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DLR

magazine

Tagging along

The Rosetta spacecraft closes in on its target

Catching insects in Cochstedt

Flight tests for improved wing aerodynamics

On top of the world

Unique glider campaign in the Himalayas

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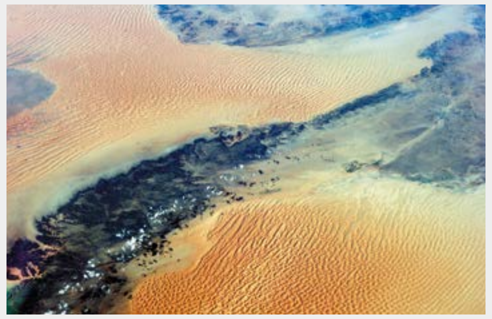
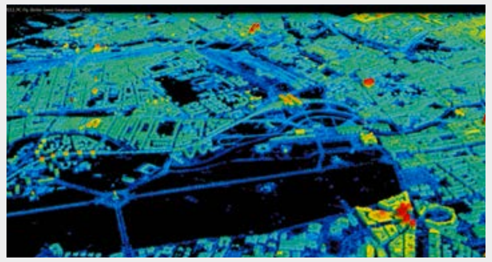
Sampling in an aircraft biofuel emission trail

Charles Bolden in the Falcon. The NASA Administrator travelled with DLR researchers as they operated the instruments on board the research aircraft. In May 2014, two US, a German and a Canadian aircraft conducted joint flight tests above California to investigate the emissions from biofuels. DLR mission leader Hans Schlager, from the Institute of Atmospheric Physics, was pleased to welcome this distinguished guest and explain the instrumentation being used for these unique flight tests. The full report about the ACCESS II mission measurement campaign can be found on page 34.





Dear readers,

Such a myriad of photographs – as fantastic as they are satisfying – has never before been available for the pages of our Magazine. German ESA astronaut Alexander Gerst is sharing snapshots of life on board the International Space Station ISS – and what our planet looks like from there – with all his social media followers on channels such as Facebook, Twitter, Google+ and Flickr. We too, stand transfixed at the magnificence of this marvel – Earth. Nevertheless, when dots of light appear in an image that give rise to the simple message 'My saddest picture', the photographs become as perplexing as they are beautiful. Involuntarily, we hold our breath – aerial warfare – this also is our Blue Planet.

There had been so much hope when the three astronauts – from Russia, the United States and Europe – embraced in silence just before they took off on their space mission – a gesture that laid bare the absurdity of our all-too-present earthly conflicts. For a moment, one could dare to believe that the trusting spirit of cooperation and coexistence must surely win in the end.

Indeed, the tasks facing humanity and the unsolved mysteries are so complex that addressing them will require an effort from everyone. We see this quite plainly in the world of science – endeavours such as environment-friendly and safe mobility demand cooperation. This is why DLR flight systems engineers are involved in the pan-European myCopter project, pursuing a vision of individual helicopter transport. Joined in a supranational community dedicated to the Rosetta mission, planetary researchers are venturing out to a comet located roughly 400 million kilometres away to discover more about how our Earth came into existence. In the interest of this grand venture, they depend on all those involved to complete their tasks with absolute reliability, thereby ensuring that decades of hard work will not be in vain.

Every story in this DLR Magazine is grounded in a spirit of partnership, whether between the institutes and other DLR sites or with universities, scientific organisations and industrial companies – throughout Germany, Europe or even the world. Nobody would claim it is easy to bring together such a range of different interests to achieve a common goal. In most cases, compromise is inevitable, and often this process is painful. However, stopping the quest for this conciliation, and instead proceeding alone, is not an option; the tasks themselves are too immense and overly interdependent. We all share Earth – this tiny blue dot – drifting in the endless expanses of the Universe. We will only survive if we work together to shape our lives here on this planet.

While one could reasonably claim that our plea for cooperation comes from a desire for utopia – faced as we are with the events unfolding across the globe – even this is no excuse to stop dreaming of peaceful, trusting collaboration. It is our immense good fortune that all of us can make a contribution, however small. So in this spirit, please enjoy these beautiful images and engaging stories. Perhaps they will inspire you and be a source of strength in tackling your personal task for making our coexistence that bit more peaceful…

Sabine Hoffmann
Head, DLR Corporate Communications Department

Perspective

Almost within reach

The DLR research aircraft ATRA flies low over the meadow at Magdeburg/Cochstedt Airport. The landing gear is nowhere to be seen, as ATRA is neither approaching nor taking off. It passes over repeatedly at altitudes as low as 15 metres. What is it doing? Collecting insects for aerodynamic research. More on this in the article 'Catching insects in Cochstedt'.

Image: Michael Häußer

Research partners in the air

By Jaiwon Shin

Jaiwon Shin
NASA Associate Administrator for Aeronautics Research

Cruising high above the California desert this past May, NASA and DLR aircraft flew closely together in the name of aeronautical and atmospheric science. As a NASA DC-8 led the way, burning a 50-50 blend of JP-8 jet fuel and renewable alternative biofuel, a DLR Falcon 20 E-5 followed right behind, slipping in and out of the DC-8's wake, as it measured the chemical makeup of the airliner's emissions and contrail formations. The ongoing research and analysis of the test results is aimed at solving some of the key operational and environmental challenges facing aviation worldwide during the 21st Century.

These Alternative Fuel Effects on Contrails and Cruise Emissions flight tests – ACCESS for short – are a current and perfect example of the kind of international collaboration that is so important in developing innovative technology in today's interconnected world.

But there is nothing new about this bilateral approach to aeronautical research between NASA and DLR. In fact, this type of partnership between our two organisations goes back at least four decades. During that time, NASA and DLR scientists have united in studying nearly every aviation discipline from noise abatement, air traffic management and structural design, to propulsion and airframe integration.

By contributing resources of every kind – personnel, facilities, finances – and approaching the same technical challenges from different directions, our respective talents and technical capabilities ideally combine to complement each other. And the collaboration continues. Today, in addition to ACCESS, NASA and DLR specialists are working together in other areas of fundamental aeronautical research, as well as improving management of air traffic around the world.

For example, together we are investigating how a composite helicopter subfloor structure might be retrofitted into current rotorcraft so it would be more crashworthy. DLR will design and build the composite subfloor, while NASA will integrate the resulting structure into a test helicopter and then drop the whole thing in a controlled crash.

Another example involves the use of NASA's Common Research Model (CRM), a scale model of a generic commercial airliner design that serves as a 'constant' among other testing variables found in operating different wind tunnels around the world. The CRM recently was deployed in the European Transonic Wind tunnel to help engineers calibrate measurements and validate computer codes – part of DLR's contribution to the European Strategic Wind Tunnel Improved Research Potential project.

Our partnership in the sky also extends to improving the way air traffic is managed in the sky. Since signing a pair of agreements during 2012, we have worked together to find new efficiencies related to aircraft arrivals, departures and surface operations at airports big and small. One outcome was a System Oriented Runway Management workshop hosted by NASA in the United States, with the next workshop planned for the summer in Germany.

With these kinds of results to boast about, all of us at NASA could not be more grateful for the opportunity to work with our DLR colleagues, and together serve as a model for international cooperation in scientific research with other nations.

Indeed, both DLR and NASA are among the 24 member nations of the International Forum for Aviation Research (IFAR), an organisation designed to connect research organisations worldwide, enable the exchange of information in the field of aviation research, and identify areas for mutually beneficial collaboration. NASA is honoured to serve as the current IFAR Chair, following in the footsteps of DLR, which served as the organisation's inaugural Chair.

Together, NASA and DLR are accomplishing so much more than by each flying solo, producing an aviation corollary to Aristotle's "The whole is greater than the sum of its parts." As we look forward to meeting the future needs of the global aviation community, the reliable and steadfast partnership demonstrated by our two agencies will ensure our continued success. ●

Two cameras film the propeller blades from different angles. The equivalent points are identified by computer with the help of the attached dot pattern. Having knowledge of the position and orientation of the cameras, the entire surface of the propeller can be visualised in three dimensions.

Visualising the deformation of a propeller in flight

DLR researchers have succeeded in making the deformation of a propeller in flight visible for the first time. To do this, they developed a camera capable of withstanding the enormous forces generated during rotation. These findings can be used to improve future aircraft propellers, helicopter rotors and wind turbines.

The scientists from the DLR Institute of Aerodynamics and Flow Technology built the stereoscopic high-speed camera into the hub of the propeller. The camera is focused on a propeller blade and rotates in synchronisation with the propeller during flight. The camera is thus subjected to centrifugal forces of up to 20 times the acceleration due to gravity as well as to high levels of vibration. Because of these forces, observation of the deformation in flight was thought to be impossible, as the sensitive measurement technology would normally be destroyed under such stresses.

The Göttingen researchers placed the camera, a miniaturised computer and other electronics inside a metal container to protect them from damage. In this way, they were able to acquire thousands of images of a special pattern of dots placed on the propeller blade. This enabled visualisation and measurement of the smallest deformations. Until now, pilots have set the speed and the pitch of the propeller by 'feel'. Now that the effects are measurable, in future pilots will know which setting results in the lowest fuel consumption or the highest speed without unnecessarily stressing the propeller. This information will also improve flight safety.

s.DLR.de/rcf7

Check-up for SOFIA in Hamburg

The Stratospheric Observatory For Infrared Astronomy (SOFIA), operated jointly by NASA and DLR, has been undergoing a check-up since July that will last until early November in Hamburg. The modified Boeing 747SP is normally stationed at the NASA Armstrong Flight Research Center in California. However, Lufthansa Technik has the most experience in the maintenance of this type of aircraft.

During its 90 flights since 2010, SOFIA has studied, among other things, how galaxies, stars and planetary systems are formed from interstellar molecular and dust clouds. A 17-ton telescope with a mirror diameter of 2.7 metres, which was developed in Germany and commissioned by the DLR Space Administration, is built into the fuselage. A total of six scientific instruments are currently in use, including the GREAT and FIFI-LS spectrometers operated by German scientists. Because SOFIA flies in the stratosphere, above most of the atmospheric water vapour, it can observe infrared radiation almost without loss.

"SOFIA is designed for a service life of 20 years," says Eddie Zavala, SOFIA Programme Manager at NASA. After the overhaul in Hamburg has been completed – notes Zavala – from 2015 onwards, SOFIA will be the essential tool for infrared astronomers with approximately 100 observation flights planned per year.

s.DLR.de/04l2

SOFIA arrives at Lufthansa Technik in Hamburg

A call for rocket and balloon experiment ideas

The countdown to the eighth competition of the German-Swedish student programme REXUS/BEXUS is under way. European university students have until 13 October 2014 to submit their proposals for experiments on stratospheric balloons or research rockets to DLR or the European Space Agency, ESA. The final experiment selection will take place in December 2014 – at DLR in Bonn for the teams from Germany and at ESTEC in Noordwijk, the Netherlands, for the other participants. The students will be notified before 25 December on whether their experiment will fly on one of the two BEXUS balloons in Autumn 2015 or on one of the two REXUS rockets in Spring 2016.

bit.ly/1qCgwnG

Novel hydrogen tank

DLR researchers, together with partners in an EU project, have developed a combination tank in which hydrogen can be stored compactly at ambient temperature and moderate pressure.

Coupled with a fuel cell, the tank has been mounted in a vehicle as a complete system for the first time. It can provide electrical power for the air conditioning, heating and lighting.

The modular hydrogen tank is constructed from individual pipes fitted side by side. These are filled with two different solids – black metallic alloys, whose consistency is similar to that of flour. These storage materials absorb the gaseous hydrogen like a sponge to which it is then bound. Due to this property, the gas can be stored in a small volume at a pressure of 70 bar and at normal ambient temperature. This is significantly less than with conventional tanks, where the hydrogen is pressurised to 700 bar.

s.DLR.de/9uph

The hydrogen tank is filled with solid materials that absorb the gas like a sponge and improve the performance of the tank.

THE MILKY WAY IN YOUR POCKET

bit.ly/1Clm37z

Mapping one billion stars in the Milky Way may seem impossible. ESA's Gaia mission is doing this. Scientists want to create the largest, most accurate three-dimensional map of our galaxy to date. With a new app developed at the University of Barcelona, you can now follow the mission. This app for iPhone, iPad or iPod brings the stars closer to you than ever – free of charge.

JAN WÖRNER BLOG

s.DLR.de/10br

Insights on aviation, space, energy, security and transport research, from a very special viewpoint. This blog is written by Chairman of the Executive Board of the German Aerospace Center, Johann-Dietrich, better known as 'Jan' Wörner. This informative blog is truly one-of-a-kind. This is a place where important issues are discussed and complex subjects tackled. And rest assured, Jan Wörner tells it like it is.

THE SOLAR SYSTEM UP CLOSE

www.solarsystemscope.com

Explore our very own neighbourhood – the Solar System – in this interesting interactive site. Here you can get an overall view of our planetary system, inspect the planets and learn about them, and more. It is also available for download on your desktop as well as on iOS and Android for your tablets and smartphones.

MAKE YOUR OWN SPACECRAFT

bit.ly/1s6eNqa

ESA has created printable paper models of the Rosetta spacecraft and its lander, Philae. The mission aims to investigate the origin and evolution of the Solar System by getting up close and personal with comet 67P/Churyumov-Gerasimenko. In early August, Rosetta went into orbit around the comet and in November the lander will be deployed to the surface for further analysis. Download the PDF of the models and put them together – fun for adults and children alike.

POPULATING SPACE

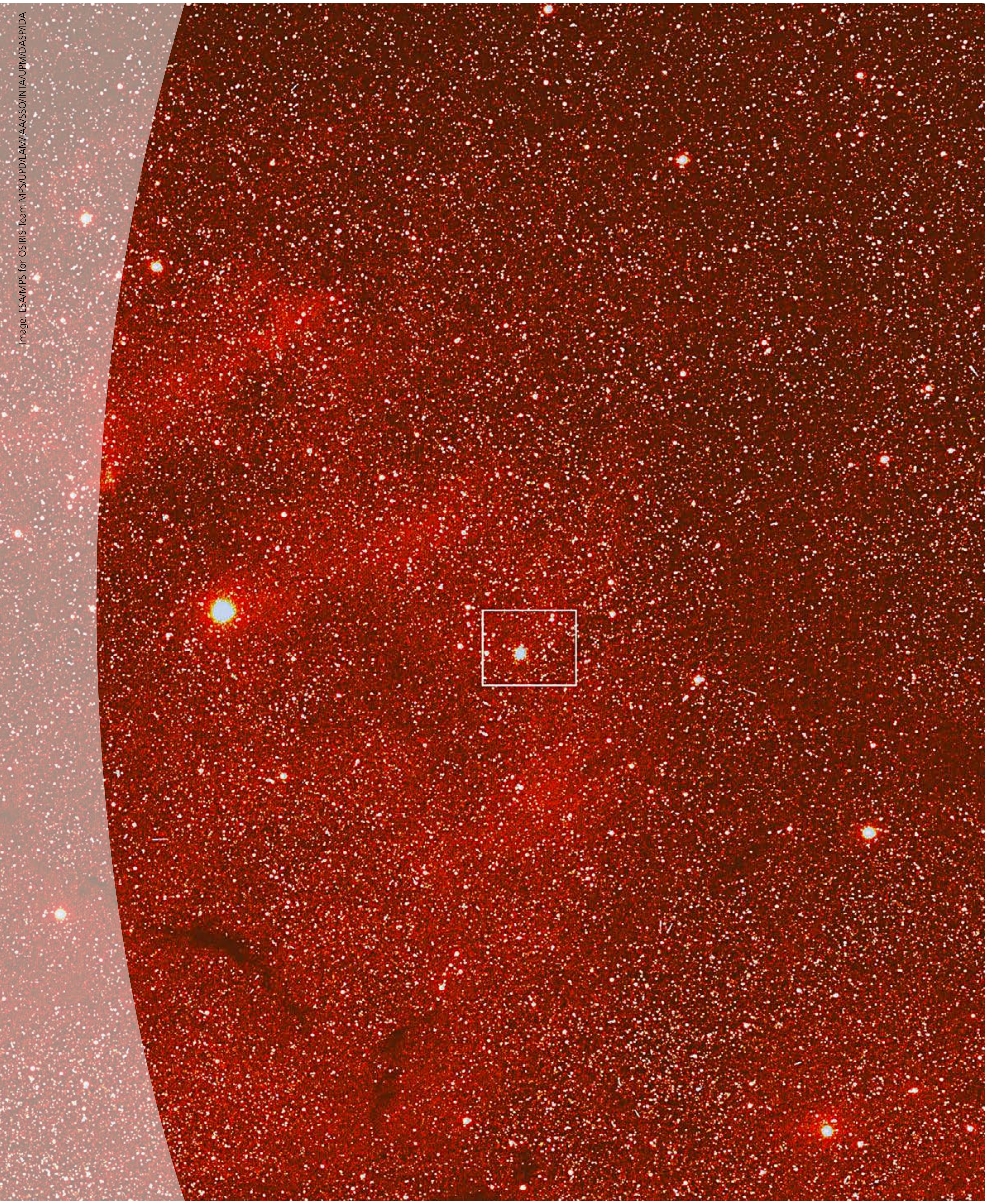
www.howmanypeopleareinspacerightnow.com

How many people are in space right now? This site holds an immediate and concise answer: the number of astronauts and some background information on each of them. For example, when looking up Alexander Gerst, the site links to his ESA astronauts profile page. With the website comes an app for iPhone that offers notifications, photos and videos from space, astronaut profiles and more – for just $2.99.

CHASING A COMET

bit.ly/1ukZmeT

How does a spacecraft land on a comet – one that is 400 million kilometres from Earth? This is what the Philae lander will attempt in a little over two months. The landing preparations started about three years ago, and the most critical moment of this ground-breaking moment is imminent. In this short film, scientists and engineers give us an insight into the incredible challenge posed by landing on a 'dirty snowball' never seen up close before – a true mission to the unknown.



Just a point in a sea of stars – this image of Comet 67P/Churyumov-Gerasimenko was acquired by the OSIRIS camera on 20 March 2014, when Rosetta was about five million kilometres from the comet.

Tagging along

Since August 2014, the European Rosetta spacecraft has been circling Comet 67P/Churyumov-Gerasimenko in a sophisticated orbit. On board is the Philae lander, which will touch down on the surface of the comet in November 2014. The mission is breaking new ground by the second – and in every way. No comet has ever been studied by a spacecraft from orbit, and measurements have never been carried out on the surface of a comet. Eleven instruments are flying on the orbiter and 10 on the Philae lander; scientists around the world are awaiting the data with bated breath. The DLR Institute of Planetary Research is playing a leading role in four of the mission's experiments, and contributing scientifically to another three experiments.

The Rosetta mission – closing in on comet 67P/Churyumov-Gerasimenko with probes, cameras and spectrometers

By Manuela Braun

Back in the 1980s, following successful comet flybys performed by the Vega and Giotto missions, the first seeds were sown for another European cometary mission as one of four European Space Agency, ESA, cornerstone missions. All of this came at a time when Helmut Kohl was elected as Chancellor of Germany and the first home computers such as the Commodore 64 and the Apple Macintosh were being introduced. CD players were being mass-produced and starting to compete with vinyl records and cassette players. In the 1990s, when plans for a lander were approved and development was underway, Germany introduced five-digit postcodes, East and West Germany were reunited, and mobile phones, email and SMS were on the rise. Colourful, wide ties were a popular accessory back then, as seen in the group photos of the lander team. In 2004, the Rosetta spacecraft was finally launched, carrying the Philae lander on board, on a 10-year journey to Comet 67P/Churyumov-Gerasimenko. By then, digital cameras had replaced those using film and Wikipedia had been founded.

Eye to eye with Churyumov-Gerasimenko

In November 2014, the moment will have arrived – 30 years after the first mission concept, Philae will set down on *Terra Incognita* and, for the first time ever, measurements will be carried out on the surface of a comet. Sitting in front row will be the Rosetta Lander Imaging System, ROLIS, located on the bottom side of Philae and oriented towards the comet. ROLIS will start to acquire images during the descent onto Churyumov-Gerasimenko. "This is important because we have to identify the exact landing site," says Stefano Mottola, the Principal Investigator for ROLIS.

Soon after a digital elevation model has been generated from images acquired by the OSIRIS camera on the orbiter, a decision will be made on a landing site – but the landing ellipse will be several hundred metres across. Too many unknowns, such as the activity of the comet, make more precise planning impossible. Philae will be released from the Rosetta orbiter several kilometres from the comet, and will then slowly descend towards it. This will all happen autonomously, in accordance with a pre-programmed landing sequence during which the watchful team in the DLR Landing Control Center will not be able to intervene. ROLIS will acquire the first high-resolution images of the actual landing site and send them to Earth for comparison with the existing OSIRIS images.

ROLIS will capture the first images immediately after Philae and the orbiter part company. "These will be sent directly to the mother craft," explains Mottola. The camera system will then image the comet every five seconds. But the camera and its technology were developed 20 years ago. "Of course, by today's standards, we only have limited storage capacity." The first images will be overwritten by more recent ones once they have been transmitted to the mother spacecraft. The first truly historical image will be acquired at a distance of around 35 metres above the surface of 67P/Churyumov-Gerasimenko, and the final image will be acquired from no more than five metres away.

Then, the actual scientific work will begin for Mottola's team. The cometary researchers intend to use ROLIS to analyse the small-scale morphology and composition of 67P/Churyumov-Gerasimenko. "After the landing, we will have a field-of-view of 30 by 30 centimetres on the comet, and will be able to examine its surface structure and composition at high resolution." Furthermore, multispectral images should enable the various materials on the surface of the comet to be identified.

A sensitive hammer

Two other instruments under the responsibility of DLR scientists will have to wait their turn in the first science phase (during which each instrument will be used at least once), as they will be generating tremors and noise on the comet – MUPUS, Multi-Purpose Sensors for Surface and Subsurface Science, and SESAME Surface Electric Sounding and Acoustic Monitoring Experiment. "MUPUS functions like a penetrometer on a building site," explains Tilman Spohn, MUPUS Principal Investigator and Director of the DLR Institute of Planetary Research. By this, he means a penetrometer in inverted commas. "Our thermal probe is – of course – much more delicate." A hammer mechanism will drive a rod equipped with 16 heat sensors vertically into the ground to a depth of 40 centimetres, to measure the temperature and thermal conductivity. Heat

Image: Centrum Badan Kosmicznych PAN / Space Research Center PAS

The MUPUS instrument will hammer a probe up to 40 centimetres into the comet to measure its temperature

sensors in the spacecraft anchors and a radiometer will also add to the measurements. The radiometer will measure the surface temperature, and the anchor sensors will measure the temperature to a depth of between one and two metres.

