(s) for a coherent quantification of CO_2e emissions of freight transport' suggests which of the existing standards and tools should be used as a starting point for further standardisation efforts for each individual transport mode, such as road freight, rail transport, inland waterways, deep sea shipping, air transport and logistics nodes and transhipment centres. In a next step, IWA 16:2015 shows which gaps still need to be closed. These include, for example, the definition of individual elements in a transport chain, the determination of limits for a transport company in terms of the distinction from its subcontractors, and the standardisation of the calculated emissions.

With IWA 16:2015, an internationally recognised format was established that extended the neutral platform of the COFRET project for the exchange of requirements and experiences of industry and research. IWA 16:2015 also enabled the involvement of further stakeholders at a global level beyond EU boundaries. Thus, by means of IWA 16:2015, the COFRET project was able to facilitate further development work on the global standardisation of the calculation of greenhouse gas emissions from transport chains. In the next step, it is important that it is the industry players that lead the work towards a global standard, in cooperation with an international standardisation organisation such as the Green House Gas Protocol or ISO, to ensure a seamless implementation of new approaches embodied in international standards that are being developed. So what is the role of scientists in these further developments? They will be needed to assess the applicability, quality and transparency of these new approaches and solutions. It will be their task to support and validate the work carried out by industry.

In light of the complexity of the subject and the large number of stakeholders, discussions regarding the development of solutions must be carried out with the specific aim of obtaining an accepted, practical, international standard on the calculation of greenhouse gas emissions for every element of the transport chain. Only then can the entire transport chain be covered and a standard established that is recognised by all in the shortest possible time. Subsequent developments and revisions cannot be ruled out, of course, and may even be desirable for further improvement and user acceptance. Transport chains are extraordinarily dynamic, and understanding the carbon dioxide footprint that a product is leaving behind is something that consumers and companies are demanding with ever-greater urgency, so they can make conscious decisions on contributing to the reduction of greenhouse gas emissions. ●

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More information:
DLR.de/vf/en

Freight trains, aircraft, ships, trucks and other transport systems form complex chains. Calculating the carbon dioxide emissions along these transport chains presents challenges for researchers. The COFRET project addresses these.

COFRET

The COFRET project is partly funded by the European Commission. It is based on the European Union's objective of reducing greenhouse emissions by 30 percent by 2020, and by 60 - 80 percent by 2050, as compared to 1990. DLR has been collaborating on the research project with 13 other European companies and institutions from eight countries. The project has been coordinated by the DLR Institute of Transport Research. The results of the COFRET project are available at:

www.cofret-project.eu

Image: Markus-Steur.de

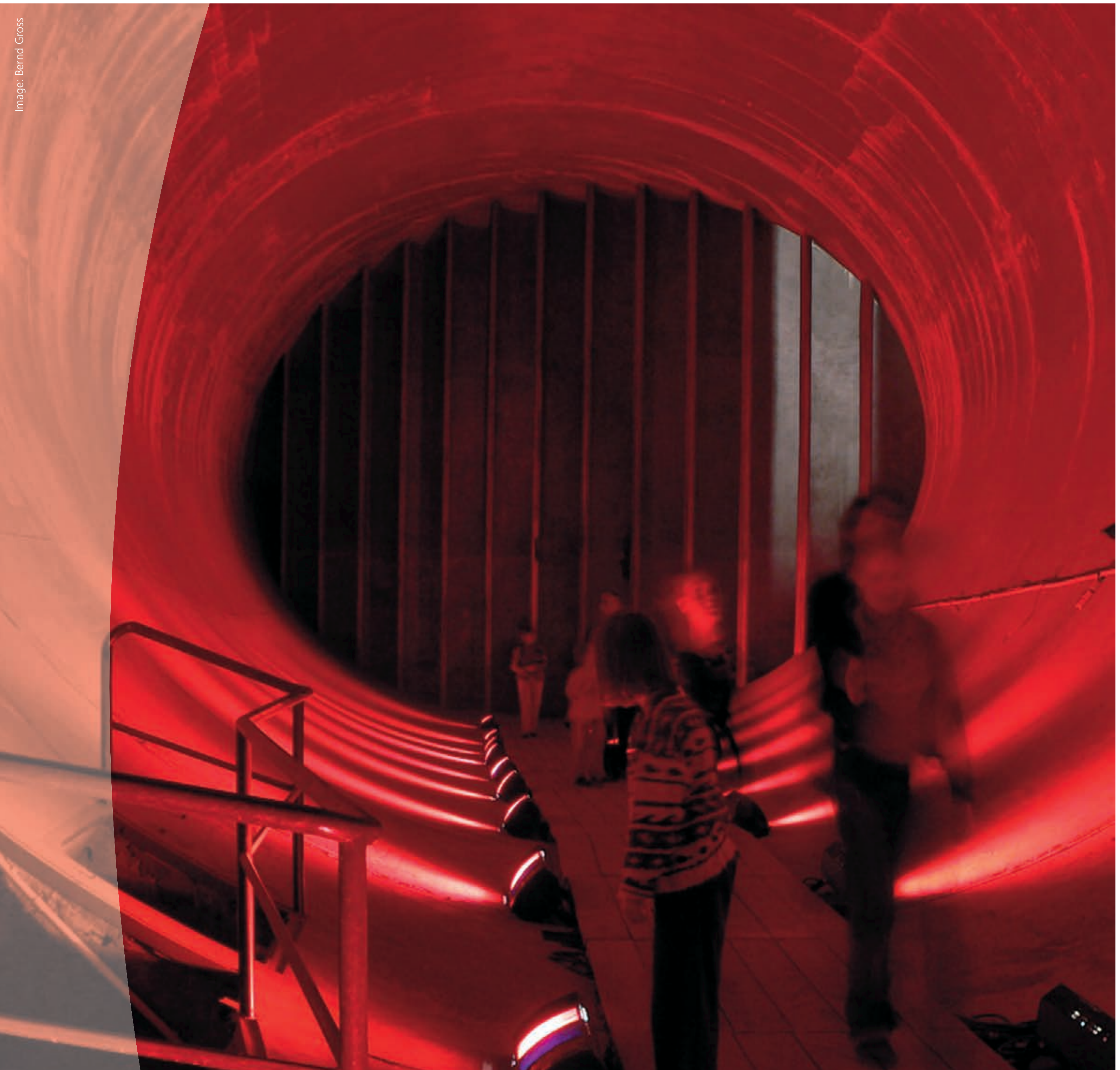


Image: Bernd Gross

Image: Steffen Zahn

Backdrop to a Hollywood blockbuster – a science-fiction movie was filmed in the large wind tunnel at the Aerodynamic facility in Berlin-Adlershof.

More than just air

Wind tunnels come in all shapes and sizes. This third article in the Wind Machines series sets out to present a few extreme examples: the largest, the coldest, the strangest – even one that served as a backdrop in a Hollywood movie …

Part 3: The Wind Machines

By Jens Wucherpfennig

Huge dimensions, a mix of curves and angular forms – some wind tunnels possess fascinating architecture. So it is hardly surprising that a wind tunnel has already featured as a backdrop for a futuristic world in the Hollywood blockbuster Aeon Flux, a 2005 comic book adaptation with Oscar award-winning Charlize Theron in the lead. The film itself is set in the year 2415 – 404 years after a deadly pathogenic virus wiped out the majority of mankind. The five million people that survived take refuge in Bregna – the last remaining city that is enclosed by a wall. The film was shot in Berlin – and some of the scenes are set in the large wind tunnel at the Aerodynamic Park in Berlin-Adlershof. The tube-shaped complex with a diameter that gradually increases from 8.5 to 12 metres along its length was built between 1932 and 1934. Although restored to its former glory, the cultural monument is structurally weak and opens rarely – and exclusively – for small groups of visitors. The large wind tunnel was part of the former DFL – the German Aviation Research Institute – complex, and is now listed as a German heritage building.

Europe's coldest wind tunnel is found in Cologne and is operated by a subsidiary of DLR, German-Dutch Wind Tunnels (DNW), and its Dutch partner organisation NLR. Inside the Cryogenic Wind Tunnel, liquid nitrogen lowers the temperature to minus 173 degrees Celsius to enable tests on aircraft or railway vehicles.

A Viennese jewel

In Austria, there is a unique facility that is used to analyse entire cars, helicopters and even trains – the Vienna Climatic Wind Tunnel, KWK. It is operated by Rail Tec Arsenal – an international research and testing institute for rail and road vehicles, new transport systems and technical facilities that are subject to extreme climatic conditions. At the heart of this test centre are two separate climate wind tunnels, which are used to conduct independent tests on vehicles under extreme weather conditions. The sheer size of this facility – the large wind tunnel has a test section 100 metres in length, and its smaller sibling measures an impressive 33.8 metres – and the physical parameters it is able to achieve (temperatures between minus 50 and plus 60 degrees Celsius, together with wind speeds of up to 300 kilometres per hour), as well as its capacity to generate any conceivable climate and even simulate different types of journey (through tunnels and cities, etc.) make this test centre the only one of its kind.