Before MUPUS can be used, the scientists must determine exactly where it should hammer into the surface. A panoramic image from the French CIVA camera will be needed for this – it will provide an overall view of the landscape. "Ideally, we would like to have a site with a completely unspectacular surface." No slope, no holes and no chunks of ice that would cause problems for MUPUS. The decision on this must be made within a well-determined time window, as the sequence of the initial scientific investigations is planned down to the minute. "This is a difficult undertaking. If we miss this, we lose the window of opportunity for the first deployment of MUPUS."

Finally, the Philae lander may have to raise or lower itself to get to the scientists' preferred position – and perhaps turn on its axis as well – before the thermal probe is extended one metre and a half outwards and driven into the ground. This is controlled by a software package that will set the force of the hammer device on the probe. "We might find a very hard or a very soft surface." So Spohn hopes the landing site will be quiet and boring in the small-scale range. "If not, a region with ice will do nicely," he says. "And we would quite appreciate some cometary activity – but not too much."

Listening for the echo

When MUPUS hammers, it will not only be the scientists on Earth listening intently; the instruments in the SESAME experiment – some of which are located in the lander's feet – will also be lending an ear. There are three instruments in the experiment: the Dust Impact Monitor (DIM) sits on the upper side of the lander and will record impacts by cometary dust and ice particles, the Permittivity Probe (PP) will determine the electrical conductivity and the water content of the surface, and CASSE (the Cometary Acoustic Surface Sounding Experiment), which is located in the feet of the lander, is programmed to listen. "The soles of the lander feet can induce acoustic and electric signals like a sonar, or receive them like a passive seismometer," says Principal Investigator Klaus Seidensticker. In this way, the period and shape of the signal are set to be measured from foot to foot, enabling the mechanical properties of the surface to be studied. The seismic waves triggered by MUPUS will be used by CASSE. The scientists on Earth can use the data to draw conclusions about the comet's features, such as the porosity and layering of the material.

The comet in three dimensions

The Rosetta orbiter also carries instruments that DLR researchers have contributed to scientifically. Planetary researchers at DLR will work with French colleagues to generate a digital elevation model of 67P/Churyumov-Gerasimenko from the data acquired with the OSIRIS camera, which will reveal the structure of the cometary terrain in three dimensions. "From orbit, we will be able to achieve a resolution in the one metre range, which is an entirely new standard," says Ekkehard Kührt, head scientist for the Rosetta mission at DLR, who is working as a Co-Investigator (CoI) on the data from OSIRIS. With the elevation model, the cometary scientists can investigate, for example, the morphology of the comet or understand the nature of craters. "Ultimately, the topography of the surface of the comet is crucial for almost every analysis – from solar radiation to structural changes such as landslides on the surface," stresses Kührt.

The OSIRIS data is also important for Stefano Mottola; according to the latest analyses, the scientist thinks that the rotation period of the comet on its axis has reduced from 12.6 hours to 12.4 hours. "This difference could simply be because the rotation speed determined from Earth used imprecise measurements and was incorrect – but we believe that the comet is now rotating faster on its axis," explains Mottola. "I want to investigate this mechanism in more detail."

Research during the approach

The cometary researchers have already received the first data from the five instruments in the Rosetta Plasma Consortium (RPC). The instrument that Kührt is also involved with as a CoI is designed to work during the approach to the comet and investigate the charged particles and magnetic field surrounding 67P/Churyumov-Gerasimenko. When ice sublimates on the surface of a comet and gas is released, it is ionised by solar radiation. "The plasma that envelops the comet interacts with the solar wind and forms characteristic structures," says Kührt. With this data, cometary researchers hope to acquire new knowledge about processes in the inner coma and their evolution with increasing cometary activity.

The VIRTIS spectrometer, which works in the visible and infrared spectral range, is also able to carry out scientific investigations remotely. DLR scientist Gabriele Arnold, VIRTIS' German National Team Leader, and her research group are investigating the composition of ice, dust and organic materials. "Comets exhibit the state of materials in the early phase of the formation of the Solar System better than any other object," explains Arnold. "By analysing the composition of the comet, we can get a glimpse of our planetary system's early 'childhood'." VIRTIS will be identifying and analysing the various materials on the surface and in the coma throughout the entire lifetime of the mission.

At the same time, the experiment will allow the creation of a thermal map of the comet's surface. "In combination with the topographic models from the OSIRIS data, we also hope to be able to discover and study the connection between the composition of the surface, its structure, the temperature and the processes involved when activity starts," adds Arnold. This data is also important when deciding on a landing site for Philae. Therefore, as with OSIRIS, the investigations conducted with VIRTIS will be used in the early phase of the approach to the comet to identify the safest possible landing site.

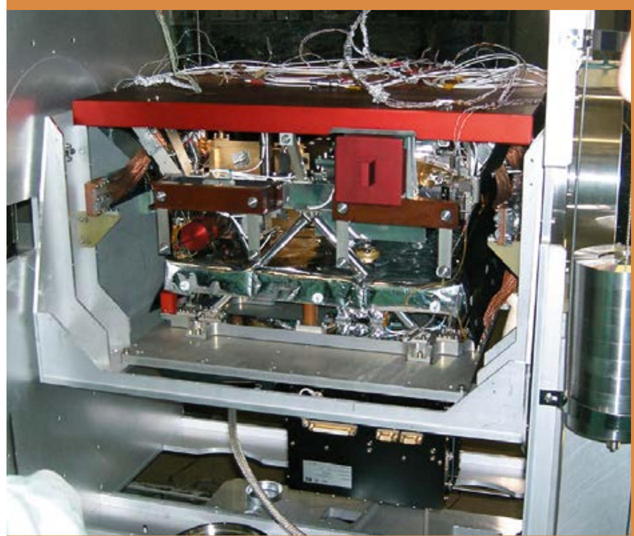
A 4.5-billion-year-old eyewitness

It has taken almost 30 years to obtain the first data and research results after the initial idea. But looking at the big picture, this is a trivially small amount of time when compared with the age of 67P/Churyumov-Gerasimenko. "Comets are eyewitnesses to the formation of the Solar System 4.5 billion years ago and, due to their deep-frozen state, they have changed less than other Solar System bodies since then." Kührt is certain of one thing: "All the data we receive from the instruments during the mission will be of an unprecedented quality. It will give us exciting evidence about the nature of these celestial bodies and take us back to the formation of our planetary system." •

More information:
DLR.de/en/Rosetta
Model of comet's shape: s.DLR.de/c15a

The SESAME instrument sensors are mounted on the feet of the lander, and will use electrical and acoustic methods to examine the composition of the cometary surface.

The ROLIS camera on the bottom side of Philae will acquire its first images during the landing on 67P/Churyumov-Gerasimenko



The VIRTIS spectrometer on the Rosetta spacecraft has already delivered its first data

A long-awaited touchdown

Philae will be the first spacecraft to touch down on a comet and acquire images of its surface, examine ground samples, analyse organic substances and more. The lander is controlled and operated from the DLR Lander Control Center in Cologne. In this interview, Stephan Ulamec, Project Manager for Philae, explains what lies ahead for the lander and the risks involved with a mission that has never been attempted.

Interview with Stephan Ulamec, Project Manager for the Philae lander

This interview, by Manuela Braun, was adapted from the German original to reflect changes in the status of the mission.

This is the first attempt to land on a comet following a 10-year journey through space. What can the lander expect when it touches down on Comet 67P/Churyumov-Gerasimenko in November?

The final decision on the landing site for Philae will be made in October. By then, we will have a high-resolution, three-dimensional elevation model of the comet, and even higher resolution maps, derived from data acquired by the navigation camera and the OSIRIS imaging system on the Rosetta orbiter. OSIRIS and NAVCAM have already started to provide data regarding the rotational axis and the shape of the comet. Five candidates for landing sites were selected at the end of August. What we will not be able to see until later on is what the surface of the comet looks like on a small scale. For example, is it rocky? Are there holes like in a sponge or maybe even ice spikes? Is there a boulder field? We will only be able to assess all that relatively late on, in September or October – in more and more detail as Rosetta's orbit gets closer to the comet. What we probably will not be able to determine prior to the landing is the strength of the surface. We may be able to deduce, from the angle of repose of the surface materials or the slope of the crater rims, whether the surface is dusty or icy. We will certainly find this out at the moment of touchdown, when we will discover whether Philae sinks into the surface.

What kinds of surface can Philae withstand?

The lander is designed for a wide range of surface types. During the design phase, we were somewhat concerned that the surface would be hard – perhaps porous ice with dust inclusions. Now, with the images acquired by OSIRIS, we are thinking more in terms of a loose regolith – a dusty, softer surface.

From what altitude will Philae be released, and how will the landing proceed?

That will be determined once the landing site has been chosen. The landing will be triggered from an altitude of a few kilometres. Philae will be pushed away from the orbiter and will descend ballistically towards the comet. Depending on the mass and the conditions, it will take a few hours until touchdown. When it touches down, two harpoons will immediately be fired into the comet's surface – almost simultaneously. The lander feet are equipped with ice screws that will be pushed into the surface. During the landing, a cold gas thruster will fire from the top of the lander and push Philae down onto the comet surface. A damping mechanism has been incorporated into the central tube of the landing mechanism to dissipate most of the descent kinetic energy, rather than having it stored in the legs as an elastic force – that way, we will prevent any rebound.

What are the challenges for a safe landing?

We will not be able to land at an exact spot, but the landing ellipse is quite large, and the terrain throughout the area needs to be relatively flat. Even if Philae rebounds at a very low speed – here, we are talking about a few centimetres per second – this will turn into a gigantic 'bounce'. After such a bounce, the risk that Philae does not get back on its legs is unacceptably high. However, it can tolerate a gradient of up to 45 degrees.

What is the role of the team in the DLR Lander Control Center?

To prepare for the landing, at LCC the team will program the command sequence. What is the ejection speed from the orbiter? When will each experiment be switched on during the descent? When will the harpoons be prepared for firing? We will also receive the telemetry data and the first images from the ROLIS and CIVA cameras directly in the control room – with a signal delay of half an hour. Then, the initial part of the first science phase will begin, involving experiments that do not require any mechanical activation. The landing will be possible, even if things do get a little bit 'bumpy'. But the parameters can still be changed over the following hours and days; for example, we can rotate the lander so it gets more sunlight. We can change the exposure time of the camera; we can determine where MUPUS, the penetrator that hammers into the ground, will be deployed. This is all controlled from the LCC using the telemetry received from Philae.

During the preparations for the landing, will the comet already be active and outgassing on its journey towards the Sun? What consequences will this have for the landing?

Our uncertainty about the exact density of the coma means that the exact trajectory is quite hard to predict. The orbiter position at the exact moment of Philae ejection cannot be foreseen with very high accuracy due to the uncertainty of the gas drag within the coma.

Stephan Ulamec, seen here in Lander Control Center at DLR in Cologne, has been involved in the mission since the beginning.

What could go wrong during the landing?

There are two kinds of problems. On the one hand, technical failures – for example, a motor that does not work, or a component that gets jammed. However, almost everything on Philae is redundant. And there is also the uncertainty in the comet environment that might cause problems. The lander might touch down at a crevasse, or a large rock and might tip over. Also, a jet – an outflow of gas – might divert it from its original landing site during the descent. There is not much we can do if any of these potential problems arise. However, we have conducted multiple tests and prepared the lander for any of the problems that could occur.

How quickly will it become clear in the control room how Philae has fared during the landing?

The last moment prior to landing at which we can still intervene directly from Earth is seven hours 15 minutes prior to separation from the orbiter. From then on, everything will run completely autonomously, following the sequence that we will have uploaded to Philae. However, we will receive initial telemetry data during the descent, sent to us from the lander via the orbiter. When we see the horizon from Philae's panoramic cameras, we will know that we have arrived and Philae is operational.

How long will Philae and its instruments work on 67P/Churyumov-Gerasimenko?

Hopefully several months! Philae is designed to be able to work throughout the approach to the Sun, until the comet reaches a heliocentric distance of two Astronomical Units, which will coincide with the end of March. What is hard to estimate is how much dust will be deposited on the solar cells and when they will stop generating sufficient power. But at some point during the mission, on the journey towards the Sun, Philae will get so hot that the batteries and the electronics will stop working. From then on, the lander will travel on the comet as a historical entity. •


The helical antenna of AISat is four metres long – and will make ship detection more accurate. The satellite gets its name from Automatic Identification System.

Helix with a sharp ear

A helical antenna that unfolds to a length of four metres, a receiver and a control room at DLR Bremen – the AISat satellite has been orbiting Earth at an altitude of 660 kilometres since 30 June 2014, and is being monitored and controlled from Bremen. Its mission is to receive signals from ships and transmit them back to Earth. It is competing with other commercial satellites that monitor shipping traffic from space, but AISat has one major advantage – it listens very closely.

AISat satellite – detecting ships from orbit

By Manuela Braun

"Congested waters such as the German Bight, Mediterranean Sea, North American Atlantic coast or big ports, such as those of Singapore or Tokyo, are like a cacophony of sounds for available commercial satellites," says project leader Jörg Behrens from the DLR Institute of Space Systems. It is like listening to 100 radio stations simultaneously. Each ship is fitted with an Automatic Identification System (AIS) – required under international law since 2000 by the International Maritime Organization. The signals carry information about the ship's identity, location, direction, speed, cargo, length and width. Conventional satellites use non-directional rod antennas, thus monitoring a large area with a diameter of between 5000 and 6000 kilometres. In this case, the subtleties are lost. In heavy traffic, the individual vessels are no longer precisely identified because the signals overlap. Behrens and his team thought they could do better.

In collaboration with the DLR Institute of Composite Structures and Adaptive Systems, Behrens developed an antenna that was sent into space compressed to a height of just a few centimetres; once in orbit, it deployed into a four-metre-long helix that points unerringly towards Earth. Instead of focusing on quantity and covering several thousand kilometres, this helical antenna focuses on a region with a diameter of just 750 kilometres, and thus on a significantly lower number of vessels. Filters and different attenuators optimise the signal, which is then processed and refined so that AISat can 'hear' individual ships. So, in future, shipping routes can be optimised and shipping lanes made safer.

Critical comparison between ground and space

During an aerial survey along the German North Sea coast, from the Netherlands all the way up to the island of Sylt, researchers counted at least 1000 ships. AISat should also be able to detect them from space. "We will subject our satellite and its performance to very demanding tests," emphasises Behrens. To this end, DLR has installed a total of 10 ground stations that receive ship signals up to a distance of 40 to 60 kilometres from land along the heavily trafficked North Sea coast. Non-directional rod antennas were also installed on the satellite to provide comparative data. "For the helical antenna to be a success, it must perform better than these conventional antennas," says Behrens. The scientists will therefore listen very closely to what AISat receives from orbit and sends back to Earth. At the moment, researchers can only contact AISat two or three times a day from the control room, when the satellite passes over northern Germany. But the future is just around the corner – literally. Next to the Institute, a container houses an antenna that will be positioned next to DLR's existing ground station in Inuvik, Canada. "Using the new antenna, we will be able to access a significantly greater number of AISat overflights and receive more data from space." •

More information:
s.DLR.de/7q4o


Tension in the Bremen Control Room – the team waits for the first signals from the satellite.


Careful work for the flight to Asteroid 1999 JU3; the MASCOT lander must be handled with care.

A small hop for an asteroid lander…

Weighing just 10 kilograms and measuring a mere 30 by 30 by 20 centimetres – barely larger than a shoebox – the DLR Mobile Asteroid Surface Scout, MASCOT, is a little powerhouse. The engineers and scientists have managed to fit four instruments into this smallest of spaces. A flywheel also ensures that, once MASCOT arrives at asteroid 1999 JU3, it will be able to 'hop' across the surface as it carries out measurements. The lander will investigate the celestial body whose material has hardly changed since the formation of the Solar System – 4.5 billion years ago.

MASCOT will be launched into space on board the Hayabusa-2 spacecraft at the end of November 2014

By Manuela Braun

MASCOT project leader Tra-Mi Ho remembers the past three years very well – moments "during which one found that the requirements were very challenging." Nonetheless, the team managed to find a solution – compact, lightweight, stable, suitable for the Japanese Hayabusa-2 space probe and fitted with scientific instruments to provide valuable data from asteroid 1999 JU3. The MASCOT asteroid lander should meet all of these requirements. The idea for the mission arose from the Japanese space agency JAXA in a roundabout way, where initially there was talk of a lander weighing 100 kilograms and of a correspondingly large size, for which DLR carried out a study. Back then, the lander under discussion was meant for the European Space Agency (ESA) Marco Polo mission. When the mission to 1999 JU3 did not 'pass' an ESA contest for its implementation, the lander study also seemed to have come to an end.

Change of plans on the fast track

"But then, DLR was called upon by JAXA for another mission," explains the project leader. The requirements were now quite different: 10 kilograms instead of 100, a perfect fit for transportation by the Japanese Hayabusa-2 spacecraft. In 2003, JAXA sent a probe to asteroid Itokawa that brought back dust grains to Earth in 2010. The accompanying MIcro/Nano Experimental Robot Vehicle for Asteroid, MINERVA lander, equipped with cameras and temperature sensors, could not be set down on the asteroid at that time and was lost in space. Now, JAXA planned a timely follow-up mission – never giving up on the idea of landing on an asteroid surface. The DLR engineers were given a challenging task: "The problem for us was that we had very little space for the lander and its instruments, and it could only weigh 10 kilograms."

What followed is what Tra-Mi Ho cautiously calls a 'process of continuous optimisation'. In the initial planning, there was no hardware, many components were still in development, and the technical requirements for the MASCOT designer were constantly changing. During the journey through space, the small lander must survive for long periods at low temperatures. The conditions under which it will operate at the asteroid location are not yet known. What was known, however, was that it will be significantly warmer than during the journey itself. It must withstand both temperature extremes. "The final MASCOT design only came to be in the course of the development phase." Finally, it was clear that four instruments had to be installed with great care and caution in the lightweight carbon-fibre composite frame: a magnetometer from TU Braunschweig, a near-infrared spectrometer from the French space agency CNES, and a camera and radiometer from DLR. The scientific investigation would last 16 hours – two asteroid days and nights.

Lander with take-off power

The time frame for preparing the mission was also extremely short. In just three years the Institute of Space Systems, together with the Institute of Composite Structures and Adaptive Systems, the Robotics and Mechatronics Center and the DLR Institute of Planetary Research developed, built and tested a compact lander with a special hopping ability. It was the first time that a lander, MASCOT, would set down on the surface of an asteroid to conduct measurements at multiple locations. The first landing on an asteroid took place in 2001 during NASA's NEAR mission. At that time, a probe orbited the asteroid Eros, then landed – even though it was not designed for this – and sent data back to Earth. But NEAR could not change its position on the surface of the asteroid – MASCOT can. A flywheel inside transmits forces to the lander and thus causes a rotation or a leap of up to 200 metres. "Hence, for the first time, we will be able to investigate how heterogeneously or uniformly an asteroid is constructed," says Ralf Jaumann from the DLR Institute of Planetary Research.

Visual acuity – near and far

The planetary scientist is sending a wide-angle camera to the asteroid 1999 JU3: "Our camera sits between the struts of MASCOT and looks out from there onto the asteroid." The device, weighing just 407 grams, also has a special capability – it can look directly onto the ground 30 centimetres away from the lander, but is also able to focus on the horizon of asteroid 1999 JU3. The camera owes this to sophisticated optics that enable near and distant focusing.

The camera will already be active during the descent, after MASCOT is pushed towards the asteroid surface via a spring mechanism at a height of around 100 metres. "Perhaps during the spin we will see only in the direction of stars, but the chances are good that we will also see the asteroid from above." After the landing, the optics will be initially focused on the ground in the immediate vicinity of MASCOT. The camera can resolve granules with a diameter of just 0.2 millimetres, thus allowing scientists to draw conclusions about the roughness and porosity of the asteroid surface. With the shift of sunlight on 1999 JU3, and consequently the change in the shadows, distances can also be estimated from the acquired images. Even in the darkness of the asteroid night, the scientists can continue to operate their camera; four coloured LEDs provide the missing light. "So we can investigate the surface material – in colour."

Asteroid 1999 JU3 is exciting because it is made of primordial material and can give us a glimpse of the formation of the Solar System. In addition, measurements acquired from Earth have already shown that the material of the asteroid may once have been in contact with water. "This interaction between dust particles and water suggests that organic substances could also have formed," says Jaumann. 1999 JU3 is a Class C asteroid, the most common class of rock asteroids in our planetary system.

Sensing the temperature

Another instrument from the DLR Institute for Planetary Research on board the lander will work together with the camera – the MASCOT RAdiometer, MARA. The small, five-by-five centimetre sensor head, together with its electronics, weighs just 195 grams. While the camera observes the structure of the asteroid surface, MARA will measure the temperature at the exact same place. "Thus, we will obtain an optical image of the surface structure with the camera and a thermal image with the radiometer," explains planetary researcher Matthias Grott. The scientists will then be able to assign the measured temperatures to the various soil structures – from fine grains to large chunks.