The world's largest climate wind tunnel has been in operation since 1 January 2003. Rail Tec Arsenal has taken out a lease on the new facility for the duration of its planned 35-year operational life, managing its international marketing and operation. All of the major European manufacturers of rail vehicles are shareholders in the operating company. The aim is to improve safety, comfort and reliability for road and rail vehicles.

A new icing facility for aircraft was officially opened in the KWK in March 2014. Now, the aviation industry can also draw on a high-performance icing wind tunnel to complete type certification tests, where previously only road and rail vehicles from throughout the world could be put through their paces under extreme climatic conditions. When an aircraft passes through upper cloud layers, super-cooled water droplets that impact its surfaces immediately freeze and – within minutes – form a centimetre-thick layer of ice on critical components such as the engines, rotors, wings and sensors. (more about this on page 24). To obtain a type approval certificate for these components and the aircraft as a whole, manufacturers must demonstrate that the protective measures taken to prevent icing are effective and that the formation of ice will not pose a risk to flight safety. To develop, test and obtain certification for their products, the aviation industry needs facilities with the capacity to perform icing tests. The icing rig can be used to transform the world's longest climatic wind tunnel into the largest ever icing wind tunnel for aircraft.

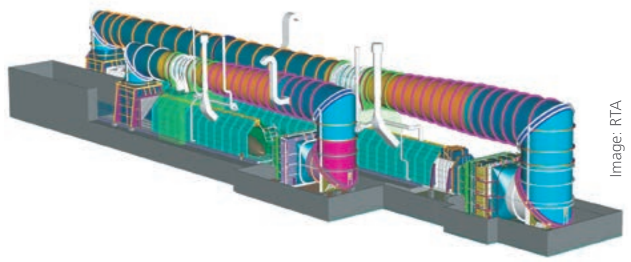


Image: RTA

Graphical representation of the Vienna Climatic Wind Tunnel – a state-of-the-art wind tunnel built in accordance with the the old Göttingen design.

Image: MAN

Entire trucks, helicopters and even trains can be analysed in this unique facility in Austria – the Vienna Climatic Wind Tunnel, KWK. It belongs to Rail Tec Arsenal – an international inspection centre conducting climatic tests on road and rail vehicles. Two separate climatic wind tunnels, used to perform independent tests on vehicles under extreme weather conditions, are at the heart of this test centre.

The biggest climate wind tunnel in the world has been in operation since 1 January 2003. Rail Tec Arsenal has taken out a lease on the new facility for the duration of its planned service life of 35 years, handling its international marketing and operation. All major European rail manufacturers are shareholders in the operating company.

Image: RTA

Simulating clouds on *terra firma*

The type certification tests require simulations of the aircraft flying through a variety of different cloud types with temperatures of between minus 2 and minus 30 degrees Celsius, and droplets measuring between 15 and 40 microns across. One of the most challenging conditions in these sub-zero temperatures is to keep the droplets liquid, as they would be in high altitude clouds. A sophisticated water treatment process and complex air pressure and system controls produce 'clouds at ground level'. Inside the wind tunnel, it is possible to conduct icing tests at speeds of almost 300 kilometres per hour across an icing cross-section of 8.75 square metres, allowing critical ice accumulation around engines, helicopter rotor blades and wings to be investigated under realistic flight conditions.

The sheer size and immense cooling capacity of the Icing Wind Tunnel make it the world's only facility able to test engines of up to 1800 horsepower at full throttle. This is extremely important because the formation of ice has a substantial influence on the performance of engines. Realistic data can only be obtained when the engine is in operation.

The land of superlatives

The world's largest wind tunnel – at least in terms of dimensions – is located in the United States. Most wind tunnels only permit the testing of aircraft models. This one, however, can accommodate real aircraft – up to the size of a Boeing 737. This wind tunnel, with a test section of 24.4 by 36.6 metres, is part of the NASA Ames Research Centre. Established on 20 December 1939 as the second laboratory operated by the National Advisory Committee for Aeronautics (NACA), the facility is located in Moffett Field (California), bordering the cities of Mountain View and Sunnyvale. The US physicist and subsequent president of John Hopkins University, Joseph S. Ames, was a founding member of NASA's predecessor organisation. It was in his honour that the research institution was

Image: NASA/JPL-Caltech

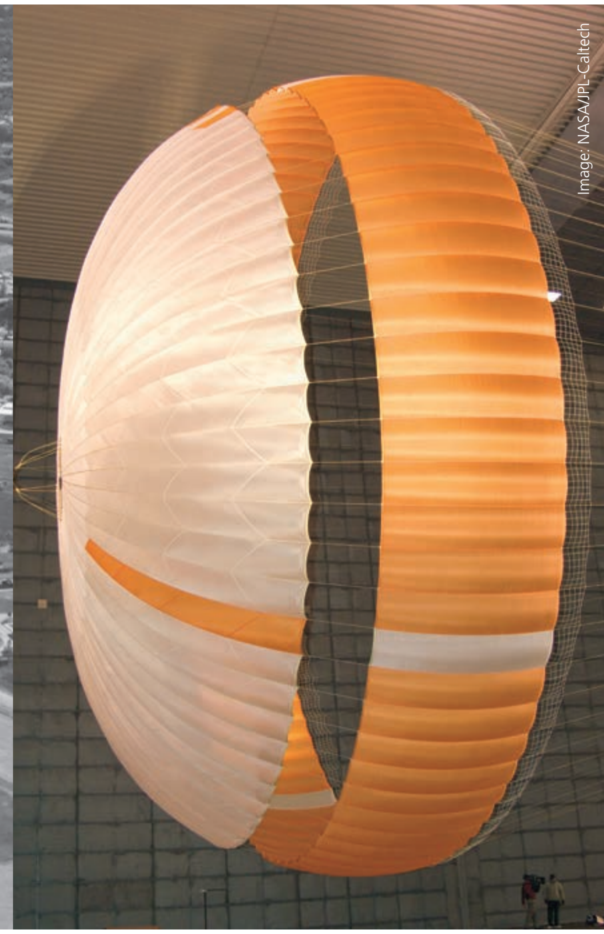


Image: NASA/JPL-Caltech

The world's largest wind tunnel is situated in California. It can accommodate an entire aircraft.

The US wind tunnel has also been used to investigate objects used in the aerospace sector – not merely to test aircraft. For example, the full-scale landing parachute with which the Mars Rover Curiosity touched down safely on the surface of Mars back in 2012 was put through its paces at this facility.

initially named the Ames Aeronautical Laboratory. Ames was integrated into NASA when the US space agency was established in 1958 and is now one of its field centres.

Constructed in the 1980s, the wind tunnel is used to research the aerodynamic properties of new developments in the field of aeronautics and aerospace. One of its focal points is the investigation of vehicle simulations conducted by supercomputers. The facility also engages in research on identifying the sources of noise produced during the operation of automobiles and aircraft. A whole series of ground-breaking, experimental aircraft have passed through the doors of the facility, among them the XV-15 – role model for the first tilt-rotor aircraft to be produced in series, the V-22 Osprey. This aircraft can take off and land vertically by tilting the propellers that are fitted to the wingtips. The wind tunnel has also been used to investigate objects used in the aerospace sector – for instance, the full-scale landing parachute with which the Mars Rover Curiosity touched down safely on the surface of Mars.

Also in the United States is the world's largest wind tunnel for automobile research. The tunnel at the General Motors Aero Lab in Warren, Michigan, is 301 metres long and features a 4500 horsepower motor that drives a propeller with a 13-metre diameter, buffeting test objects with winds reaching up to 222 kilometres per hour. The test section itself is 21.7 metres long and 10.4 metres wide. Originally used exclusively by General Motors to conduct its own research, the wind tunnel has been available to private customers for a few years now, among them racing drivers, to complete their own testing – with a price tag of 2000 dollars per hour.

Although the large costs and safety requirements usually limit private individuals in their use of wind tunnels, a new trend has emerged since the 1990s – the old human dream of flying. 'Body flying' or 'indoor skydiving' have made this possible. It involved the development of a special kind of wind tunnel – the vertical wind tunnel. Unlike traditional wind tunnels used in aerodynamic or aero-acoustic measurements, a vertical wind tunnel possesses a vertical test section – the flight chamber. The first vertical wind tunnels were used in aerospace research for spin recovery testing. Now, vertical wind tunnels are mainly used in the sport and leisure sector as training facilities for parachutists.

As varied as these wind machines are and the myriad of possibilities for testing that they offer, almost all of them are based on the facility constructed in Göttingen over 100 years ago – based on the plans drawn up by Ludwig Prandtl. ●

More information:
bit.ly/1MoeX4d
1.usa.gov/1Cjd74k

GPS in gold

Upon entering the Salon one breathes in the Baroque culture, spellbound by its architecture, interior design and, above all, the magnificence of the exhibits. Scenes from the historical television series 'Sachsens Glanz und Preußens Gloria' ('Saxony's Splendour and Prussia's Glory') are evoked. The superbly produced mini-series brought in unprecedented viewing figures for East German TV in the late 1980s. However, 'Prussia's Glory' is not so important here. We are in Saxony, at the oldest museum in the Dresden Zwinger. Augustus the Strong founded the Mathematisch-Physikalischer Salon (Salon of Mathematics and Physics) here in 1728, filling it with scientific instruments from the Dresden Kunstkammer (Chamber of Arts). In the nineteenth century, the collection had a big impact on Dresden's technological culture. When the doors of the first gallery opened in April 2013, the display – one of the most significant of its kind in the world – acquired a new splendour. Behold the glorious world of the elector-kings …