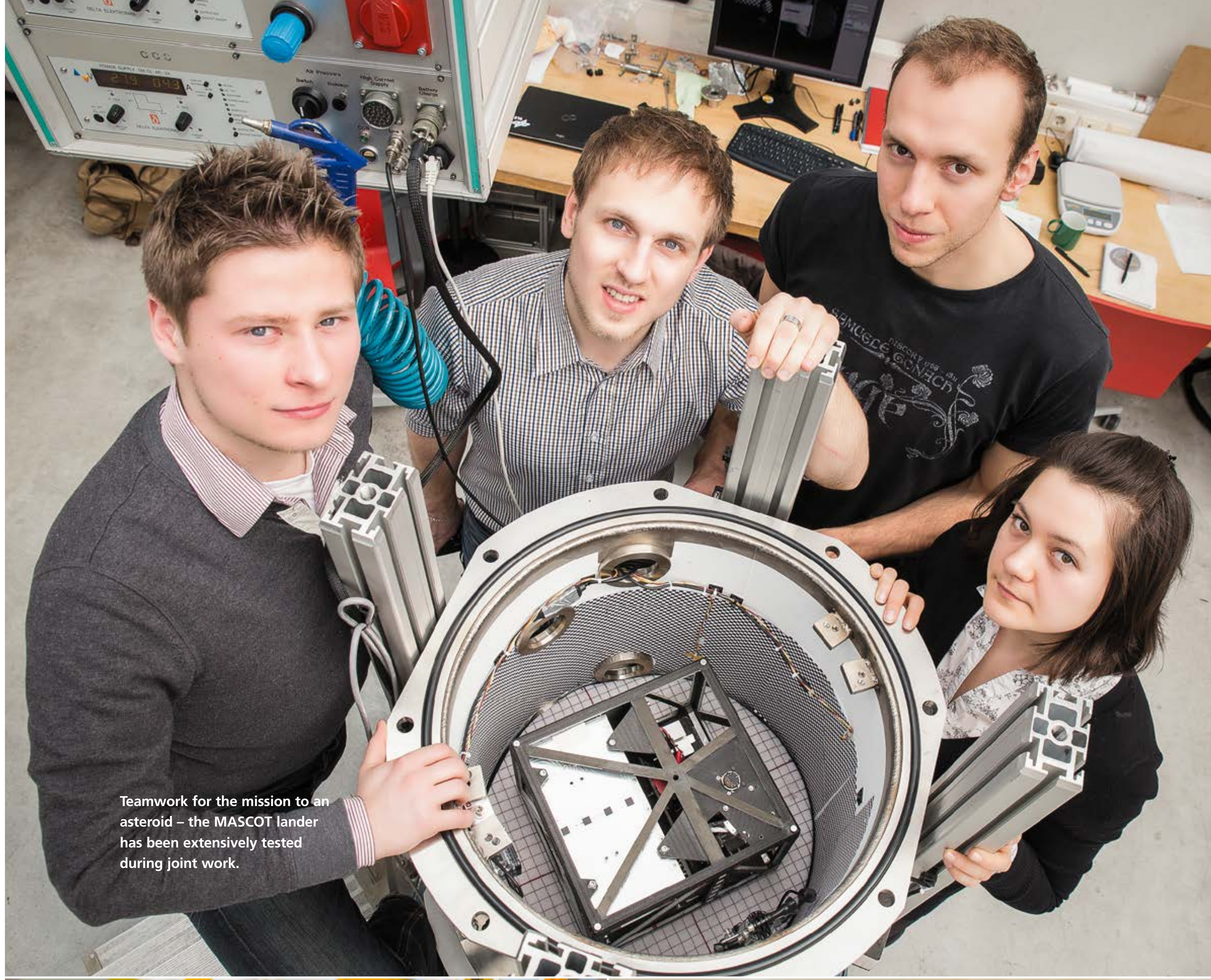
The radiometer measures the temperatures at the asteroid surface not only by day, but also at night. "It takes some materials a long time to absorb and release heat again; for others it is quicker." These regular measurements during the day and night cycles provide the data to detect this. The spectral properties of the asteroid material can also be determined with MARA. Through comparison with measurements conducted on known materials in terrestrial laboratories, it is possible to determine the composition of the asteroid. For the scientists, the glimpse into when the asteroid was formed is especially important. Is 1999 JU3 a rather compact body, consisting of a single piece, or is it a loosely collected 'pile of rubble'? But the path of an asteroid can be affected by the heat generated in the course of its life: "It is definitely one of the effects that must be taken into account in the calculation of its future trajectory," emphasises Grott.

Test marathon before the launch

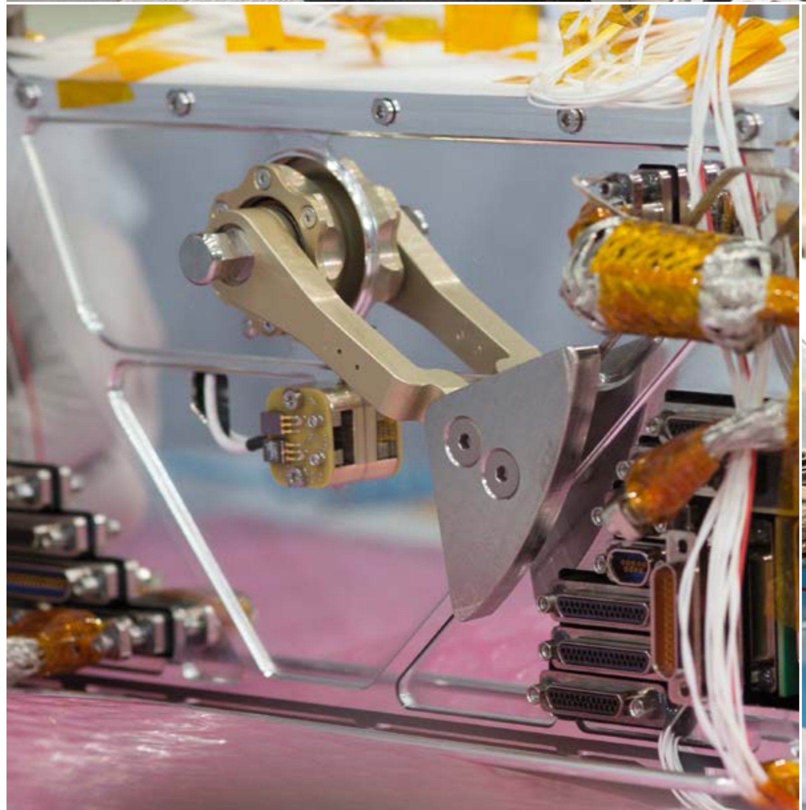
Before that happens – before MASCOT hops from measuring point to measuring point, the lander must face the stresses of the launch in November 2014, the multi-year journey through space and a difficult landing. A mere one-sixtieth thousandth of Earth's gravity is present on 1999 JU3, so if MASCOT approaches the surface too quickly, it could just bounce off and drift into space. This could also happen if the small lander hops on the asteroid surface with too much momentum. In numerous tests, including in a drop tower, on a vibration table and in the thermal vacuum chamber, the engineers at DLR have extensively tested their lander and its separation mechanism. Since August 2014, MASCOT has been installed in the Hayabusa-2 spacecraft and is going through the last tests in Japan regarding communication between the probe and lander. "Our test calendar in Germany and in Japan has been nearly full every day for months," says Tra-Mi Ho.

It will then take some time – until 2018 – before the Hayabusa-2 spacecraft reaches the asteroid, pushes MASCOT gently towards 1999 JU3 and the scientists get their first data from the DLR Microgravity User Support Center, MUSC. "We are excited about everything," says Jaumann. "With MASCOT, we will explore the, until then, untouched asteroid surface, Hayabusa-2 will observe the asteroid from orbit, and hopefully a soil sample will be brought back to Earth successfully. This mission has it all." What scientists know so far about their target asteroid is very limited: "With a diameter of barely one kilometre, it is really small," says Jaumann, "and really dark." •

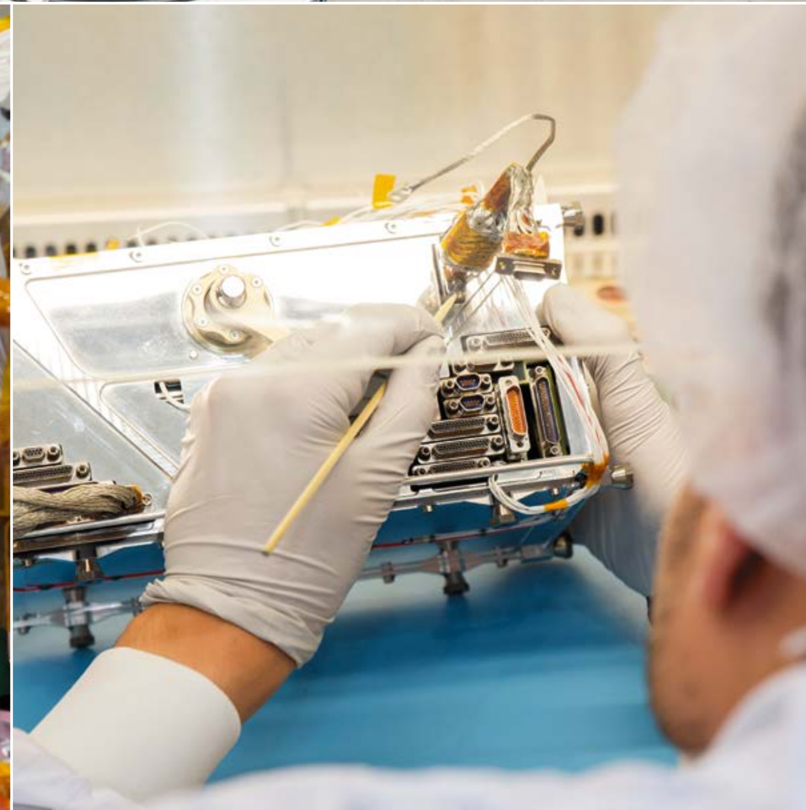
More information:
s.DLR.de/0q75



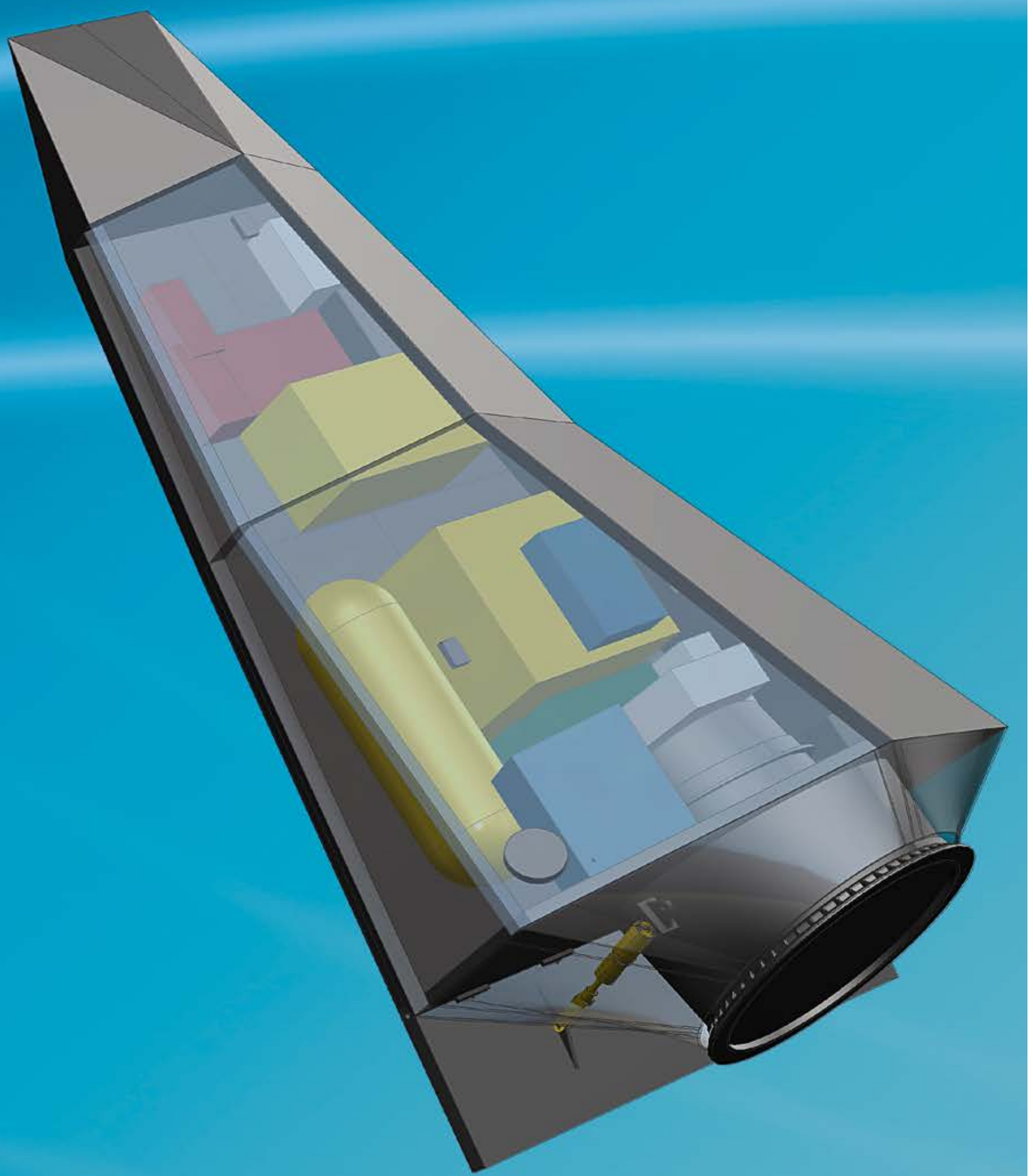
Teamwork for the mission to an asteroid – the MASCOT lander has been extensively tested during joint work.



A moving mass will enable MASCOT to move around on the asteroid by 'hopping'.



Each connector is meticulously fixed so that the MASCOT lander is capable of withstanding the stresses during launch



Schematic structure of SHEFEX III and the onboard systems for flight control and instrumentation

Resistance, when things get hot

Only those who master all three phases of a space mission attain full competence in space. In addition to the launch into space and the operational phase in orbit, there is also the transportation back to Earth – and with this comes the necessary re-entry technology. The development, construction and flight testing of this technology are conducted at DLR under the name SHEFEX – Sharp Edge Flight EXperiment. Currently, DLR researchers are preparing for the third phase of the SHEFEX flight test programme. Making such a complex flight mission feasible at reasonable cost is unique in Europe.

The autonomous spacecraft SHEFEX III demonstrates the effects of re-entry into Earth's atmosphere

By Hendrik Weihs

The technological challenge associated with atmospheric re-entry and the subsequent flight until landing is the rapidly changing aerodynamic conditions between the first noticeable gas effects – at an altitude of about 100 kilometres and a speed of nearly 28,000 kilometres per hour – and that of the landing, at a speed of only a few hundred kilometres per hour (or significantly lower when parachutes are used). The speed and air density within this range are constantly changing. The key to mastering re-entry lies in understanding and predicting the aerodynamic conditions over the entire range of speeds and optimising structures to withstand the thermal and mechanical loads.

For capsule-like ballistic space vehicles this is rather straightforward. However, a spacecraft that exhibits a high degree of flexibility and controllability to approach a specific landing site in the final phase of the flight must have two properties: a high aerodynamic quality in the hypersonic range (speeds well above 1000 kilometres per hour) and an intelligent flight control system. Using the measurement data acquired during flight, the SHEFEX programme provides the most important answers for improving and verifying simulations and predictions.

With SHEFEX I it was possible to reach Mach 6, six times the speed of sound. This was extended to Mach 11 with SHEFEX II, which also provided fundamental experience concerning the complex effects associated with aerodynamic flight control. The next major step is being taken with the third mission, SHEFEX III, which has recently been initiated. In contrast to the previous two missions that cruised through all altitude ranges with a nearly constant velocity, the autonomous space vehicle SHEFEX III will demonstrate a continuous deceleration from the beginning of the re-entry at an altitude of 100 kilometres (at around Mach 17) until the end of the experiment window at an altitude of 20 kilometres (at Mach 2).

Thus, the flight conditions will come very close to that of a real re-entry from orbit and will cover the critical atmospheric effects. Here, the sharp-edged shape of the spacecraft offers lower drag and significant lift, which in conjunction with a complex control system that features flaps, a sliding weight and reaction nozzles, enables flight along a predetermined trajectory. From a structural point of view, SHEFEX III retains the faceted and thus more cost-effective form of thermal protection, as well as the sharp leading edge with special ceramics and cooling techniques.

The SHEFEX programme encompasses all the relevant disciplines and DLR institutes. Airbus Defence and Space has been brought in as industry partner for the flight control systems for SHEFEX III. •

Author:
Hendrik Weihs has worked at the DLR Institute of Structures and Design in Stuttgart for 27 years. He is responsible for the SHEFEX project.

More information:
DLR.de/en/SHEFEX

PROJECT INFORMATION

As part of the SHEFEX flight test programme, the German Aerospace Center, DLR, is developing technologies for spacecraft atmospheric re-entry. The research includes the development of basic technologies, such as material systems and structural concepts, numerical design tools, aero-thermodynamic design of the vehicle, as well as the development of appropriate flight guidance and control systems.

Wired up for the monthly fitness test

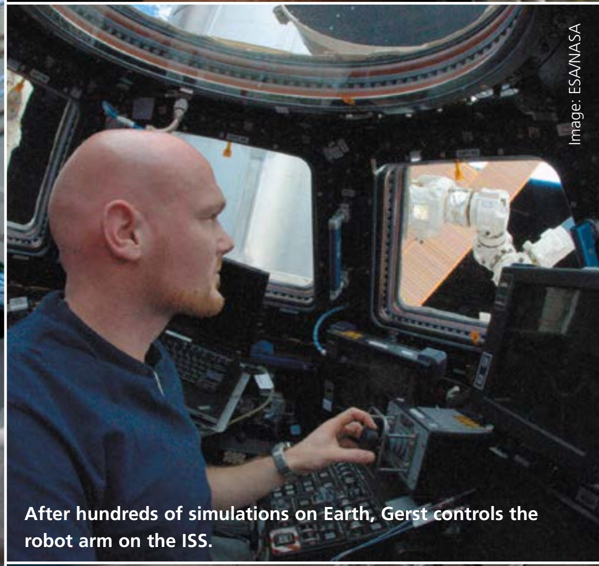
Blue Dot – snapshots of a mission

German ESA astronaut Alexander Gerst has done more than just conduct scientific experiments since setting off for the International Space Station ISS on 28 May 2014: he has also sent images and videos back to Earth. The 38-year-old geophysicist and volcanologist is taking this opportunity to allow thousands of people to catch a glimpse of his unique mission – and not just about living and working on board the Space Station. On social media channels such as Facebook, Twitter, Google+ and Flickr, he shares pictures of the Blue Planet as well. Although breathtakingly beautiful, they do provide food for thought…

More information:
s.DLR.de/rr10
www.flickr.com/astro_alex

No room for mistakes – space suits, all set to go, are the top priority on the Space Station.

The BASS experiment – burning materials in outer space is intended to improve fire safety back on Earth.



After hundreds of simulations on Earth, Gerst controls the robot arm on the ISS.

The ISS crew congratulates the German national soccer team after winning the FIFA World Cup

Image: ESA/NASA

The Banks Peninsula in New Zealand, one of the places where the geophysicist has gone hiking…

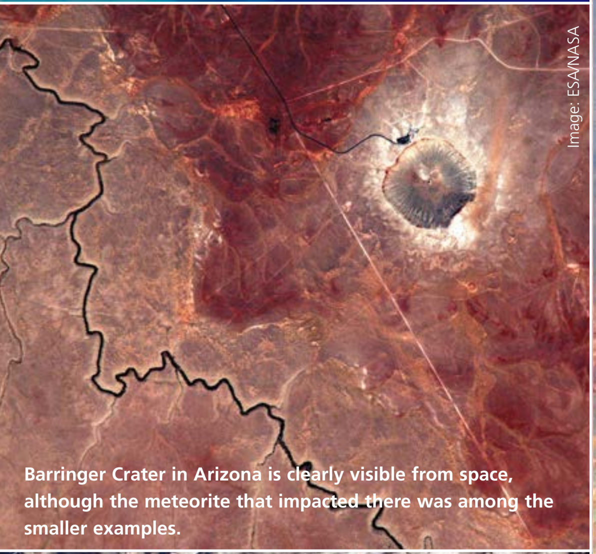
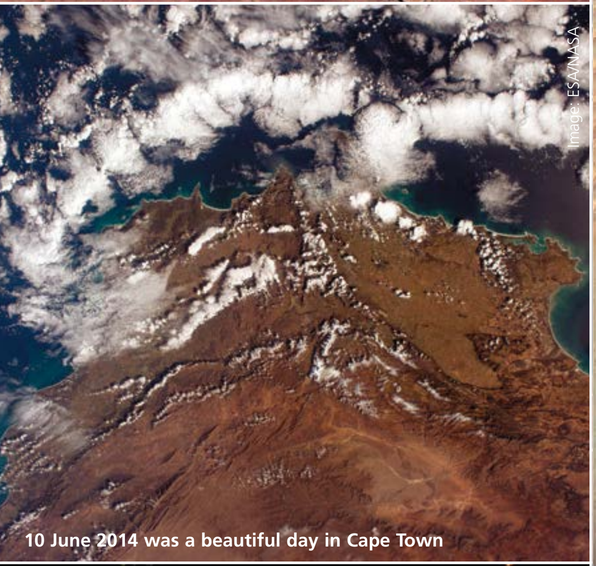
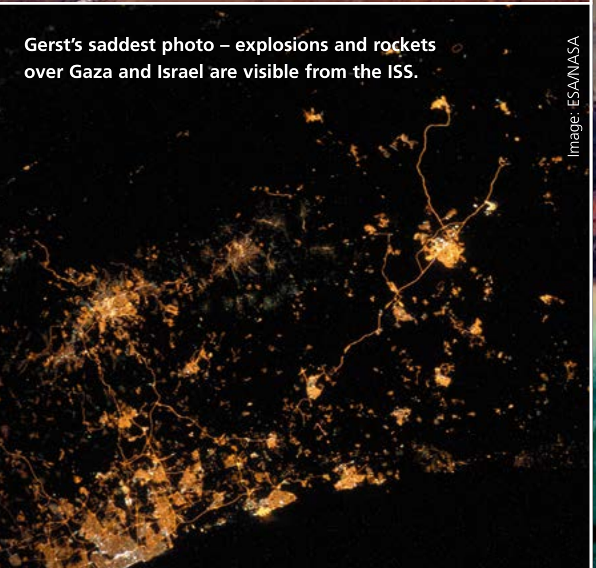


Image: ESA/NASA

Barringer Crater in Arizona is clearly visible from space, although the meteorite that impacted there was among the smaller examples.