Mechanical marvels of the Mathematisch-Physikalischer Salon in the Dresden Zwinger

By Cordula Tegen

GPS in gold. In 1584, Dresden mechanic Christoph Trechsler the Elder built a mechanical odometer made of fire-gilded brass with a sophisticated measuring element consisting of 12 gears. Its face was finely engraved to show routes and miles – just as the Saxon Elector Augustus had ordered. In 1575, he had crossed Saxony and succeeded in accurately measuring the distance he had travelled. Today, a 13-metre-long scroll illustrating the route lies before the eyes of visitors behind the glass of a display cabinet. At the time, Augustus wanted to measure more than just distances – as with today's Global Positioning System, he also wanted to pinpoint locations. Trechsler transformed the idea into an impressive piece of technical craftsmanship. The 40-centimetre carriage odometer is one of the most prized pieces in the collection at the Mathematisch-Physikalischer Salon.

The sophistication of the mechanical marvels and mathematical instruments is amazing. It is not surprising that Saxony was one of the very first territories to be mapped, nor that the early devices for land surveying get particular attention from the museum director, Peter Plaßmeyer, whilst also representing the long history of the collection. Which other museum can look back on a history of more than 300 years? "We do not try to deny that we are a historical collection," he says. "We combine this history with the modern-day transfer of knowledge through elaborately-produced visual and audio guide content as well as Internet videos." These are often produced as part of scientific projects. One of the explanatory map projections was produced as part of a thesis at TU Dresden, which was sponsored by DLR.

A total of 370 exhibition pieces can be admired in the collection – reopened in April 2013 following restoration and extension. "Our floor area has almost doubled, although we have cut the number of exhibits by one third," says Plaßmeyer as he explains the concept. The significant increase in the number of visitors as well as the time they generally spend at the museum prove him right. From April to November 2013 more than 120,000 visitors from all over the world came to see the small yet excellent exhibition, which is no less impressive than its famous neighbours, such as the Alte Meister (Old Masters) Art Gallery and the Grüne Gewölbe (Green Vault). Those wandering through the galleries of the Salon will admire its magnificent toy automata, finely crafted measurement and drawing instruments and multidimensional world clocks made of gilded brass. One feels somewhat transported away from the modern world when surrounded by calculating devices and coin scales, ornate reflecting telescopes and concave mirrors, refracting telescopes, planetary orbit and world time clocks, skilfully decorated pendant and pocket watches, as well as terrestrial and celestial globes, which include one of the five oldest Arabic globes in the world and one of Mars. While leaving the collection, one can luckily get a glimpse of the beautiful inner courtyard of the Zwinger – before the city traffic of modern-day Dresden brings one back to the present day. ●

Images: Mathematisch-Physikalischer Salon, Staatliche Kunstsammlungen Dresden

Exhibits with a story to tell – a mechanical odometer from 1584 and a globe of Mars dated 1886.

skd.museum

Mathematisch-Physikalischer Salon
in the Dresden Zwinger
– Semperbau am Zwinger –
Theaterplatz 1
01067 Dresden
Germany

Opening times **10:00 to 18.00**
closed Mondays
Entrance fee **6 Euro, concessions 4.50 Euro**

skd.museum.de

Image: Mathematisch-Physikalischer Salon, Langgalerie, Der Kosmos des Fürsten
Staatliche Kunstsammlungen Dresden Photograph: Hans Christian Krass