10 June 2014 was a beautiful day in Cape Town

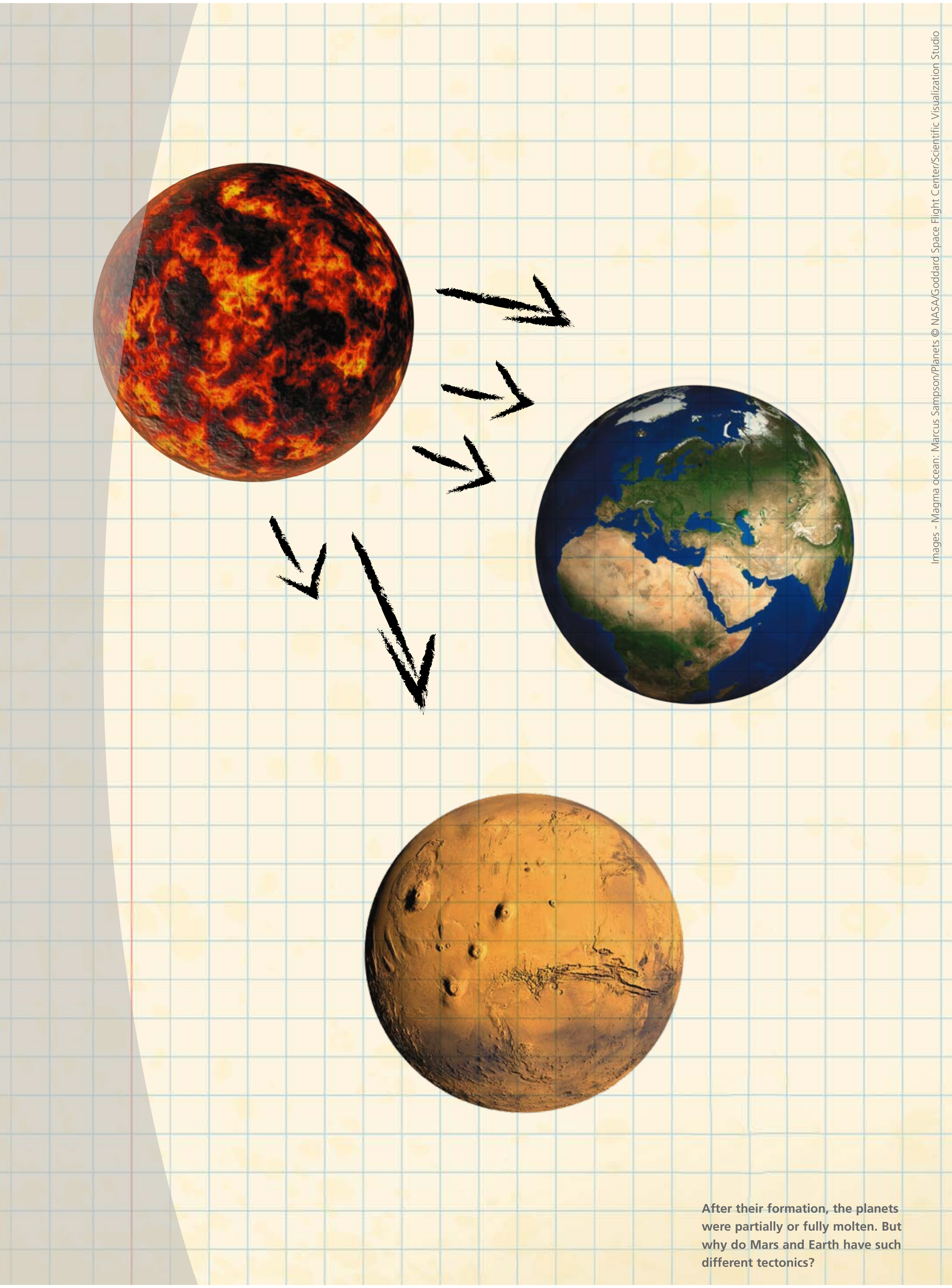


Gerst's saddest photo – explosions and rockets over Gaza and Israel are visible from the ISS.

Image: ESA/NASA

Image: ESA/NASA

Dunes in the Sahara desert



Images - Magma ocean: Marcus Sampson/Planets © NASA/Goddard Space Flight Center/Scientific Visualization Studio

After their formation, the planets were partially or fully molten. But why do Mars and Earth have such different tectonics?

Career momentum

For the eleventh time, the Helmholtz Association of German Research Centres is helping scientists set up their own teams of trainees. Sixty-six young researchers from across the world applied in 2013; 19 were selected in a rigorous competitive process conducted by international experts and are now setting up their own groups of young investigators. With three scientists, DLR is well represented here – Nicola Tosi, Hella Garny and Xiaoxiang Zhu. Four groups from previous competitions are already at work. Hannah Böhrk's is one of those.

Young scientists form dedicated research groups

By Melanie-Konstanze Wiese and Miriam Kamin

Gaining knowledge of the development of planets

Milan-born Nicola Tosi obtained a degree in physics in his hometown, completed a PhD in geophysics at the German Research Centre for Geosciences in Potsdam, and then conducted research as a post-doctoral student at the Charles University in Prague for two years. "The sponsorship offered by the Helmholtz Association is a real stroke of luck, and it came at just the right time. My research work is currently being funded by the German Research Foundation, but this funding ends in 2014," says Tosi, and he is looking forward to furthering his research under the best possible conditions and – with a group – intensifying the work conducted on his research topic.

Nicola Tosi

The Italian, who specialises in planetary physics, has been working at the DLR Institute of Planetary Research in Berlin for over three years. Tosi is studying how terrestrial, or Earth-like, planets form and develop. He is particularly interested in the thermal development of planets and the shapes of their surfaces. To research this, he is able to use methods and processes that he has already employed during his studies of the Blue Planet. "The methods we use here are very similar, yet there are a number of significant differences, for example with regard to plate tectonics," explains Tosi. Earth has seven major lithospheric plates, which are in constant motion. Mars and Mercury, however, are characterised by a single immobile plate. "I am trying to find out what conditions prevailed during and after the formation of the planets," explains Tosi.

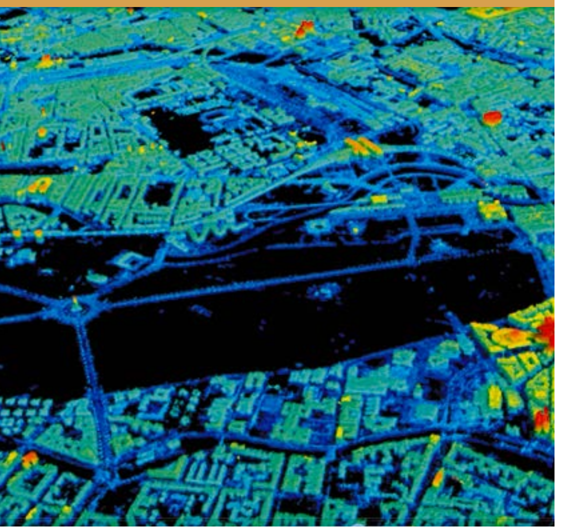
He uses software to simulate these conditions to, ultimately, model the formation of planetary surfaces and mantles. During the formation process, the surface and, potentially, a large proportion of a planet's interior consist of molten, liquid rock – magma. During this stage, the planet's entire surface consists of a single ocean of magma. Tosi and his team want to investigate the cooling of the surface and mantle, as well as the associated chemical and physical processes. The role of the atmosphere during the cooling of the surface is also being studied, as the ocean of magma releases volatile compounds, such as water and carbon dioxide. In this regard, the scientists in the trainee group will principally be considering the influence of the atmosphere on the solidification process of the cooling molten rock.

These investigations are in turn motivated by the fundamental question of how the conditions for life might arise. Tosi's team will be looking into the relationship between plate tectonics and the biosphere, ultimately clarifying the influence of the biosphere on the water balance of a planet's interior and whether this, in turn, entails that the biosphere affects the movement of the plates.

In the Helmholtz Association sponsorship, Tosi sees very good possibilities not only for his research, but also for his personal life plan. As a father of three, clear career prospects are important to him. There is still much to prepare before the project begins. Besides teaching at the Technical University of Berlin, he must assemble his group of trainees. The climbing enthusiast knows how important having a competent, reliable team is. All will be ready for mid-2014 – he will be devoting himself to answering questions about the development of planets with one post-doctoral and two doctoral students.

Hella Garny

Xiaoxiang Zhu



3D cloud diagram of Berlin calculated from SAR tomography using TerraSAR-X data. The colours represent altitude differences.

Considering climate change

Climate change is her field, and 30-year-old scientist Hella Garny is getting to the bottom of it. She has been a scientist at the DLR Institute of Atmospheric Physics for six years. In her Middle Atmosphere in a Changing Climate (MACClim) project, she is looking to gain a better understanding of the role that the middle atmosphere (10 to 100 kilometres above Earth's surface) has on climate change. This will primarily involve the question of whether and why there is any change in the global circulation of the middle atmosphere, and what effect this has on atmospheric composition and on climate change in the layers closer to the surface. To answer this, the scientist and her group of trainees will generate a global climate chemistry model – a regional high-resolution model and an idealised model, and combine these with observational data. The group, consisting of one post-doctoral and three doctoral students as well as the team leader, will be based at the DLR Institute of Atmospheric Physics and the Meteorological Institute at the Ludwig Maximilian University in Munich.

Looking at Earth

SiPEO is the name of the project 28-year-old scientist Xiaoxiang Zhu from the DLR Remote Sensing Technology Institute is working on. SiPEO stands for 'Modern Signal Processing Methods for the Next Generation of Earth Observation Satellite Missions'. SiPEO is a joint trainee group from the DLR Remote Sensing Technology Institute and the Department of Remote Sensing at the Technical University of Munich. There are two post-doctoral and six doctoral students in Zhu's team. Several German and European Earth observation satellites with innovative technologies and mission plans will be developed and launched in the next five to 10 years – for example TerraSAR-X HD, EnMAP, Tandem-L and the European Space Agency, ESA, Sentinel family. In this Helmholtz trainee group, new algorithms will be developed to derive geo-information from the data provided by this new generation of satellites.

The quality of the data analysis, which will be even better then, is expected to produce, for example, significantly higher resolution images and more accurately derived geophysical variables than originally planned for these satellites. Hence, the valuable space infrastructure – the satellites – will be put to better use and new applications, such as the detection of natural disasters or mapping of cities, will be developed. The technological focus is on multidimensional Synthetic Aperture Radar (SAR) imaging and hyperspectral technology. The new methods are expected to make current and future developments in signal processing for Earth observation practical.

Cooling hot edges

Heat shields for spaceflight are Hannah Böhrk's field. Such high temperature structures are of critical importance in spaceflight, where parts of the vehicle are exposed to temperatures exceeding 2000 degrees Celsius. The 38-year-old engineer now heads the 'High Temperature Management for Hypersonic Flight' Helmholtz group of trainees at the DLR site in Stuttgart, in collaboration with the University of Stuttgart, where she completed a doctorate in improving the performance of electric propulsion systems using hybrid plasma generators. Since 2007, she has been carrying out research at the DLR Institute of Structures and Design in Stuttgart. "The group of trainees offers an excellent opportunity to head a research group at the University for five years and accumulate teaching experience at the same time," Böhrk is delighted to say.

Atmospheric re-entry is one of the most precarious phases in a space mission. A great deal of kinetic energy is converted into heat as the vehicle decelerates. A heat shield prevents the space vehicle from suffering any damage. Engineers on earlier space vehicles used to rely on a rounded outer skin, whereas, in future, sharp corners and edges are expected to make re-entry into Earth's atmosphere more cost-effective, safer and increasingly flexible.

DLR has already successfully tested the principle as part of the SHEFEX I and SHEFEX II re-entry experiments (SHEFEX stands for SHarp Edge Flight EXperiment). Heat shields are currently still designed with very high safety factors, as the scientists still do not understand the thermal behaviour well enough, principally the interplay with the incident flow. Therefore, the new research group will continue investigating various cooling mechanisms such as radiation, transpiration and ablation, to enable the safety factors to be reduced. •

Momentum for a career in science

By setting up dedicated research groups, the Helmholtz Association is offering young scientists very good career prospects. The money for the trainee programme allows them to open up paths, conduct autonomous research, implement their own ideas and benefit from the excellent working conditions of the research centres. The annual sponsorship of 250,000 euros for five years and the option of a obtaining a permanent position ease the trainee researchers' entry into a career in science. Furthermore, the programme strengthens communication with universities, as the young investigators give lectures or seminars at the partner university. This qualifies them for a career in university.

Re-entry vehicles have previously only been rounded in shape. But large, curved, fibre-reinforced ceramic structures require complex manufacturing methods and appropriate moulds for each individual component. The potential for savings lies in simplifying the external contours. Having the smallest possible number of surfaces with different levels would make the production process more cost-effective. DLR is working on producing flat panels from one basic shape and trimming them to fit. Hannah Böhrk is studying the behaviour of these structures under extreme temperatures. Her work is being presented in the DLR Magazine as an example of Helmholtz Young Investigators groups already at work.

Hannah Böhrk

More information:
DLR.de/PF/en
DLR.de/PA/en
DLR.de/EOC/en
DLR.de/BK/en

Young investigators groups currently at work using Helmholtz sponsorship

High temperature management in hypersonic flight

Head of trainee group:	Hannah Böhrk
Partner university:	University of Stuttgart
Period:	2013 – 2018

AerCARE – Impacts of aerosol layers on atmosphere and climate

Head of trainee group:	Bernadett Weinzierl
Partner university:	University of Munich
Period:	2010 – 2015

Multi-scale modelling and in-situ diagnostics of solid oxide fuel cells

Head of trainee group:	Wolfgang G. Bessler
Partner university:	University of Stuttgart
Period:	2010 – 2015

Dynamic control of humanoid walking machines

Head of trainee group:	Christian Ott
Partner university:	Technical University of Munich
Period:	2011 – 2016

Electric mobility for aircraft – DLR researchers have developed a fuel-saving electric propulsion system for aircraft nose wheels. The drive system is equipped with two high-efficiency electric motors, which have been incorporated into the two rims of the nose wheel of an Airbus A320 and successfully tested in the laboratory.

Impetus for industry

By Gerardo Walle

In July, DLR updated and approved its strategic, structural and cultural orientation under the title 'Next generation'. This is reason enough to comment on the topic from the perspective of the German aerospace industry.

For a long time, DLR has been a leading player in the global concert of research institutions in the aerospace field. Other business areas have been added to this, dealing in particular with mobility in the broader sense and the efficient use of energy.

Our industry is characterised by a particularly high intensity of research. This is true for both fundamental research in universities and institutions such as DLR, as well as for the development work that is being carried out close to production in industry.

Without excellence in research and development, no one in our industry is competitive in the long run. Since the beginning of modern aviation at the end of the nineteenth century, Germany has been one of the world pioneers, but these are not laurels on which one can rest. Rather, the attainments of our predecessors are early achievements that must inspire us to further research and development work. This is why the interplay between research institutions and development in companies in the sector is necessary. And this is exactly where the new DLR strategy will begin.

Aeronautics is a long-term and sustainably growing industry because the world will experience increased demand for air transport in the future. With growing traffic, however, we increasingly encounter the limits of reasonable environmental impact and the required level of safety. The aerospace and other transport sectors must also face challenges with which DLR is concerned.

With regard to the aviation industry, DLR therefore places the environmental impact and safety of flying at the centre of its strategy. As one of the world's leading research institutions it will – as in the past – give fundamental impetus to industry, based on which companies can strengthen their position in the world market.

As an institution that is mainly supported by German taxpayers, this particularly concerns the interlocking and complementarity with the development work carried out by companies in the German aerospace industry. Therefore, it is very important that the aerospace industry participates in the specification of the guiding concepts.

Decades ago, our industry had already begun to tackle large projects and new technologies across international borders. This will become increasingly important in the future, which is why DLR is aligning its national, European and international strategies. From an enterprise perspective, it is important that this German research centre is at least as globally networked as is the case in our day-to-day work with our suppliers, partners and customers from America to Asia.

The proposed DLR strategy is based on a decades-long tradition. I am looking forward – as an industry representative – to supporting the research activities where possible and appropriate, and participating in the implementation of the results. ●

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All aviation activities within the Diehl Group are consolidated under the auspices of Diehl Aerosystems – one of the corporate divisions in the Group. Diehl Aerosystems is a first-tier supplier for avionics and cabin integration, and is an important partner for the international aviation industry. Its customers include major aircraft manufacturers such as Airbus, Boeing, Eurocopter, and Embraer, as well as airlines and other operators of commercial and executive aircraft.

The biofuel-filled four-engine DC-8 with the NASA Falcon following closely behind, seen from the DLR Falcon.

Sampling in an aircraft biofuel emission trail

Four research aircraft and over 100 scientists, engineers and pilots completed a unique measurement campaign in California between 7 and 16 May 2014. In a series of joint flight experiments, the US National Aeronautics and Space Administration (NASA), the German Aerospace Center (DLR) and the Canadian National Research Council (NRC) focused on a universally topical research area – biofuels. They measured the emissions from a biofuel/kerosene mixture at typical cruising altitudes and studied their effect on the formation and properties of condensation trails. The campaign was based at NASA's Armstrong Flight Research Center in Palmdale, California.

Unique joint NASA and DLR flight experiments

By Falk Dambowsky

Two hangars in the distance – bright ochre buildings shimmering in the midst of the arid semi-desert and accompanied solely by a few cacti, bushes and trees. The road curves almost imperceptibly to the left in the approach to the simple, yet strikingly large structures. It is not long before the stately silhouette of a 'jumbo jet' can be seen between the buildings. The car pulls up in a parking lot big enough to contain several football pitches. As we approach, the lettering on the jumbo jet reads: 'SOFIA'. The Stratospheric Observatory for Infrared Astronomy is based here in Palmdale.

Just like the parking lot, the hangar that shelters SOFIA is enormous – there is enough space to fit three Boeing 747 jumbo jets. So there is plenty of room for the four research aircraft being used for the joint ACCESS II mission – Alternative Fuel Effects on Contrails and Cruise Emissions – carried out in May 2014 by NASA, DLR and the Canadian NRC. Together, they aim to measure the soot content of exhaust gases from biofuels, various trace gases and the size distribution of ice crystals in the resulting condensation trails. The focus of this research is the effect of biofuels on the environment and climate. Three aircraft

The DC-8, seen from the window of the DLR Falcon, shortly before the Falcon is positioned behind it to measure the exhaust gas plume.

DLR test pilots Philipp Weber (left) and Roland Welser with the Falcon in front of the NASA hangar in Palmdale, California.

The sensor for measuring wake turbulence is installed in an underwing pod the Canadian T-33 research aircraft

Daniel Sauer and Bernadett Weinzierl install a soot measurement probe in the instrument holder

Particle measurement probes under one of the DLR Falcon's wings


NASA administrator Charles Bolden asks DLR mission leader Hans Schlager about the instruments on board the DLR Falcon

have travelled to Palmdale for this purpose, and one is already on site. The four-engine NASA DC-8, which will be operated with biofuel during the flight experiments, is already prepared for use. A NASA Falcon, based at the Langley Research Center in Virginia, has flown in from the east coast of the United States and an NRC T-33 has arrived from Ottawa in Canada. The DLR Falcon has had the longest journey – it has come to California all the way from Oberpfaffenhofen, near Munich, Germany.

Stopover in Greenland

The Falcon covered some 12,000 kilometres on its trip to Palmdale. The route – via Iceland, Greenland and North America. The pilots were in the air for over 22 flight hours during three transfer days. Now Philipp Weber and Roland Welser from the DLR Flight Facility are standing before the much-travelled DLR aircraft. On a laptop, they show me the Falcon's intercontinental route. The two pilots and three scientist passengers from the DLR Institute of Atmospheric Physics flew from Oberpfaffenhofen to Scotland, refuelled, and continued on to Keflavik in Iceland. "Kangerlussuaq Airport in Greenland was impressive," recalls Weber. The US military built a large airbase there in the 1940s where aircraft travelling between the United States and Europe could stop over. With the onset of large, long haul aircraft, the airport lost its significance, but its size remained. "Flying into Kangerlussuaq is a real pleasure. At the most picturesque end of the long Søndre Strømfjord lies the runway," explains Weber. After Greenland, they stopped over in Gander, Newfoundland (Canada), Syracuse, New York, and Salina, Kansas before finally reaching Palmdale.

In good company

"Talking to colleagues from US air traffic control over the radio is always a pleasure," says test pilot Weber. "They are thrilled when we approach and are often somewhat surprised at the aircraft that is crossing their air space." The D-CMET registration alone is unusual to the air traffic controllers, as US identifiers consist of a row of numbers. However, the US air traffic controllers are well prepared for 'the Germans' when it comes to the flight experiments with NASA in the restricted air space over Edwards Air Force Base.

Once in Palmdale, the Falcon and its pilots find themselves in good company. The ER-2 high altitude research aircraft is parked close by in the NASA hangar. It can reach an altitude of over 21,000 metres in the stratosphere. The SOFIA airborne telescope is also in its home hangar. A little off to the side and in front of it stands a Boeing 747 that used to transport the Space Shuttle and now performs its last service as a supplier of 'spare parts' for SOFIA. Also parked within view of the DLR Falcon are the other ACCESS II mission aircraft: a DC-8, a NASA Falcon and a Canadian T-33.

The plan for the four research aircraft brought together in Palmdale is somewhat unique. The NASA scientists intend to fly the DC-8 using a mixture of biofuel and kerosene with 50 percent biofuel fraction. When the DC-8 is in flight, the other aircraft will follow and measure the exhaust composition and contrail properties of the biofuel/kerosene mixture. The researchers expect that biofuels will generate less soot particles and therefore potentially fewer – yet larger – ice crystals in the contrails. This could reduce their contribution to global warming. The use of biofuels would therefore benefit air travel, not because of the lower carbon dioxide footprint using fuel from renewable sources, but also due to the reduction of climate-sensitive emissions.

To address these issues, a DLR team has travelled to Palmdale – 20 members of the DLR Institute of Atmospheric Physics and the DLR Flight Facility are preparing for the measurement flights using the Falcon. The flight engineers are responsible for the safety on board and provide power, cooling and – above all – ensure smooth operation of the research aircraft. Scientists prepare and calibrate their measurement equipment for the detection of soot, ice particles and trace gases. The pilots will take the research aircraft safely into the air, where the experiments will be carried out at an altitude of over 10 kilometres. Atmospheric researcher Tina Jurkat is part of the team. She is one of the three scientists on board the DLR Falcon during one of the flights in the measurement campaign. On the apron, she and her colleagues discuss the final details of the forthcoming measurements with project leader Hans Schlager. The three mission participants then board the research aircraft. This particular measurement campaign is quite special, as many young women are taking part – this is not usually the case in aviation.

The pilots start the engines. The external power and air conditioning units are uncoupled. The pressurised gas canisters containing nitrogen, which the scientists have just used to flush the sensitive instruments, are stowed away. All those standing outside have moved back to a safe distance. The Falcon rolls out.

The biofuel-filled DC-8 had taken off 90 minutes earlier. During the research flights, its four CFM56 engines are alternately operated using regular JP-8 kerosene and a mixture of JP-8 with up to 50 percent of the biofuel HEFA (Hydroprocessed Esters and Fatty Acids), which is produced from Camelina plant oil. The DC-8 was immediately followed by the Canadian T-33 research aircraft, a 1950s twin-seater jet. Its chrome-plated fuselage is an eye-catcher. The Canadians follow the path of the DC-8 closely at a cruising altitude of between nine and 12 kilometres, with the primary task of measuring the wake turbulence generated by the four-engine aircraft. The NASA Falcon took to the air 40 minutes later. As it starts conducting measurements in the exhaust gas plume, the DLR Falcon is just rolling out to the runway. The two Falcons will fly alongside one another for a short while; then, the NASA Falcon will begin its return to base while the DLR Falcon continues conducting measurements alone. Both Falcons are equipped with complementary measurement instruments.

"Okay, we're going in!"

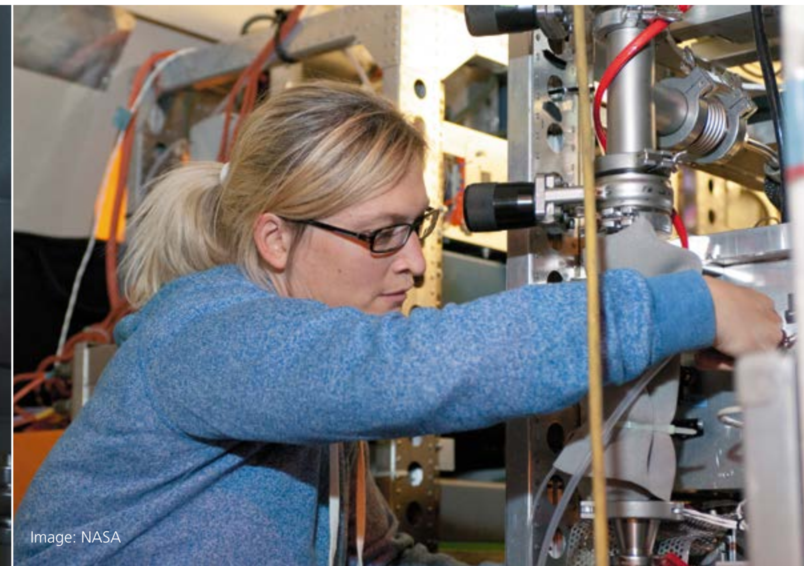
The three scientists sit together in the cabin while the two test pilots accelerate the DLR Falcon. They take off and fly north, climb to 10.9 kilometres and close in on the DC-8. The Falcon banks into its course in a stomach-churning curve and slowly approaches the seemingly endless condensation trail of the large research aircraft. Just behind, the NASA Falcon sparkles in

The NASA Falcon, the DLR Falcon and the Canadian NRC T-33 have plenty of space in the large NASA hangar.

DLR atmospheric researcher Jin Kim prepares the aerosol measurement equipment in the Falcon cabin

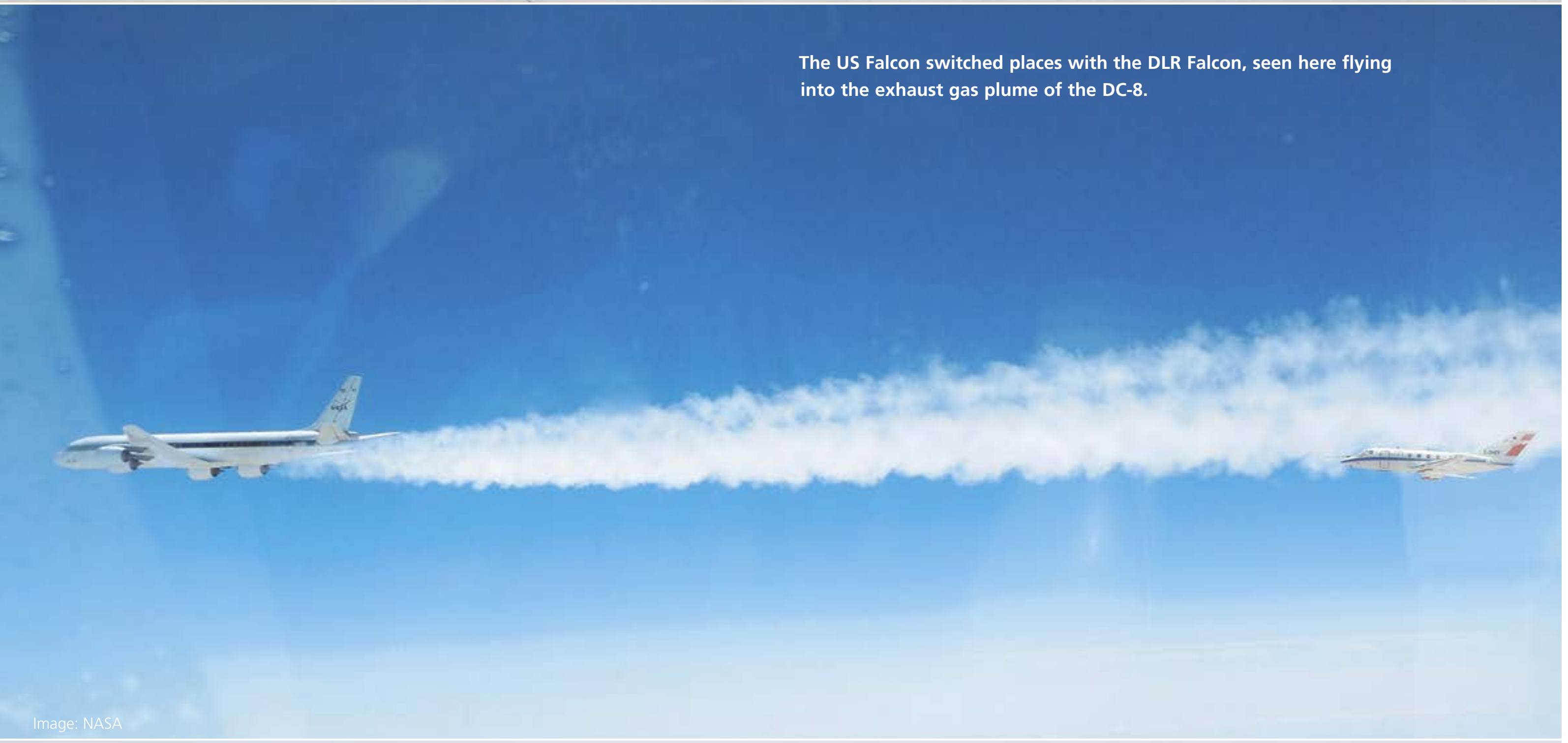
Tina Jurkat (front) from the DLR Institute of Atmospheric Physics on board the DLR Falcon during a measurement flight

Anke Roiger prepares a mass spectrometer for measuring sulphur gases by flushing it with high purity nitrogen



The DLR Falcon is rolled out of the hangar at the NASA Armstrong Flight Research Center

Image: NASA



The US Falcon switched places with the DLR Falcon, seen here flying into the exhaust gas plume of the DC-8.

Image: NASA

The Canadian T-33 jet takes off to measure the wake turbulence produced by the DC-8

Image: NASA

the sunlight. A moment later, it exits the condensation trail and navigates into a stand-by position to the side, some distance from the exhaust trail.

"Okay, we're going in!" is the announcement from the cockpit, and the DLR researchers prepare for the first flight into the DC-8's exhaust gas plume. That means quickly buckling in again and making sure the equipment is ready to measure the gas and particle emissions. Until just a few minutes ago, the DC-8 was still visible out of the side window – its impressive contrail majestic and colossal from up close. Beneath the aircraft trio is the extensive Californian desert. The NASA Falcon is still visible in the distance. As the DLR Falcon approaches the exhaust gas plume, the NASA colleagues film the operation from their own Falcon. The weather is ideal. "The forecast of the formation height of the condensation trail, which is vital to the researchers, has turned out to be correct," says Tina Jurkat.

The DLR test pilots change altitude, climbing into the exhaust gas plume from below. Following a carefully agreed plan, the measurements are conducted alternately between the exhaust plume from the starboard and port inner engines. Some of the measurement equipment is mounted beneath the Falcon's wings, and the rest is located in the cabin. The air being analysed flows into the equipment through inlets in the fuselage. The pilots try to interchangeably position one of the two wings and the fuselage inside the exhaust stream through numerous delicate manoeuvres. The elongated exhaust stream from one engine is too narrow for the Falcon to fit completely inside it.

Every time the aircraft encounters a condensation trail, the interior of the cabin darkens. There is tension in the air – everyone is focused. "Exhaust gas from the starboard engine," pilot Roland Welser announces to those in the back. He takes turns with Phillip Weber at the controls. Trying to fly close enough – but not too close – to the DC-8 to acquire good data is the watchword for both pilots and researchers alike. Then the bumpy approach begins once again. The exhaust plume announces itself with a roar and powerful vibrations. All the sensors and instruments are being pushed to their limits. It is no different for the scientists! They have a slight knot in their stomachs and a trace of sweat on their brows.

Two or three minutes later, the distance between the Falcon and the DC-8 increases. The small aircraft is forced back by the strong momentum of the exhaust gas. The researchers quickly carry out another couple of scans of the inbound micron-sized ice particles to determine their size distribution and the pilots manoeuvre the Falcon out of the contrail. For a brief moment, the researchers feel almost like they are in weightlessness in front of their equipment. Another 10 measurement sequences follow, and then relief spreads among the researchers in the aircraft. Tension turns into excitement about the smoothness of the entire procedure. Only in this very unconventional way can the aviation researchers investigate the composition of the exhaust gas and the formation of ice particles in the exhaust gas plume, to finally draw reliable conclusions about the effect air traffic is having on the environment and climate. The test flights lasted a total of two weeks, at the end of which the required measurement data had been acquired.

The analysis has begun…

When measuring the exhaust gases from biofuels, the DLR scientists concentrate on soot particles and sulphur compounds as well as the size distribution of ice crystals in the condensation trails. "Initial analyses of the measurements have now shown that particle emissions – and particularly soot emissions – are significantly lower when using biofuels compared to conventional kerosene," reports mission scientist Hans Schlager. Furthermore, gaseous and particulate emissions of sulphur compounds are also greatly reduced. "Further analysis will show whether our assumption that this lower soot level allows fewer but larger ice crystals to be formed in the condensation trails is correct, and whether the effect of air traffic on the climate can be generally reduced by using biofuels," he summarises. "In the flight tests, we were able to measure the microphysical properties of the condensation trails when biofuel is used." On the basis of this data, potential differences in the climate-related properties of condensation trails for various fuels can be analysed.

"Detailed analysis of our measurement results has begun," says Schlager looking ahead. Scientists from 23 countries, working for various national aviation research institutions under the International Forum for Aviation Research (IFAR), will have access to the results and, together with Schlager and his team at DLR, NASA and NRC scientists, they will continue to investigate alternative fuels. •

More information:
s.DLR.de/624w

Image: NASA

Four research aircraft and a team – as international as it is interdisciplinary – were involved in the flight experiments as part of the ACCESS II project.

On top of the world

A German team of pilots from the Mountain Wave Project – MWP – and scientists from the DLR Institute of Optical Sensor Systems in Berlin succeeded in flying over the Nepalese side of the highest mountain in the world – Mount Everest – in a powered glider for the first time in January 2014. On board was a camera system developed especially for this expedition that now provides us with a highly accurate 3D model of the Everest region in Nepal that has a ground resolution down to 15 centimetres. The success of this mission was in no way guaranteed. It not only demanded technical expertise, but also great patience and strength of nerve on the part of those involved. Berlin-based DLR scientists Jörg Brauchle and Daniel Hein report on the run-up to the mission and the challenges of surveying this mountain.

Unique glider campaign in the Himalayas provides valuable image data for environment and civil protection

By Jörg Brauchle and Daniel Hein

The Stemme powered glider can finally be refuelled

Jörg Brauchle checks the camera system developed by DLR before it undergoes an endurance test in the skies on the Nepalese side of Mount Everest

Two years ago at the Berlin Air Show 2012, we were approached by the head of the MWP turbulence research project and asked whether we would be prepared to participate in an expedition to the Himalayas in Nepal with a MACS 3D camera system. We were very enthusiastic about this unique opportunity and keen to show what new aerial photography cameras are capable of achieving. However, the start of the expedition was planned for October 2013 – just 13 months later. The one-year time limit was a great challenge; we needed to get financing in place and build a camera system that would function under high mountain conditions.

Once the flight areas had been selected, it became clear that previous technical approaches would not be suitable. The cameras look through an opening on the underside of an external pod, which exposes the system to the environmental conditions at an altitude exceeding 8000 metres. The air pressure is low and the temperature can drop below minus 30 degrees Celsius. In addition to ensuring that all the components function correctly, the optical properties of the camera lenses must not change under these extreme conditions – otherwise the calibration of the sensors will fail and it would no longer be possible to analyse the acquired data automatically, if at all.

The unusual landscape posed another challenge. The differences in altitude between the mountain ridges and valley floors on Mount Everest are so great that vertically acquired images will not work. Consistent ground pixel resolution in aerial photography requires an approximately constant flight altitude above the ground. For this reason, we would have had to perform a very time-consuming series of flights at various height bands along the slopes. With only four weeks planned for the expedition, we had to find another solution. In addition to two vertically orientated cameras, we installed cameras pointing sideways and in opposite directions to one another so that we could acquire images of both the valley floor and the slopes to the side when flying along a valley. The additional lateral images not only considerably reduced the amount of flying, but were also essential for achieving high-resolution 3D terrain models. A working group at the DLR Institute of Optical Sensor Systems that specialises in oblique image photogrammetry is developing assessment methods for image strips of this nature.

Furthermore, we needed to account for the extreme differences in brightness in a high mountain region. The snow and ice make the shaded side of a mountain sufficiently bright. However, there are also very poorly lit areas with patches of dark rock or vegetation. Then, on the sunlit side of the mountain we have to deal with extremely bright regions where ice and snow reflect sunlight. In places, there is such great radiometric contrast within a single image that it is impossible to acquire images that can be analysed using a fixed exposure time. So, for the first time ever, a high dynamic range mode has been introduced in an aerial photography camera. This creates a sequence of images with different exposure times, ensuring that we acquire at least one ideally exposed image of every detail in the region we are flying over. This is crucial for the subsequent analysis. The image data rate in this mode is approximately four images per second per camera.

The search for a suitable aircraft

Finding an aircraft fit for the expedition turned out to be unexpectedly difficult. Using a helicopter, we could only reach the required flight altitudes for a short period – or not at all. The aircraft available locally were an ultralight aircraft or a commercial aircraft in the form of a Twin Otter or Do 228. These were not suitable for taking scientific measurements in the high Himalayas or safely fulfilling the mission profile flying in an altitude range of 6000 to 9000 metres. The best visibility conditions of the year are present between October and December; however, a strong wind frequently blows at these altitudes – the jet stream – generating up and downdraughts as well as turbulence above the peaks of the Himalaya range. Ultralight aircraft quickly become a plaything of these extreme wind conditions, and the turboprop aircraft mentioned would only enable mission flights at a sufficiently safe altitude above the mountain terrain.

We finally found the solution at our own doorstep, in Strausberg near Berlin – a single-engine high performance Stemme S10VT powered glider. The VTX version of this powered glider can be fitted with external pods, which provide room for the camera system. A turbocharged engine and oxygen supplies for the two pilots enable flights at high altitudes. The extreme manoeuvrability of the powered glider makes almost any flight path possible, while thermals and updraughts can be used for climbing. Finally, the most important argument was the safety element – the aerodynamic properties of a glider become particularly important in the event of an engine failure. Thanks to the retractable folding propeller, the Stemme has a glide ratio of 1:50; that is, in pure glider mode and in still air, the glider loses just one kilometre of altitude for every 50 kilometres travelled – that is life insurance for the pilots in this high mountain region where emergency landing sites are few and far between. This was ideal for our expedition!

However, there are only a few of these special powered gliders. Luckily, the University of Applied Sciences in Aachen was able to contribute its Stemme S10VTX, which is used for scientific flights, to the project. They also provided pilot Klaus Ohlmann, one of the most experienced mountain pilots in the world. He is part of the MWP team, which investigates wave rotor turbulence on the lee side of mountains (the side facing away from the wind). The project was managed by René Heise, an atmospheric physicist specialising in mountain waves and a flight meteorology expert for sport flying. In 2010, he explored Tibet together with Klaus Ohlmann, to investigate the wind flows on the north side of the main ridge of the Himalayas and to look for emergency landing fields.

The pilots prepared themselves by carrying out high-altitude flight training in a hypobaric chamber and simulator training for approaches to Kathmandu International Airport. In parallel, René Heise coordinated the work with other scientific collaborative partners and the Nepalese authorities. Meanwhile, at the DLR Institute of Optical Sensor Systems, we worked on the construction, approval, software development and laboratory tests for the camera system. Everything went to plan. Individual components were subjected to a simulated flight altitude of 10,000 metres in the hypobaric chamber. The lenses were manufactured to space qualification standards.

In March 2013, six months after the conversation at ILA, we were able to carry out the first flight using the new MACS Himalaya camera system over the snowy landscape near aircraft manufacturer Stemme AG in Strausberg. Test flights were conducted near Aachen in July, and a month later, a 'dress rehearsal' took place in the Alps with a successful survey flight over the Stubai Glacier. Everything was ready.

In Kathmandu – with no fuel or flight approval

The Stemme S10VTX and a S10VT set off from Berlin to Nepal in October 2013. After 12 stopovers, 45 flying hours and 10,000 kilometres without incidents, the aircraft landed safely in Kathmandu. This was no easy undertaking given the politically charged situation in North Africa and the difficulties with overflight permissions. Our scientific equipment arrived shortly after as well – thanks to the German Embassy and the International Centre for Integrated Mountain Development (ICIMOD), the dreaded customs procedures were quickly dealt with. Along with the measurement technology, a full 300 kilograms of material arrived – everything from a power generator to a soldering iron. As it would turn out, we needed almost all of it.

The second powered glider – the S10VT – was planned to be the exploration aircraft in the Himalayan region and the secondary aircraft for the other scientific projects in the expedition: aerosol measurements, altitude physiology measurements and collecting MWP data on wind flows.

Then came a setback: the promised fuel for our powered gliders was not delivered. There was no aviation fuel (AvGas) available in the whole of Nepal for days – weeks. The flight approval also ran into difficulties as a result of parliamentary elections and a stream of new bureaucratic hurdles. A year is not long for obtaining flight approval by Nepalese standards when eight Nepalese ministries are involved. By that time, it was already the beginning of December and the flying season was coming to a close. There was nothing we could do. The team agreed to try again in January.

The flight approval arrived in mid-December; however, there was still no fuel. It had apparently made it as far as Calcutta – but how reliable was this information? Nevertheless, we prepared for January 2014 – it was now or never! Using the fuel remaining in the tanks, we transferred the powered gliders from Kathmandu to Pokhara. This airport in central Nepal became our base. It was an ideal starting point, as it is located on the edge of the Annapurna massif, which has peaks of over 8000 metres and numerous glaciers. The Kali Gandaki Gorge, the deepest in the world, lies to the west.

From an aerial remote sensing perspective, every area here is very complex terrain. Flying over all of it is a major challenge, but there is hardly a more appealing area. And the mission had to be completed by the end of January because most of the pilots and scientists had to leave. If only the fuel would arrive…

Suddenly, on 22 January, blue barrels of AvGas stood in the hangar – one year and a half to obtain this fuel. Now we had just seven days to carry out the flights. We abandoned the test programme and began the flights straight away. The weather cooperated: clear visibility, no clouds. But how would the camera behave at altitudes of over 5000 metres, and how would the combination of the pilots, the aircraft and the specially developed flight guidance system work?

The long-awaited first flight on 23 January 2014, in the Kali Gandaki Gorge, was completed without noticeable problems. During the contour flights following the terrain, the Stemme demonstrated why it was the ideal choice for this expedition. Thanks to the high glide ratio, it always remained inside the footprint of emergency landing sites. The aircraft climbed higher and higher. The first images of glaciers in the Annapurna region were acquired. On the following day, we were forced to cancel the flight in the Seti Gorge a third of the way through because of clouds. We lost the third day completely due to a problem with the navigation system. After it was restarted because of extreme flight manoeuvres, the cameras did not function properly – we needed to readjust the filter parameters.

On the fourth day, the target was Kathmandu, and everything went perfectly. The critical collaboration with Nepalese air traffic control went unexpectedly smoothly. The fifth day took us into the Annapurna region at altitudes in excess of 7000 metres and the camera system functioned to perfection. More images were acquired than could be backed up during the day and night. On the ground, numerous grid power cuts caused some difficulties, but our extensive selection of equipment paid off.

Meteorologist René Heise forecast clear skies at high altitudes for the sixth day, with almost no troublesome convection clouds and weak upper winds in our next target area – the Lukla Gorge and Mount Everest region. These were perfect conditions for the final day of the expedition – and we only had this one attempt. In Germany, high-resolution daily weather forecasting models had been calculated especially for this flight campaign to predict dangerous turbulence and vertical wind speeds in the Mount Everest region.