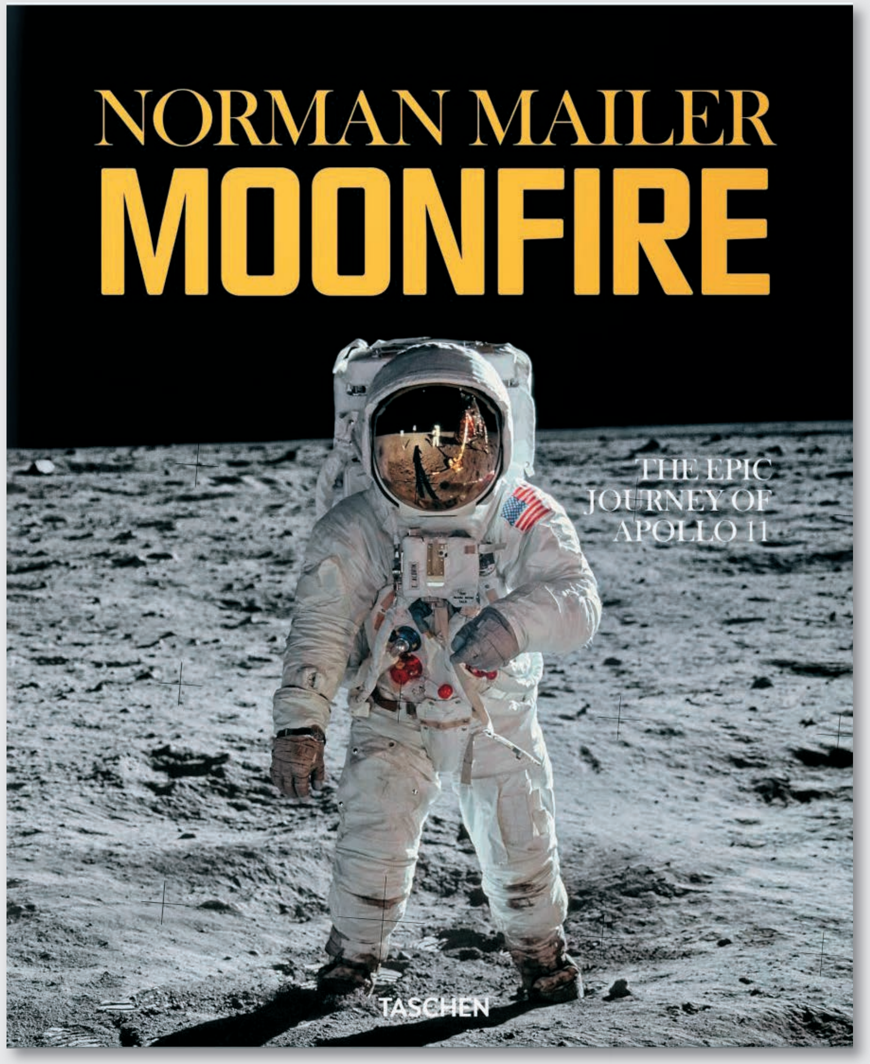
Image: Mathematisch-Physikalischer Salon, Langgalerie, Der Kosmos des Fürsten
Staatliche Kunstsammlungen Dresden Photograph: Hans Christian Krass

The Long Gallery in the Mathematisch-Physikalischer Salon is a truly exquisite setting for the Elector's exhibits from every angle

Reviews

Close to Apollo, but completely unemotional

There are images that have become legendary and are now part of the collective consciousness – for example, Neil Armstrong's boot mark, finely imprinted in the lunar dust; or the iconic picture of Buzz Aldrin in the blackness of space and Armstrong's reflection in his visor. **Moonfire: The legendary journey of Apollo 11 (Taschen)** goes well beyond these classics – among the hundreds of photographs are many unknown, even to Apollo fans, and they exude history. Armstrong's wife, Jan, and their son look out across the water from a yacht, spellbound; it could be a holiday snapshot, were it not for the Saturn V rocket in the background, climbing into the sky with Armstrong on board. Stills from the television broadcast show Aldrin during the return flight, spreading meat paste onto a slice of bread and eating it as if at home. As the astronauts return to Earth safe and sound after the first Moon landing, and the images of their safe landing in the water are broadcast, Joan Aldrin beams with happiness in a contemporary short dress, next to a table on which is an ashtray filled with cigarette ends. This thick, large-format book also contains photographs of the plaster casts of the astronauts' hands, which were used for tailoring their gloves, and an X-ray of Armstrong's overshoes for space.



But Moonfire is a treasure for another reason – the 347 pages of photographs are supplemented by text from Norman Mailer. In 1969, the celebrated author was asked to draft a three-part report on the mission to the Moon for LIFE magazine. This was exceptional; LIFE had never before published such a long non-fiction article. Excerpts from Mailer's text, published as a book in 1970, are included in Moonfire. Mailer takes his time and creates the alter ego Aquarius, who observes what is going on around him – sometimes amazed, sometimes bored. Mailer does not interact directly with those involved; he presents an external, yet close-up view of the historic mission. The description of the three Apollo 11 astronauts' final press conference, held in a glass box built on a stage, fills several pages. He analyses each of their personalities a little disrespectfully, and is amused by the disruptive rattling sound that Armstrong, speaking with pauses and somewhat woodenly, unconsciously makes as he talks. Mailer also surveys the gigantic 'Vehicle Assembly Building', with its vertiginous height of over 40 storeys, absorbs the atmosphere among the tourists in their campers and tents during the launch, and sits in front of the screens with the journalists during the landing.