Pilot Klaus Ohlmann and co-pilot Jona Keimer flew into the Everest region. The rest of the team could do nothing but wait. A malfunction with the measurement system or a technical fault with the aircraft would ruin this unique opportunity. In the end, they flew for four hours. The pilots were satisfied. A quick look at the navigation data showed clean flight lines along the gorge between the Lukla and Khumbu glaciers, which is also known as the Everest Rescue Route. The aircraft climbed up at the south side of the Mount Everest in a spiral before slowly gliding back down along the Khumbu glacier and into the Khumbu Valley. The altitude profile showed a maximum value of 9200 metres above sea level. In a quick review, the image data proved to be obviously valuable. The relief among the whole team was palpable. Subsequent photogrammetric analysis showed that the camera system had performed reliably despite the extreme conditions. The high dynamic range technique had delivered sequences of good quality in every lighting condition encountered.

In the end, there was even time on January 29 for a few hours of flight, during which parts of the Annapurna region could be explored. In fact, with these final images, almost every target area that we had planned was flown over within this one week. Sixteen months after the ILA 2012, on the last possible day, we achieved our initial goal – to acquire images of Mount Everest with a 3D-capable aerial photography camera. The first results, among others a high resolution 3D model of the Khumbu glacier and the Mount Everest, were showcased at the following airshow, the ILA 2014. •

3D terrain model for security research

The mission in the Himalayas enabled DLR to demonstrate new airborne remote sensing technologies as part of its security research. Using new methods for analysing oblique aerial images, high-resolution terrain models were generated that can be used for disaster response, civilian security applications and environmental monitoring. With a ground resolution of 10 to 25 centimetres and optimum perspective, changes in glaciers can be determined more precisely than with conventional remote sensing methods. Furthermore, the Everest Rescue Route and difficult airfields and their surroundings can be precisely modelled, so that rescue flights can be carried out using pilot assistance systems, which can also be used in poor visibility conditions. In addition, recurrent flooding can be predicted more accurately using precise change analyses, and the population better protected as a result. Flood simulations, almost real-time positional data and deployment planning for aid workers will improve disaster response.

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More information:
DLR.de/macs

Mosaic of MACS camera images. Mount Everest can be seen on the right-hand edge of the image.

Waiting for flight approval at Pokhara Airport – the base. In the background is the Annapurna mountain chain with its 8000-metre peaks. Annapurna II, which is 7937 metres high (left), is 40 kilometres away.

Workspace next to the aircraft in the Avia Club Nepal hangar – improvisation and having the right tool for any situation is everything in a mission like this…

Data acquisition above the Kali Gandaki Gorge, which has the largest altitude difference in the world – 5571 metres separate the valley floor from the peak of Annapurna I. The gorge is 50 kilometres long.

The flight guidance system assists the pilots during the systematic flight pattern. The green areas were flown over and the expected large brightness differences encountered.

Bianca Gursky and test pilot Uwe Göhmann discuss the first test flight with the myCopter steering wheel inside the ACT/FHS. It passed the first tests in the simulator and now Göhmann will use the steering wheel to fly a real helicopter.

A steering wheel to the third dimension

Slow commuter traffic, bottlenecks on the motorway and roadwork in built-up areas; our roads are overloaded in many places. Engineer Bianca Gursky from the DLR Institute of Flight Systems has found a way to solve this – the third dimension. The EU myCopter project aims to take private transport into the air.

myCopter – investigating technologies to make helicopters suitable for everyday use

By Anna Boos

Bianca Gursky is on her way to work. She has a tight grip on a small black steering wheel. Above Braunschweig Airport she takes her foot off the accelerator pedal, banks gently to the left and flies in a smooth curve towards the runway. The 28-year-old is not in a car – she is sitting in the cockpit of an EC 135 and is controlling the helicopter with a steering wheel.

Gursky is actually in a helicopter simulator, flying through a virtual landscape. The young engineer can absolutely imagine the scenario described here becoming reality – albeit in the distant future. The helicopter steering wheel is part of her doctorate thesis, which she is writing as part of the EU myCopter research project. The aim of this project is to develop basic technologies and concepts for Personal Aerial Vehicles (PAVs), to relieve the ground-based traffic system that is overloaded and congested in many places. PAVs could then be used by almost anyone to travel quickly and easily through the air for daily journeys, commuting or going shopping – at least, that is the researchers' vision.

The skill lies in simplification

myCopter is an interesting idea – and one that conceals a number of challenges. Flying a helicopter is a highly complex task. During flight, the pilot uses the right hand to operate the cyclic stick, which rolls or pitches the helicopter. The left hand is used to operate the collective pitch lever, which adjusts the amount of lift produced by the main rotor. And at the same time, the pilot uses two pedals in the footwell of the cockpit to vary the torque generated by the tail rotor and so cause the helicopter to yaw. Especially when hovering, the pilot must keep both hands on the controls all the time and simultaneously operate the pedals to keep the helicopter stable in the air. "Monitoring and adjusting all four control axes at the same time requires a high degree of concentration and a lot of practice," explains Gursky.

To be able to use the helicopter as an everyday means of transport, flying must become simpler. This is where the engineer's steering wheel idea comes in. "I want to redesign the helicopter cockpit in the style of a car and make it more intuitive to control for future pilots," says Gursky. She intends to make instinctive knowledge from ground-based traffic usable for future pilots.

'Making three from four' is the aerospace engineer's idea. The cyclic stick, which controls rotation about the longitudinal axis (roll) and the transverse axis (pitch), becomes completely redundant when a steering wheel is installed as the control element. The pilot can just use a rotational movement of the steering wheel to fly the helicopter in the desired direction. Depending on the speed, a combination of yaw and roll movements will be implemented. In the simplified control system, the collective pitch lever only controls the helicopter's flying altitude. How quickly or slowly the vehicle flies is controlled by pedals in the footwell – just like in a car. "The pilot accelerates with the right pedal, and uses the left pedal to decelerate and hover," explains Gursky. In addition, an eight-way switch on the steering wheel enables the myCopter to fly backwards and sideways. In this way, even non-professional pilots should be able to intuitively 'drive' a helicopter.

But making the controls more instinctive is still not enough to make flying easier. "The flight characteristics of the helicopter must be adapted to the skills of future pilots and certainly become somewhat more user-friendly," says Gursky.

"This would be a major change for professional pilots, as they would no longer be able to fly helicopters in the way they are used to. However, this method would make flying easier for less experienced people who only have experience driving a car."

Professional pilot split between scepticism and surprise

DLR test pilot Uwe Göhmann tried out the steering wheel during a test flight in the simulator. His first experience with the myCopter steering wheel was in the Air VEhicle Simulator (AVES) at the DLR Institute of Flight Systems in Braunschweig. "For a trained pilot, it is more a matter of getting used to flying a helicopter using a steering wheel," says Göhmann, who has been a test pilot at DLR for 18 years and has over 36 years of flying experience. "However, people will get used to the new controls fairly quickly." Göhmann was initially quite sceptical about the helicopter steering wheel, and was somewhat surprised at how easy it is to fly with. "Any driver is familiar with controlling a vehicle with a steering wheel, and the helicopter actually responds in the way you would expect," explains Göhmann. "I can imagine that it would make it somewhat easier for people who are not professional pilots to fly – as long as there is an intelligent autopilot in the background to assist them." Forty-five hours of flight training and knowledge of air traffic law, radiotelephony, airspace structure and meteorology, as well as a medical examination, are all required to get a helicopter private pilot licence (PPL-H). But the PAV pilot of the future might perhaps be able to get into the flying vehicle and take off after just a few hours of training.

The technical feasibility of the helicopter steering wheel has already been successfully demonstrated during test flights in the simulator. Now, research is being carried out with volunteers, to see how well various participants cope with the new helicopter steering system. Trained pilots and people with no flying experience – both with and without a driver's licence – are due to fly in the helicopter simulator, a realistic replica of the cockpit of an EC 135, using the steering wheel.

The helicopter steering wheel has already passed its trial by fire in the simulator. The next stage will be to check it out thoroughly in a real test flight. In the ACT/FHS (Active Control Technology/Flying Helicopter Simulator), DLR has the appropriate platform for testing the steering wheel in flight. Using a model-based control system developed for the DLR research helicopter by the Institute of Flight Systems, the FHS can simulate the flight behaviour of various models of helicopter under real environmental conditions. The first flight using the myCopter steering wheel is scheduled to take place later this year in the FHS, a modified Eurocopter EC 135. Then, the PAV flight dynamics will be tested as well. For this, the test pilot will perform special manoeuvres with the steering wheel and control system installed, to test the handling qualities of the helicopter.

For Gursky, who has been working at the Institute of Flight Systems for three years, the benefits of flying are obvious: "Helicopter use offers much more flexibility. If you want to get from point A to point B in a car, you are obliged to follow the zigzag course of the roads. Sometimes roadwork blocks a direct route to the destination, which forces the driver to change routes, perhaps take a detour on the motorway, and still end up in a traffic jam." These problems that occur in ground-based traffic would not exist in the air. "The third dimension offers much more space and opportunity. With a helicopter, I can fly directly from point A to point B taking the shortest route. It saves an incredible amount of time."

Partners across Europe in various research areas

Of course, PAVs also present a few challenges of their own. How can the numerous private pilots be incorporated into normal air traffic? What training will PAV pilots of the future receive? These are the issues that the project partners in myCopter are working on. The Max Planck Institute for Biological Cybernetics, which is heading the myCopter project, is investigating the human-machine interface. The flight dynamics model for PAVs and the structure of the training required for future private pilots are being looked into at the University of Liverpool. Meanwhile, scientists at the École Polytechnique Fédérale de Lausanne are using unmanned flight devices to investigate collision prevention, 'swarm' flying and automated take-off and landing, and the Swiss Federal Institute of Technology (ETH Zurich) is working on control strategies for personal flying vehicles and take-off, landing and navigation using unmanned aerial vehicles. The Karlsruhe Institute of Technology is looking into the socio-technological aspects of the projects and, hence, on the impact that the introduction of PAVs might have on our society. DLR is using its research helicopter to conduct demonstrations of selected technologies developed in the project. "We are supporting the development of flight dynamics models and are developing a 'highway in the sky' display for PAVs," explains Gursky. This is a type of intuitive navigational aid for PAV pilots. Lines that specify the optimum flight path in a visual way are presented to the pilot in a tunnel display.

"Flying a helicopter with a steering wheel is actually a slightly crazy idea," says Gursky. All the more so as the prototype of the small black steering wheel is more like an accessory for a games console than a control element for a real helicopter. But she quickly gained enthusiasm. And for the young researcher, completing the first test flight in the simulator with her helicopter steering wheel was absolutely incredible. "I was surprised at how easy it is to fly with the steering wheel," she says, as she circles above the virtual Braunschweig Airport. "I know it is going in the right direction" – in the truest sense of the word. •

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More information:
DLR.de/FT/en
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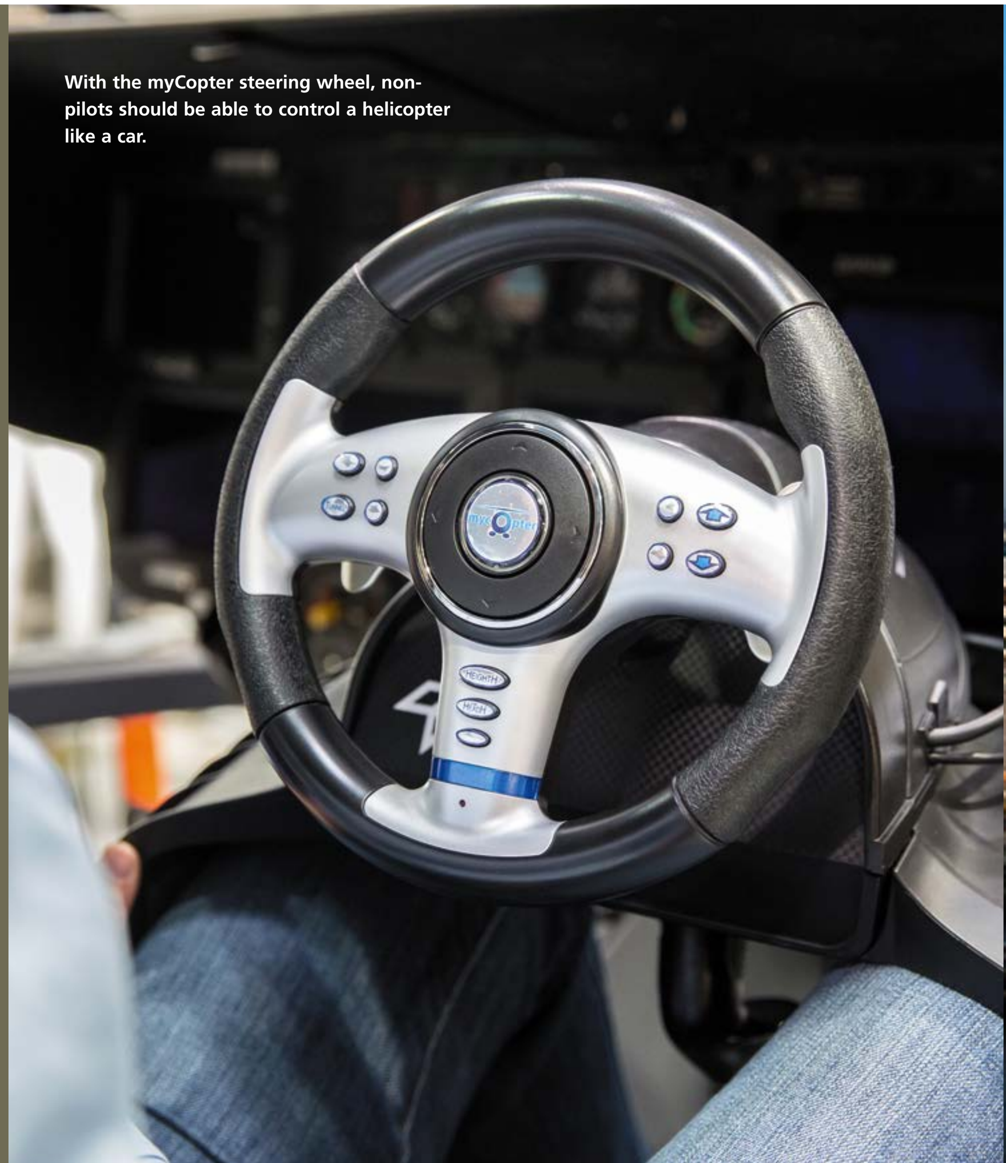
THE MYCOPTER PROJECT

The 'myCopter – Enabling Technologies for Personal Aerial Transportation Systems' project began in January 2011 and is due to be completed in December 2014. It is funded by the European Commission under the 7th Framework Programme for Aeronautics and Air Traffic Research. Partners include the Max Planck Institute for Biological Cybernetics, the University of Liverpool, the École Polytechnique Fédérale de Lausanne, the Swiss Federal Institute of Technology (ETH Zurich), the Karlsruhe Institute of Technology and the German Aerospace Center (DLR).



With the myCopter steering wheel, non-pilots should be able to control a helicopter like a car.

The Skyrider, a concept of a personal aerial vehicle (PAV).

Image: Gareth D. Padfield, © Flight Stability and Control

Adhesive films under the wings serve as insect traps. The foils are mounted behind the leading-edge flap. DLR researchers want to find out how many insect remains accumulate there, despite the flaps being upstream in the airflow.

Image: DLR/Marek Krusewski

Catching insects in Cochstedt

Mosquitoes can be a nuisance – not just for people in the summer, but occasionally for technology as well. An example – the aircraft wings of the future. When insects are deposited on the ultra-smooth surfaces of these wings, they interfere with the optimised airflow and ultimately reduce the desired fuel-saving effect. DLR researchers want to find out how many insects accumulate on the wings and where they impact most frequently. Their goal is to develop an insect protection system for aircraft wings. Before the development process can begin, they flew the DLR Airbus A320 Advanced Technology Research Aircraft, ATRA, over the grounds of Magdeburg/Cochstedt Airport to collect insects for aerodynamic research.

ATRA flight tests for improved aerodynamics of future aircraft wings

By Falk Dambowsky

A light summer breeze blows through the blades of grass. On the horizon, the rocky outline of the Harz mountains. Test pilot Jens Heider and researcher Dominic Gloß from the DLR Institute of Aerodynamics and Flow Technology fly along the runway at Magdeburg/Cochstedt International Airport in DLR Braunschweig's small LFU 205 single-engine propeller aircraft. They pass over expanses of grass – spared from the mower for several weeks for the sake of airborne science. After landing, they take a look at the insect contamination on the wings. For his research, Gloß needs a large number of insects to thrive in the tall grass. Insect remains – which are more of a visual problem on many a summer drive – become aerodynamically significant on the skin of aircraft. They impair the effectiveness of the latest high-technology smooth wing surfaces. Aerodynamics engineer Gloß wants to find out how insect remains are distributed over the wings of a commercial aircraft. This first time, Gloß flew to Cochstedt in the small propeller aircraft to explore the terrain. The reconnaissance flight was well worth it. The conditions for the complex flight tests are good.

A little later, in mid-July, Gloß returned, along with the necessary dry and warm summer weather, to Cochstedt – this time with DLR's largest research aircraft – the Advanced Technology Research Aircraft ATRA. A whole team consisting of flight test engineers, test pilots, technicians and scientific colleagues have accompanied him. For just under a week, the DLR team will bring life to the otherwise rather quiet commercial airport in Saxony-Anhalt, to conduct up to 30 low-level flights per day. With these, the aviation researchers intend to simulate the take-off and landing flight phases, in which insects are most likely to collide with the aircraft.

Before each flight test, Gloß climbs a ladder to precisely align and position adhesive foils in strips under the wing surfaces. Together with colleagues, he places the foil behind the leading-edge flap. Gloß is pursuing the idea of protecting the wing surfaces against insect residue with a kind of protective shield – he wants to modify the existing leading-edge flaps so that no mosquitoes, flies or other winged insects get past them.

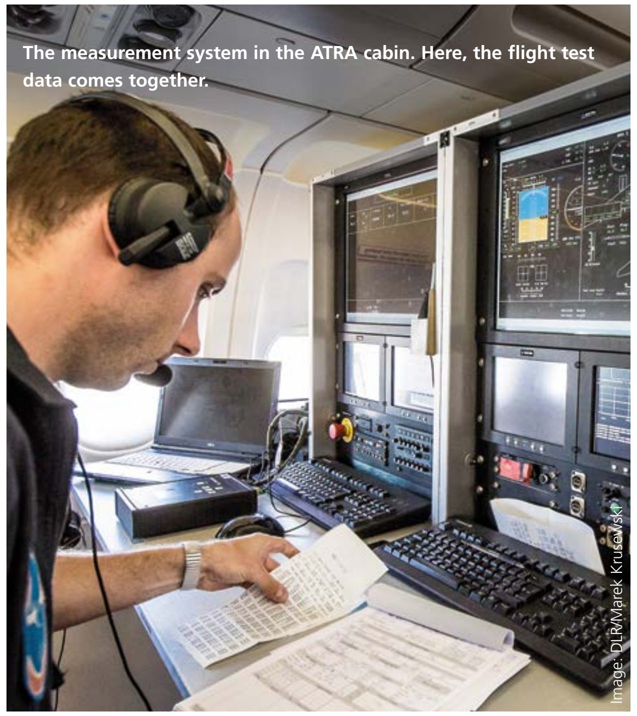
Heiko Geyr von Schweppenburg, from the DLR Institute of Aerodynamics and Flow Technology and Gloß's Department Head, explains why future aircraft need such insect protection from the leading-edge flaps. "Engineers and researchers around the world are developing extremely smooth wing surfaces, referred to as laminar flow wings, which produce less drag and therefore offer reduced fuel consumption. However, to achieve the full fuel savings, this new type of wing surface must stay clean." Modern gliders, which have already come a long way with ultra-smooth carbon-fibre wing surfaces, are already using what are referred to as 'bug wipers' to increase flight performance. This is a device that removes insect remains from the wing surfaces in flight. Because of their high flight speeds, such

Image: DLR/Marek Krusewski

An ideal environment for insects at Magdeburg/Cochstedt Airport

The nose of the A320 ATRA after landing – the surface was spotless at take-off, but countless insects have left their mark.

Image: DLR/Marek Krusewski



The measurement system in the ATRA cabin. Here, the flight test data comes together.

Image: DLR/Marek Krusewski

a device is not very practical for large commercial aircraft, which is why Gloß is pursuing the idea of insect protection flaps for airliners.

Before each of the nearly one-hour test flights, the films under the wing surfaces of the ATRA are gleaming white and clean. The engineer checks the camera system – mounted on the side of the fuselage and pointed at the films – one last time. "With the help of the cameras, we can identify how many insects are already stuck to the films while in flight. The more insects there are in the air, the sooner we will have a usable result." One more procedure follows, which is almost a reminder of regular scheduled airliner services. The loading staff brings three air cargo containers, each one carrying about one ton of sandbags. Adrian Müller, the flight test engineer responsible for the Cochstedt test flights, says: "We are gradually loading ATRA with defined weights to investigate a variety of flight conditions. As ATRA gets heavier, the angle of attack changes. This means that with increasing weight, ATRA's flight attitude varies, as does the insect contamination pattern on the wing surfaces."

After the final preparations, Gloß and Müller board the A320 ATRA and take their seats at the measuring system in the cabin. From here, they can monitor all the important measurement values during the flight, and keep in contact with the cockpit via headsets. In the cockpit, test pilots Hans-Jürgen Berns and Stefan Seydel prepare for take-off. The cabin door is closed, the staircase is removed and the pilots start the engines.

ATRA taxies – slowly at first, with a 90-degree turn towards the runway, and then faster. It goes to the eastern end of the runway, for a take-off towards the west. Thrust is applied; steadily increasing speed and then take-off – the largest DLR research aircraft is in the air over Saxony-Anhalt. Test pilot Berns turns to the south and climbs to just 300 metres. Beneath him, fields and small villages. The airport remains in sight. After a few minutes, Berns turns and begins the approach to Cochstedt. From the ground, however, a crucial difference can be seen when compared to a normal approach – no landing gear beneath ATRA. It remains retracted at low altitude for the simulated arrivals and departures.