This all happens with mixture of remote dissection and simultaneous fascination. You have to read carefully; sometimes, the poetic and extremely idiosyncratic writing style does not make it easy to follow. Even so, it is rare for someone to be so close to the lunar mission, yet so dispassionate in their observations. It is unfortunate that the images and text do not accompany each other – for example, the photo of the press conference described so vividly by Mailer appears several pages later. Still, Moonfire offers an unprecedented view of the legendary journey of Apollo 11 and the astronauts who made space history.

Manuela Braun

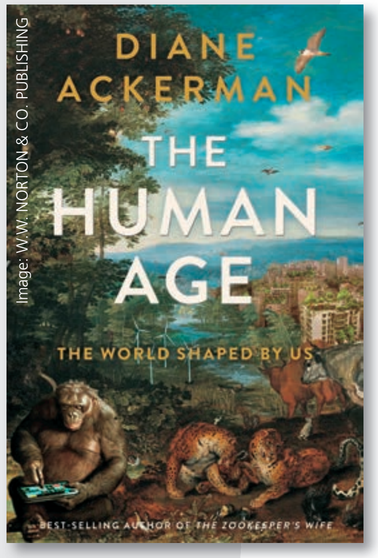


Image: W.W. NORTON & CO. PUBLISHING

Marvels of mankind

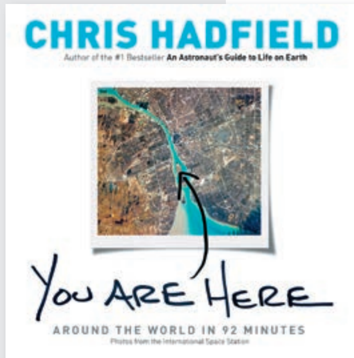
The planet on which we live today is not the same as it was thousands of years ago. In **The Human Age: The World Shaped By Us**, Diane Ackerman follows the evolution of the human species, following its constant move forward and examining life in an era of technological advancements that did not exist centuries ago. Although the human age is seen by many as having a negative effect on the planet, the author definitely views the 'Anthropocene Era' in a positive light and celebrates it.

Ackerman explores fields ranging from evolutionary robotics to nanotechnology and 3-D printing. The book raises ethical and political questions regarding the Anthropocene Era. The author addresses awareness in primates and contrasts it with robots that can solve problems by analysing their own experiences. The anthropogenic point of view is examined on land, deep in the ocean, from space and even the wider universe. The rapid change in society, science, technology, and mankind's impact on Earth's environment are explored even-handedly.

The author profiles the good and the bad – not only climate change as the result of human industrialisation, but also the continuous new ground that mankind is breaking and the technologies that are being developed. For example, creating an 'ark' of seeds and animal DNA, collecting human body warmth from 250,000 commuters in Stockholm's main railway station and using it to heat a nearby office building, vertical mariculture farms in the ocean off the coast of Maine, and teaching orang-utans to use iPads to communicate.

A great read for those interested in the development and evolution – technologically and biologically – of the human species. This book delves into how the technology available today will affect how humans will continue to evolve. For readers wanting to be more aware of the world that surrounds them, this is the book.

Karin Ranero Celius



Around the world in 92 minutes

Have you ever wondered what our planet looks like from space? Have you ever thought about how astronauts see Earth during one International Space Station orbit – that is, once every 92 minutes? Former astronaut Chris Hadfield gives anyone the chance to experience this in **You Are Here**. Hadfield's final space mission lasted five months, from December 2012 to May 2013; during this time, he orbited Earth 2597 times and took about 45,000 photographs – he could be regarded as a paparazzi of Earth. In this book, there are 150 pictures, carefully selected by the astronaut in his attempt to tell a story about our home in space – a world we all share and that adorns the pages of this interesting volume.

The book immerses the reader in a journey across the continents during one ISS orbit. The pictures themselves are breathtaking, but what makes the book special is the commentary. Hadfield explains what can be seen in each photograph. With his vast knowledge of geology, geography and meteorology, he is able to explain, for example, the geographic points of interest or the atmospheric phenomena revealed in each image. The explanations are not merely scientific – they vary between serious and fun, and can even be philosophical.

You Are Here is visually appealing and easy to read. It will definitely capture the attention of adults and children alike, and is sure to remind everyone of the beauty of our one and only home – Earth.