ATRA taking off from Magdeburg/Cochstedt Airport. During the low-level overflights at an altitude of 15 metres, the undercarriage remained retracted.

Image: DLR/Marek Krusewski

In the cockpit, this unusual approach has all sorts of consequences and is only possible with a research aircraft. Numerous warnings sound and warning lights flash. Test pilot Berns guides the ATRA with a steady hand in manual mode and Stefan Seydel switches the various warnings off one by one. "Actually, our Airbus is designed to land with automatic assistance. For the low-altitude research flights to collect insects, we have to perform a manoeuvre that conflicts with the automatic pre-recorded sequences for a regular passenger flight."

Before the overflight, Seydel requests clearance from the Cochstedt tower. Then he brings ATRA down to just 15 metres above the ground – about half its wingspan. The Airbus flies parallel to the runway over the flourishing grassland of the airport grounds. It moves so slowly and quietly that it seems as though ATRA is just floating above the ground. It flies low over the airport like this for more than three kilometres until the end of the runway. Meanwhile, Gloß, can see on his laptop how the insects have left their mark on the film applied to the wing surfaces. Then, test pilot Berns pulls the machine up again, veering towards the south and starts the next pass. There will be a total of 14 passes in this test flight, and then the extended landing gear will announce the imminent landing.

Back on the ground, Gloß and his colleagues immediately remove the foils, which are clearly marked by insects, from the wing surfaces. "The area directly behind the leading-edge flaps is already quite well protected from insects by the flaps," says Gloß and shows one of the films that he has just removed from the ATRA before stowing it in a narrow drawer in a homemade roller container. "But, further back, the wing surfaces are clearly contaminated." In total, 132 films are collected during the 11 test flights at Cochstedt.

Once Gloß has immortalised the insect samples on his films, he captures them at his DLR home base in Braunschweig using an oversized scanner with an area of two by one metres and then transfers the pattern into a flow model. "Our goal is to develop a computer model that can predict exactly how large the flaps must be at the leading edge to adequately protect the wing surfaces from insects." 'As large as necessary, but as small as possible' is the motto, because the flaps should not be too heavy, as this would unnecessarily increase the fuel consumption. In addition, the flaps should, as always, give enough lift for the take-off and landing approach.

For the flap system, the engineers have developed an innovation. It is not intended to, as usual, just be extended forwards and then retracted; instead, the researchers want to use what is referred to as a Krüger flap system. Its folding principle was developed in the 1940s and could now come back into favour. "The trick of this technique is the rotation," explains Gloß. "The front edge of the Krüger flap is indeed heavily contaminated during take-off and landing, but the wing surface behind it is protected from insects." During the aerodynamically sensitive cruise phase at high speeds and altitudes, the insect-contaminated areas are folded under the wing surface. The insect remains do not disrupt the airflow during cruising flight.

Gloß is very satisfied with the overflights conducted in Cochstedt. "There have been a lot of mosquitoes this year, which has significantly facilitated our flight tests." In addition, the DLR team has been supported by numerous airport staff. Taxiing, refuelling, and loading – everything has run smoothly. This was fortunate, because the summer weather was a long time coming at the beginning of the flight project. Gloß flew until the last possible day with his dedicated team of researchers, who had to resolve many technical details in the meantime – and then, the task was complete. All scheduled insect flights have been performed, and the films with the insect remains have been removed from the wings and neatly stowed away. Gloß plans to have completed the evaluation of the insect data by 2015. This will demonstrate what the leading-edge flap system for a clean laminar flow wing should look like. •

More information:
s.DLR.de/0pk9

Athlete in the wind tunnel – the paraplegic skier Georg Kreiter competes on a mono-ski. The optimal posture was studied at the DLR Göttingen wind tunnel by researchers from the University of Technology at Hamburg-Harburg.

Moths, men, machines

Moths, men and machines – almost everything has been studied in a wind tunnel. What have we learnt from grasshoppers? How are wind tunnel tests revolutionising ski jumping? And how do fish, tanks and prehistoric birds fit into a wind tunnel experiment? This and more in part 2 of the series 'Wind machines'.

Part 2
Wind tunnel tests – of great interest, and not just for aircraft designers

By Jens Wucherpfennig

Polyphonic chirping, unusual fluttering noises and strange boxes set up all around – this awaited anyone entering the control room of the one-metre wind tunnel at DLR Göttingen in April 2012. Excited scientists immediately instructed everyone to close the door, 'so that none of them escape'. A peek inside the boxes revealed what the researchers meant by 'none of them' – grasshoppers and moths. The specimens were brought to the wind tunnel by scientists from the University of Oxford to be examined with state-of-the-art measurement technology. To this end, the control room was converted into an oversized insect incubator. The scientists wanted to learn from the extraordinary flight characteristics of these small creatures. The findings will bring engineers closer to building micro-aircraft that will – one day – fly in a similar manner to insects.

Researchers strive to understand and imitate nature's creatures – they have had a long tradition as the subjects of scientific research. In the early days of aerodynamics, birds were studied in a wind tunnel as a model for aircraft. For example, lifeless pigeons were prepared and suspended from a pole or wire at the beginning of the 20th century and exposed to airflow – with moderate success. Time and again, the scientists found that once an animal is dead, it no longer has the same aerodynamic properties as when it is alive. Nowadays, researchers investigate with live pigeons, falcons or owls that are encouraged to fly past measuring instruments – without harming the birds in any way.

Journey back to prehistoric times

But the wind tunnel has also been visited by other large, flying animals, even pterosaurs – only as a model of course. Eberhard Frey, a palaeontologist at the State Museum of Natural History in Karlsruhe, studied one of the most agile pterosaurs – the Rhamphorhynchus and DLR Göttingen supported him in his research. The aerodynamics and gliding performance of the pterosaurs were of particular interest to their research. The results have been taken into account in the development of new types of small aircraft.

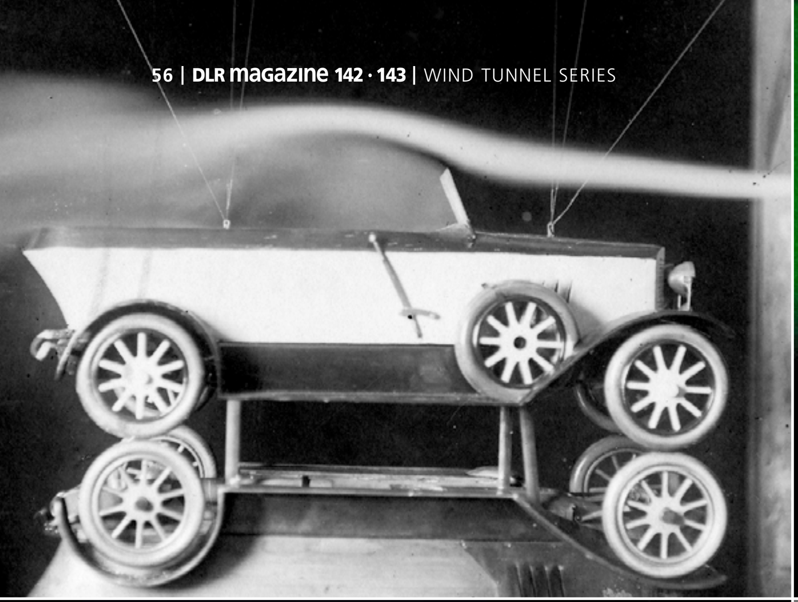
Birds, pterosaurs and flying insects in a wind tunnel – it makes sense. But fish? A few years ago, researchers from South Korea put fish in a wind tunnel. Although this might sound somewhat strange, it makes more sense when you know that, firstly, they were flying fish and, secondly, only taxidermy specimens were used. Flying fish have amazing capabilities – they can stay in the air for up to 40 seconds and reach a speed of up to 70 kilometres per hour. To do so, they use a special aerodynamic trick – the ground effect. Near the ground or a water surface, an air cushion can form that provides extra lift under a wing. This principle has been used in special aircraft – Ground Effect Vehicles (GEV). But perhaps there is still much more knowledge to gain from flying fish…

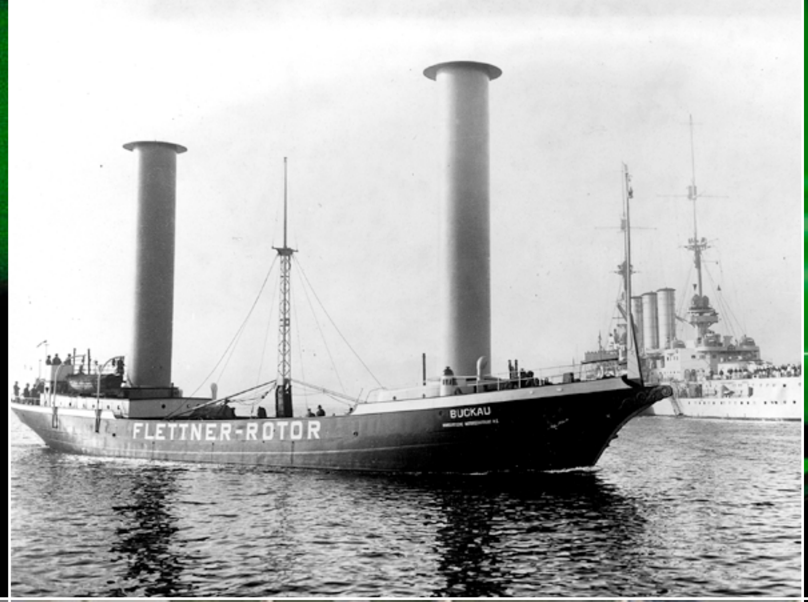
Flying farther with skis?

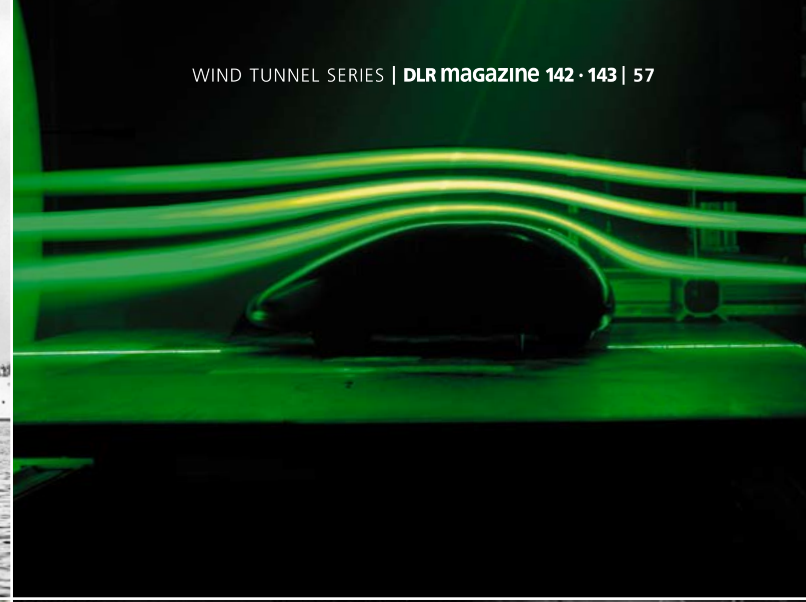
Generally, experiments involving people in a wind tunnel relate to sports. The first tests with human-representative dummies were conducted mainly to find out how a human can fly as far as possible. As early as 1924, a Swiss aircraft engineer, Reinhard Straumann, was the first to recognise the decisive influence of the air as a factor in ski jumping. From 1926, he became engrossed in winter sports from a scientific standpoint, and studied the relationship between speed, technique, posture, and ski slope profile. He conducted measurements during ski-jumping events, and experimented with ski-jumper dolls in a wind tunnel in Göttingen. Between 1926 and 1927, he published a theory about the best aerodynamic posture.

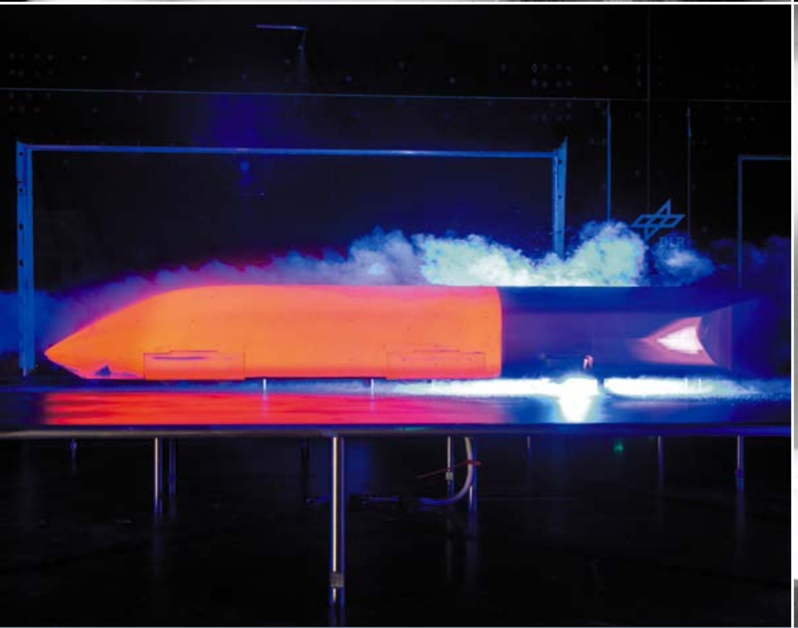
Straumann came to the realisation that ski jumpers achieve the best distance when they adopt a flying posture that is modelled on the aerodynamic principle of aircraft wings. Ski jumpers therefore soar with their whole body positioned parallel to their skis – 2.6 metres in length and weighing up to six kilograms – and with their arms close to their body. Thus, they can only make small adjustments to their direction with their hands, much like fish fins in the water – hence the name 'fish style'. Straumann's theory, however, was only put into practice 20 years later. From 1953, this style became established at the first Four Hills Tournament. Until the 1980s, the stretched forward position parallel to the skis dominated, albeit with minor variations. In conjunction with the V-style that appeared at the end of the 1980s, the fish style is nowadays referred to as a parallel style mostly because of the position with respect to the skis. One of the most successful German ski jumpers, Jens Weißflog, achieved outstanding results with this style.

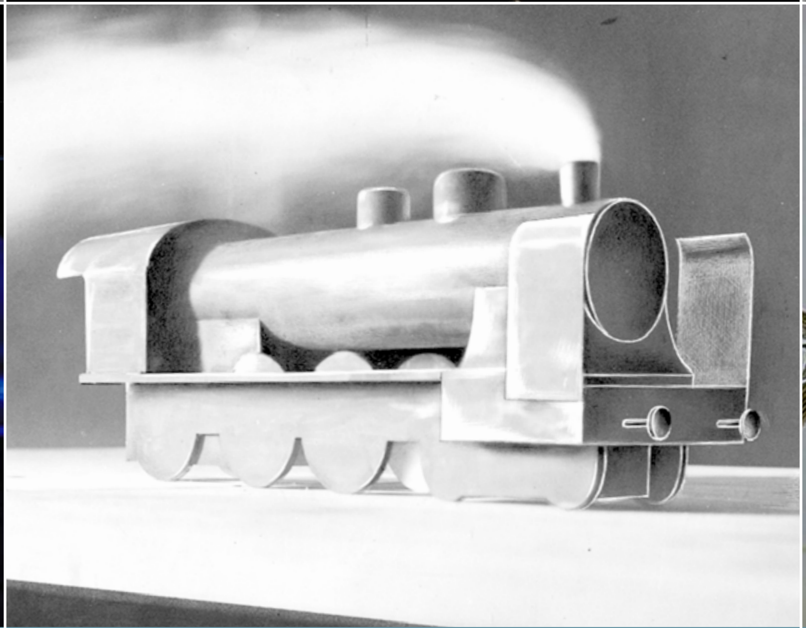
In 1974, the lugers and bobsledders as well as the skiers from the German team were studied in a wind tunnel in Göttingen in preparation for the Olympic games. Knowledge of the best aerodynamic posture promised a gain of several tenths of a second. Nowadays, these tests are not unusual for athletes. Scientists from Göttingen were the first to use wind tunnels to prepare physically impaired athletes for competitions. In 2010, scientists invited members of the German Paralympic alpine skiing team to take part in tests to measure the drag, the lift generated by the skis and the torque forces – in other words, the forces that make a skier tilt backwards or forwards.

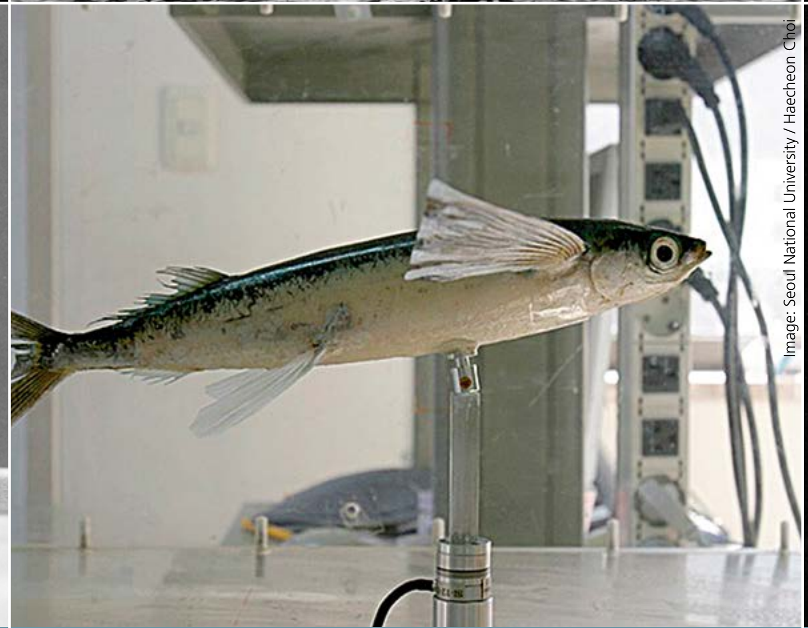


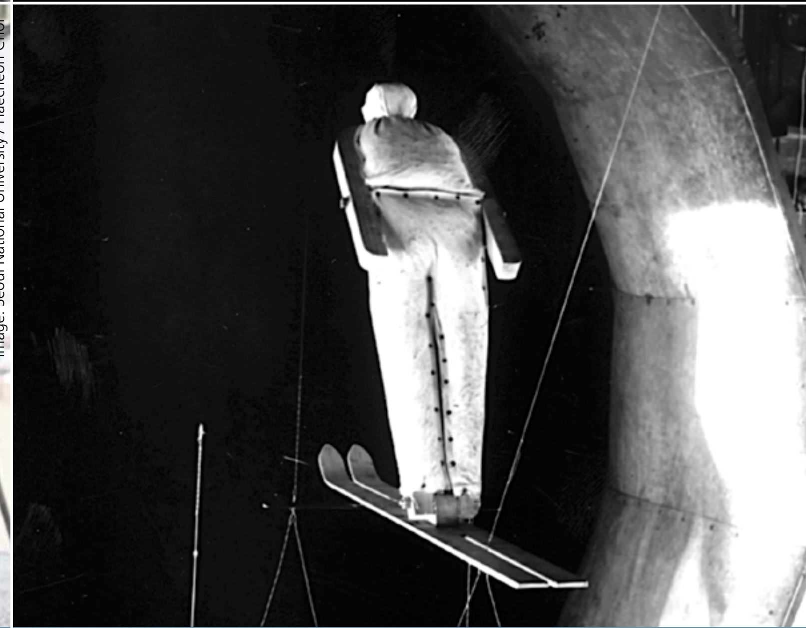












Above: the aerodynamics of a motor vehicle are studied on a model. Smoke makes the airflow visible (1921).

Below: high-speed rail studies in the wind tunnel also produce important findings. Here, a model of the DLR Next Generation Train (NGT) project is being tested.

Above: grasshoppers are excellent fliers and can serve as a model for small aircraft. They were therefore investigated at DLR Göttingen in the airflow.

Below: locomotive models were used in wind tunnel tests to the side-mounted Betz deflectors, which prevent smoke obscuring the view from the cab (1922).

Above: the Flettner rotor ship Buckau was tested in wind tunnels before its first voyage from the port of Kiel in 1924. The investigations enabled it to make better use of the wind for propulsion.

Below: a stuffed flying fish in a wind tunnel at the Seoul National University in Korea.

Above: the Schlörwagen was built in 1939 as a 'wing on wheels'. Its aerodynamic properties are visible in the wind tunnel.

Below: tests with a ski jumper model in parallel style conducted in a wind tunnel at DLR's predecessor, AVA Göttingen (1927).

Everyone can agree that aircraft and cars are likely objects to be studied in wind tunnels – even spacecraft and high-speed trains being investigated for their aerodynamic capabilities. So why not take a closer look at ships as well? This is understandable, especially for aircraft carriers, where take-off and landing on a floating airfield places particularly large demands on aerodynamics. The Göttingen wind tunnel was also used to carry out measurements on a model of the planned German aircraft carrier Graf Zeppelin in 1937, where tufts of yarn attached to the model revealed the airflow. The Graf Zeppelin however, never entered service as the course of the war turned and prevented its deployment; it was destroyed in 1947 by the Soviets during target tests.

Anton Flettner's rotor ship

The most unusual ship design ever owes its wind propulsion system to a special aerodynamic equation, and was therefore extensively studied in a wind tunnel – the rotor ship. This type of ship moves using Flettner rotors instead of sails, in addition to a conventional primary propulsion system. Flettner rotors are rotating cylinders in which a crosswind can flow in such a way that a reduced pressure is created on the side of the rotor, where the rotation goes into the same direction as the incident flow. In the same manner, there is an overpressure on the opposite side of the cylinder, where the motion of the surface is directed against the motion of the air. Both effects cause a force perpendicular to the main flow. The inventor, Anton Flettner, built the first rotor ship, the Buckau, in 1924; it crossed the Atlantic in 1926 and caused much of a stir. Flettner came upon this idea after seeing previous work by Ludwig Prandtl, considered to be Göttingen's 'Father of Aerodynamics' and the founder of the first institutional predecessor of today's DLR. Initially, Prandtl wanted to use the rotating cylinder as a replacement for aircraft wings, but this proved to be impractical. Flettner then revived the idea for ship propulsion. The maiden voyage of the Buckau was preceded by numerous tests of the rotors and ship models in the Göttingen wind tunnels.