Karin Ranero Celius

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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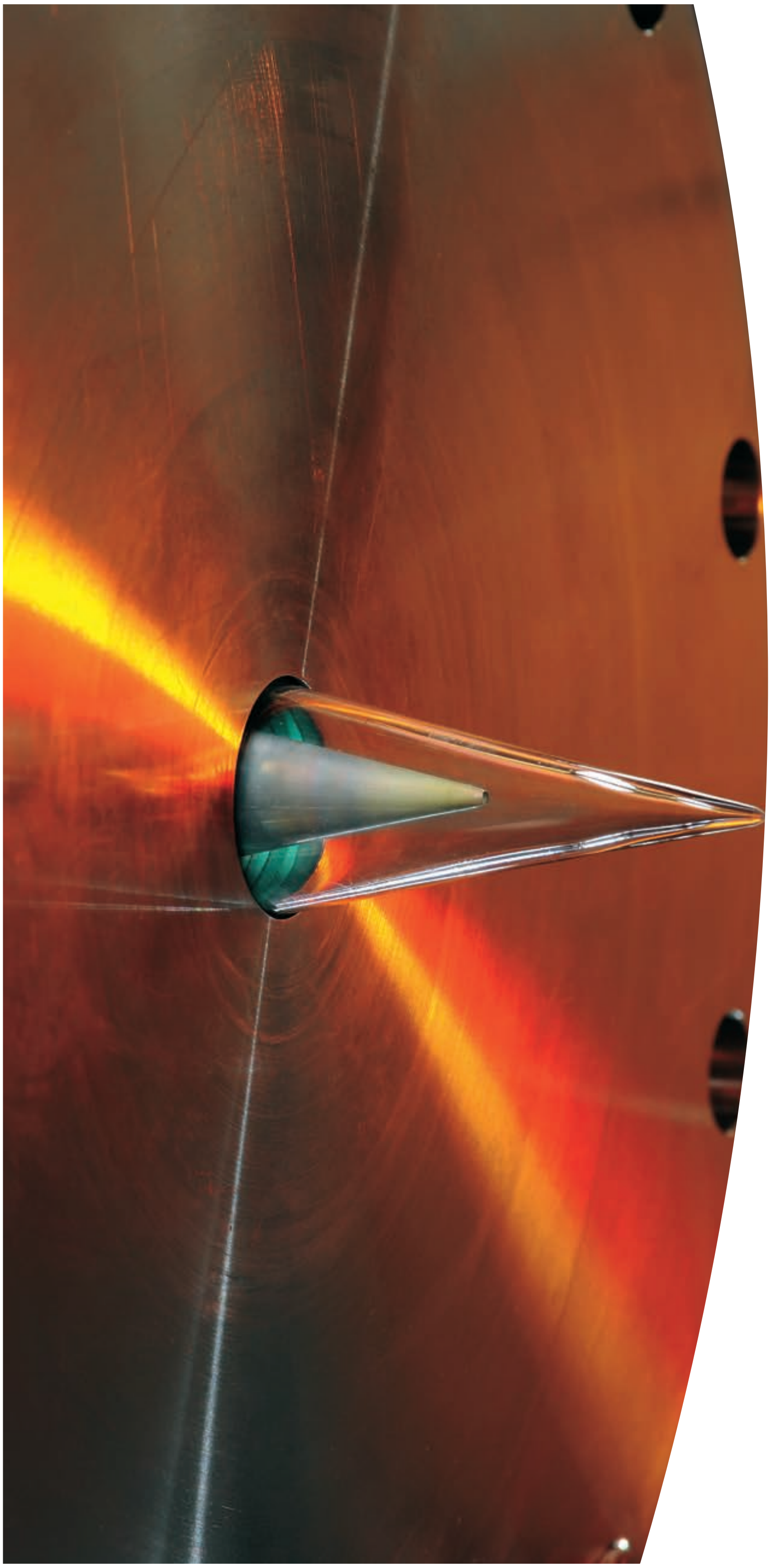

Imprint

DLR Magazine – the magazine of the German Aerospace Center

Publisher: DLR German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt)
Editorial staff: Sabine Hoffmann (Legally responsible for editorial content), Cordula Tegen, Elke Heinemann (Editorial management), Karin Ranero Celius, Peter Clissold and Linda Carrette (English-language Editors, EJR-Quartz BV)
In this edition, contributions from: Jasmin Begli, Manuela Braun, Dorothee Bürkle and Jens Wucherpfennig

Story submission deadline: 20 February 2015

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Printing: AZ Druck und Datentechnik GmbH, 87437 Kempten

Design: CD Werbeagentur GmbH, D 53842 Troisdorf, www.cdonline.de

ISSN 2190-0108

To order:
DLR.de/magazine-sub

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center