Bridges? Yes, bridges

Even objects that do not move, such as buildings, can be studied in wind tunnels. The importance of these studies was clear after what happened with the Tacoma Narrows Bridge. This suspension bridge in the US state of Washington was, upon its completion in July 1940, one of the largest in the world. By November of the same year it had collapsed in a dramatic fashion – with the incident being impressively captured on photographs and film, and earning it the name Galloping Gertie. The cause of this extraordinary event can be found in the realm of aeroelasticity, the interaction between aerodynamics and structure. Göttingen was where aeroelasticity was developed into a science. Time and again, DLR researchers have helped to test bridges and other structures for aeroelastic safety. These include Baltic Sea bridges as well as wind turbines, which were tested as models in the wind tunnel. For more than 100 years, a wide variety of creatures, people and objects have been the subject of studies in wind tunnels. The aforementioned tanks incidentally did not need to be aerodynamically optimised. The experiments were conducted to see how the air conditioning of the vehicles needed to be constructed so as not to draw in their own exhaust fumes. However, on occasion, the researchers reject a request to use a wind tunnel. Some years ago when an art project was to be set up in a Göttingen wind tunnel, the answer was – no, the wind tunnel carries out research towards a better understanding of the world and what we can learn from it. ●

More information:
s.DLR.de/vv9v
DLR.de/AS/en/
s.DLR.de/4tgt

The Concorde is the undisputed star of the Brooklands collection. Operated from 1976 to 2003, the supersonic airliner exhibited a form and function never again attained in such an elegant symbiosis. It is also symbolic that the name of the Anglo-French co-production means harmony.

The power and glory – the legend lives on

It stands – the interest in old technology, historic aeroplanes and aircraft, engines and even old airfields has not dwindled. More than 1000 aviation museums exist around the world. The historic Brooklands, in the southern English county of Surrey, is the birthplace of British motor racing, so there are reasons enough to take a look at the large aerospace and motorsport museum that stands there. While in the area it is worth your time to drive the extra miles to Cambridge and visit the no less promising Duxford Aviation Museum, south of the old university town.

A visit to the British aviation museums at Brooklands and Duxford

By Hans-Leo Richter

Small flight simulation with the Concorde

The Brooklands Museum, south of London, in Weybridge, is easy to find. Right next door is a major Daimler AG presentation and test centre – the giant, rotating, three-pointed star can hardly be missed. A roughly oval track with steeply banked curves was constructed here in 1907 – the first automobile test track in the United Kingdom. Up until the 1930s, high-profile races and even record-breaking attempts took place here. But, from the beginning, it was the aviation industry in particular that called this historic place home. Even before 1910, the first aviators would turn up with their fragile Wright flyers, Bleriot monoplanes and other flying machines. In 1915, during the First World War, the newly established Vickers aircraft company opened its production facilities at Brooklands. Other companies also settled here, such as Sopwith (later Hawker), the British Aircraft Corporation (BAC) and the Bristol Aeroplane Company. After the Second World War, the renowned Vickers Valiant and Vickers VC 10, a four-engine, long-range airliner, were built here. This magnificent place is also the birthplace of fuselage parts, nose sections and wiring harnesses for the Concorde. The length of the wiring harnesses was about 140 kilometres for each model of this famous supersonic commercial aircraft. So Brooklands looks back today with great pride on a long and successful tradition of British aircraft manufacturing.

The Concorde is, of course, one of the major attractions of the museum. The aircraft with registration G-BBDG, known as the 'Delta Golf', completed its first flight in February 1974; its last flight took place on Christmas Eve 1981. For the first time ever, 100 passengers were 'shot' across the North Atlantic in about three hours. At just about 600 metres per second, roughly twice the speed of sound, using the word 'transported' seems perhaps a little old-fashioned. Thus, the time it took to travel between the 'old' and 'new' world became the equivalent of the duration of a good dinner…

Inside the narrow Concorde cabin, information boards, graphics and photographs take travellers back to the era of this unique supersonic airliner. The icing on the cake is a short, simulated flight for visitors on site. On screen, the captain explains the flight phases and procedures, whilst the audience, in the tight seats, feels a slight rumble and vibration accompanied by a discreet engine noise. But above all, just a few minutes later, the large digital display at the front of the cabin shows a cruising speed of Mach 2.02 at an altitude of 53,500 feet – around 16,500 metres. It all appears to be in working order. But you do not want to spoil the perfect illusion by looking out of the small windows – because you can only see the old Vickers Viscount parked right next to the Concorde – something impossible at Mach 2.02…

The large aircraft hangar houses numerous aircraft – mainly British – ranging from the dainty Sopwith Camel single-seater fighter to the most important representatives from the World War II period until the 1950s and 1960s, which were very good years for the British aviation industry. Indoors – and outdoors – you can marvel at the feeder and transport aircraft from Vickers, de Havilland and Hawker – names that, though hardly remembered today, but still renowned in the aviation community.

Especially worth seeing is the Vickers Varsity, a twin-engine trainer aircraft designed in the late 1940s. An unusual sight is the BAC 1-11 from 1965, a twin-engine short-haul jet popular until the 80s, later converted into a test aircraft. The 'Fly by Light Control Technology' inscription on the body shows that other scientists – not just those at DLR – were concerned with the possibilities of fibre-optic flight control. Numerous control panels with a large number of round analogue gauges in the cramped cockpit point to the former use of this airliner as a research aircraft – a salute to ATTAS, the former DLR research aircraft, with its comparable range of applications…

No less interesting are the historic racing cars. There they stand, neatly queuing up: the old Campbell world record breaker, beautifully long-legged racing cars from the twenties and thirties, Bentleys, Napiers, the beautiful Morgan Three-Wheelers with their exposed, powerful J.A.P engines. Many motorcycles from those pioneering days also have a place here.

Even a couple of Formula 1 vehicles from old times honour visitors with their presence – a dark red Cooper Climax, a Vanwall with its never-ending front hood from the late fifties, a McLaren MP4 once driven by the legendary Ayrton Senna in the 90s, a Jordan and other rarities.

The crowning touch of the museum tour is the London Bus Museum, where the familiar red colour of the famous double-decker London buses dominates. Large-scale wall charts, photos and drawings immerse the visitor in the history and technology of this particularly popular means of transport in Britain.

At Duxford, the Catalina makes a couple of circuits

Travelling along the M11 motorway north of London, you reach the aviation museum at Duxford, Cambridge. This equally interesting establishment is part of London's famous Imperial War Museum and presents a wide variety of aircraft and numerous exhibits from the history of British aviation as well as the Battle of Britain during the Second World War.

Once again, the Concorde is the eye-catcher of the museum. After all, it is the prime example of British (and French) aircraft manufacture, even after the end of its service life. The aircraft shown here with registration G-AXDN was not in scheduled service, but was part of the small preliminary series. The racks, test equipment and instruments are still present in the cabin and document the numerous scientific test missions of this remarkable supersonic aircraft.

A gallery offers a magnificent overview of the numerous, and sometimes very closely parked aircraft. The large strategic bombers 'eat up the room' – an Avro Vulcan (from the famous V family: Avro Vulcan, Vickers Valiant, Handley Page Victor) and the clearly much older Shackleton and Lancaster. The two big four-engine Avro York and Handley Page Hastings transport aircraft, which played a major role during the Berlin airlift in 1948/49 because of their size, were both in military and later civilian use.

Almost lost in a corner of the hangar stands the beautiful de Havilland Comet, the first Western European jet airliner – from the 1950s. This model promised to be a commercial success until an inexplicable series of accidents stopped its development. Although the cause of the accidents was later identified via very elaborate reconstructions and de Havilland revised the design of this beautiful airliner, the Americans, in the meantime, had caught up with their long-range success model, the Boeing 707. The Comet could no longer regain the ground it had lost. In later years it was finally developed into the Nimrod long-range reconnaissance aircraft, flown by the Royal Air Force until 2011.

Numerous rarities from the aviation history await visitors in other halls. In one of the next hangars, for instance, are many wartime aircraft. Although most of these are being restored, for aviation enthusiasts it must be incredibly exciting to see the old warbirds in a more or less stripped state. Find yourself face to face with an old Grumman Wildcat carrier-based aircraft, Spitfires, a beautiful Beech Staggerwing – they are all here and, to top it all off, a larger aircraft in light beige desert colours, with German wartime markings. Is it not amazing that aircraft like this Heinkel He 111, which made a career as the standard bomber for the German Luftwaffe during World War II, are restored and exhibited here?

Outside, one's gaze is immediately drawn to the airfield runway, where a beautiful old Consolidated Catalina makes training and maintenance test flights. Time after time, the large flying boat completes a circuit and then returns with the magnificent roar of its two Wasp radial piston engines. But the Catalina is not alone here – a number of other aviation veterans are also still in flying condition and are shown on aviation days.

If nothing has caught your eye yet, then the last hangar will surely fully awaken your interest, as this modern hangar was designed by renowned architect Sir Norman Foster to house the American Air Museum. Here, visitors are invited to study the largest collection of US military aircraft outside the United States. Must-see items are the huge, eight-engine Boeing B-52 'Stratofortress', which was the backbone of the US strategic bomber command for decades, as well as the still futuristic-looking although retired, pitch black, supersonic reconnaissance aircraft, the Lockheed SR 71 'Blackbird'.

A more friendly impression is conveyed by the early English civilian airliners from the fifties and sixties that are very strikingly arranged in the outdoor area; various aircraft from Vickers, Bristol and de Havilland, each of them outstanding airliners, for short or long-haul service. With the advent of jet airliners at the end of the 1950s, however, these aircraft lost their significance. Nevertheless, England should be proud of this remarkable chapter in its aviation history. •

More information:
brooklandsmuseum.com

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Opening hours
Summer 10:00 – 17:00
Winter 10:00 – 16:00

Tickets

Adult	£12.10
Senior citizen/Student	£ 11.00
Children (5–16)	£ 6.60
Children under 5	free of charge
Family ticket	£ 33.00
(2 adults and up to 3 children)	

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Winter 10:00 – 16:00; last admission is at 15:00
Closed on 24, 25 and 26 December

Tickets
Adult £ 17.50
Children (under 16) free of charge

This Lockheed SR 71 'Blackbird', capable of flying at speeds in excess of Mach 3, on show at Duxford is the only example of this supersonic reconnaissance aircraft outside the USA.

Classic 'watch shop' of past eras – the author in the cockpit of the four-engined Vickers VC 10 commercial airliner.

The numerous 'ground-based' transport items in the Brooklands Aviation Museum contrast with the aircraft, as does their color scheme…

The large exhibition hangar at Duxford is tightly packed – in front, the supersonic reconnaissance BAC TSR 2; behind, the Avro Vulcan strategic bomber; left, hanging from the ceiling, an English Electric Canberra.

A legend was the inspiration – the Light Aircraft Carbon SS Cup, a more modern and faster version of the proven Piper Super Cup training aircraft at Duxford.

Reviews

We live in a material world

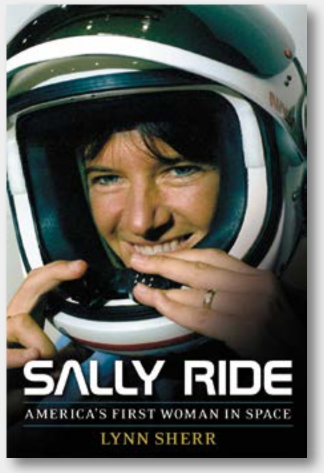
Atoms are the building blocks of materials. These, in turn, make up our world, yet we rarely stop to contemplate them. **Stuff Matters: The Strange Stories of the Marvellous Materials that Shape Our Man-made World** by Mark Miodownik will enlighten you about materials that you use every day – the paper of this magazine, if you are reading the print version or the glass through which you can read it on other devices. His enthusiasm for materials is clear from page one – indomitable steel, trusted paper, marvellous aerogels, imaginative plastic, and the list continues.

Miodownik introduces a field that, although, unknown to some, is thousands of years old – materials science. "The material world is not just a display of our technology and culture, it is part of us. We invented it, we made it, and in turn it makes us who we are," he says, and this is what he tries to convey. For every material in the book, the author tells us its story, the science behind it, and its uses. For example, aerogels – a man-made material that weighs barely more than air, is the best thermal insulator ever created. In his words, holding a piece of silica aerogel is like having "the sky in your hands." It was developed in the 1930s, but was not truly used until the 1980s, when scientific institutions such as CERN and NASA began to use it to test particles and for spacecraft. Eventually, this material revolutionised our knowledge of the Solar System by capturing cometary particles as part of the Stardust mission.

Miodownik's account of steel is also fascinating. Why don't we taste metal when using cutlery? Making hard steel that is not brittle is no easy task, yet the Samurais had a method for creating hard, sharp steel that made excellent swords. At that time, the Japanese were not aware of the science, so they discovered an empirical way of selecting the sharpest steel. Miodownik recounts how disposable razor blades came to our homes – razor blades are particularly interesting for him due to a close encounter with one. The book continues with carbon, paper, glass and plastic. His story of plastic is a script. Glass is the material of scientific instruments – of microscopes, telescopes and chemical apparatus. With the stories comes the science behind the material – from atoms to the structures and what we see and can touch. All of this together gives each material a special property – sharpness, taste, colour, smell…

This book is a jewel – it takes us back to the time when our ancestors began producing what we use today, explains our present, and how those materials will affect our future. Do not miss this "journey into a microscopic world that reveals the science behind our food, our clothes, our gadgets, our jewellery and, of course, our bodies."

Karin Ranero Celius



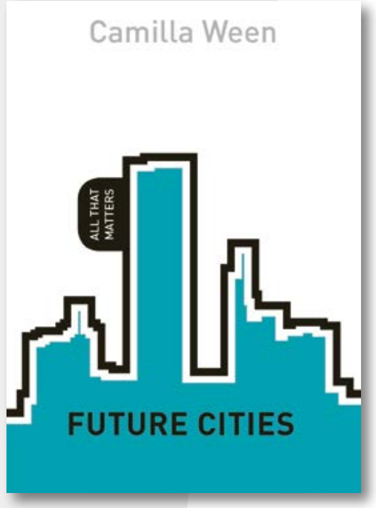
At heart, a scientist

On 18 June 1983, Sally Ride became the first US woman in space, and an icon and role model – but she disliked the media attention and strived to keep her personal life private. In the biography **'Sally Ride: America's first woman in space'**, Lynn Sherr tells her story – the person, the astronaut and a tireless advocate for science education.

Just months before obtaining a PhD in Physics from Stanford University in 1977, Ride came across a NASA recruitment ad for women. Within a year, she had become one of 35 new astronauts. Ride flew on two Shuttle flights and served on the panels investigating the Challenger and Columbia disasters. Later, in a change of career, she left NASA. While teaching and writing children's books about space, she started looking for ways to help women and girls who wanted to study science and mathematics. In 2001, she co-founded 'Sally Ride Science' to create entertaining science programmes and publications for students, with a particular focus on girls. From the mid-90s until her death, Ride also led two NASA public outreach programmes.

This book is a must – a window into the life of a remarkable woman and her achievements, all of which should be remembered.

Dirma van Eck



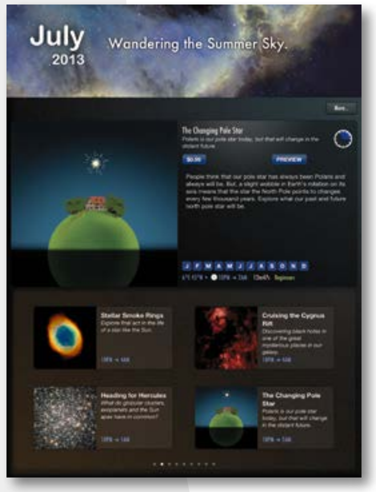
The future is here

In 1950, Earth had 83 cities inhabited by more than one million people. Today, this number has risen to 470 cities, including 26 megacities with a population that exceeds 10 million. It is predicted that up to 80 percent of people worldwide will be living in cities by the year 2030. This massive urbanisation creates a specific set of problems surrounding infrastructure – how to move people and goods, deliver power and water, and remove waste – as well as affecting the quality of life for the inhabitants and the strain on natural resources to sustain city life. In **Future Cities: All That Matters**, Camilla Ween discusses these issues, showing how certain cities are already working on overcoming some of these challenges and provides an optimistic outline of the way ahead.

Geo-engineering is a techno-scientific approach which looks for technological solutions for current environmental problems, for example by fostering the growth of phytoplankton or by reducing the amount of solar radiation that reaches Earth. However, the underlying assumption of this approach, which is to address the consequences of our behaviour rather than changing the behaviour itself, is challenged by Ween and many others who favour a more sustainable engagement with our planet's resources. The author argues that many small-scale adjustments can make a big difference. An example of this is switching from conventional, energy-demanding sewage systems to anaerobic digestion, which can become a source of energy.

Modern cities will face an impressive array of issues in the coming decades, such as heavy demands on transport capacity, increasing carbon dioxide emissions, the need for affordable housing and sufficient drinking water, feeding an expanding population and managing waste. However, Ween argues that if we accept that the way in which we have been living is no longer sustainable and are creative, there is plenty of hope for the future. What do you think?

Merel Groentjes



The sky in your hands

If you are one of many who has looked at the night sky and wanted to know what you are seeing, the **Starmap** app (available for iOS) is for you. The standard edition provides a handy guide to the night sky for the casual observer. The Pro and HD versions offer the user telescope previews as well.

The main feature of Starmap is a virtual sky display. It recreates the sky above you by determining your location via the GPS system and WiFi/IP address of its host system and uses the host's compass to orient itself. If these are unavailable, you can set an observing location manually. The app shows you the location of the Moon, planets, stars and more. Guided by the compass, the sky display turns as you move your device, which is useful for knowing what you are observing. It offers the option of zooming in to get a close-up of something. Tap on it and get more information.

Starmap offers a great variety of special features. For example, the 'tonight' menu brings up a selection of interesting objects to observe. The 'extras' menu gives you the ability to switch to a low-brightness, red display – to help preserve night vision. This is also where the help menu is located. The 'find' function allows the user to search for planets, constellations, stars, deep-sky objects, meteor showers, the ISS, and reveals where they are in the sky. The 'visible' button restricts the list to what can be seen from the current location. If you do not have a telescope, you can limit it to things you can see with the naked eye.

All in all, this is a very useful and informative app for experts and amateurs alike. Definitely a great addition to a night expedition to watch the sky.

Peter Clissold

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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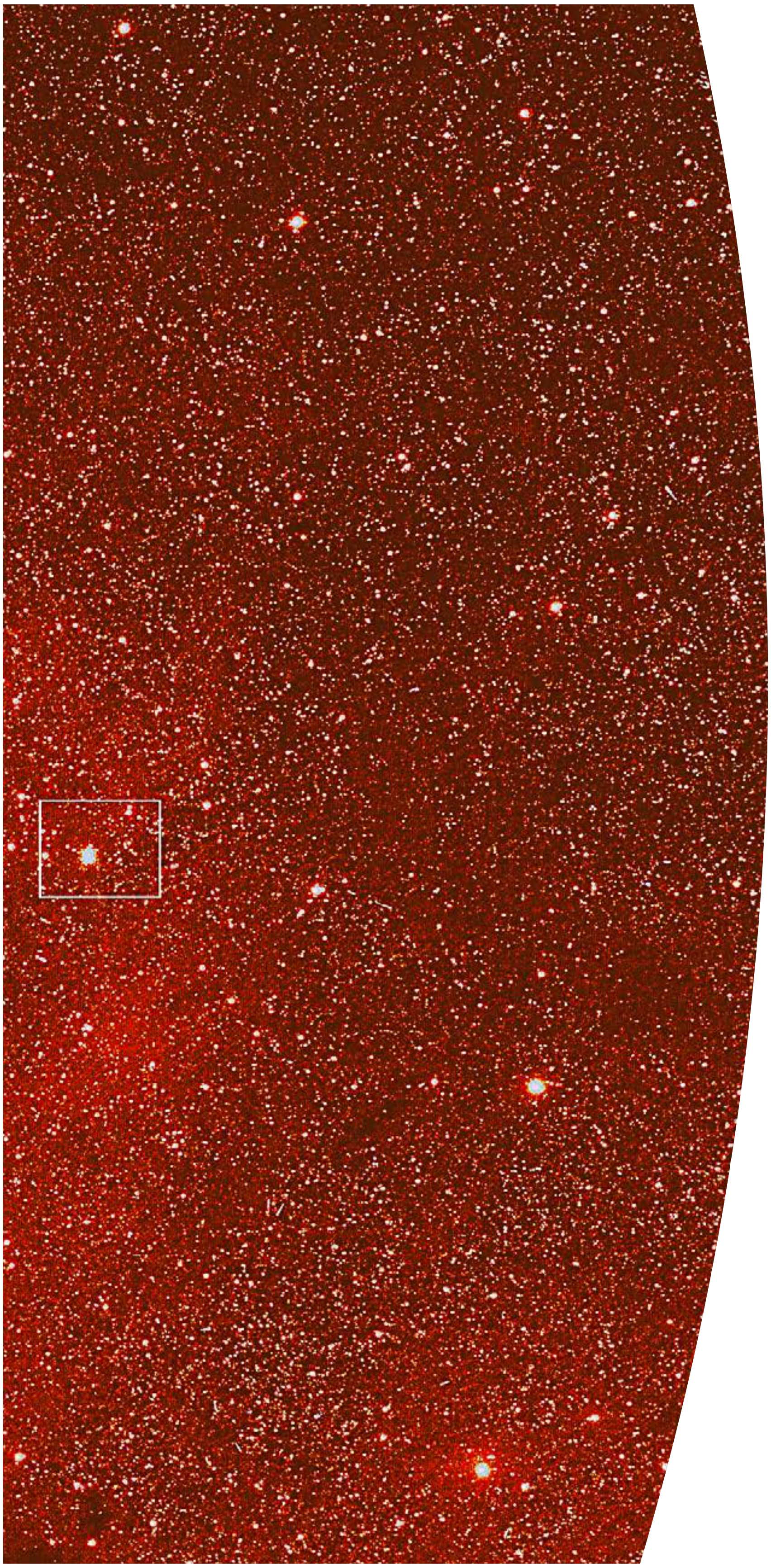

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