Magazine of DLR, the German Aerospace Center · DLR.de/en · No. 138/139 · September 2013

# DLR magazine

# Why the apple falls ...

**Three DLR_School_Labs celebrate 10 years of success**

**A family-run rocket business –** Launch of MAPHEUS-4

**The small all-rounder makes it big –** Gyrocopter in the spotlight

# DLR magazine 138·139


**Family enterprise with a propensity for ignition**

**Through the persistent mosquito swarms at the Swedish Esrange Space Center, the motor for the MAPHEUS-4 sounding rocket is moved to the launch pad. When the team from the MORABA mobile rocket base transports scientist's experiments to altitude, explosives come into play. For this campaign, in which two materials physics experiments will fly up to an altitude of 154 kilometres, the technicians and engineers have prepared the rocket motor, developed and built a recovery system, and assembled the payload elements. Finally, it is ready; the sounding rocket hangs on the launch rail, the igniter is primed and, in the control room, tension is rising by the minute. For yet another of the nearly 500 launches by MORABA over the past 46 years, the countdown begins.**


**Editorial** 3

**Foreword** 4

**Perspective** 6

**Commentary** 8

**In brief** 10

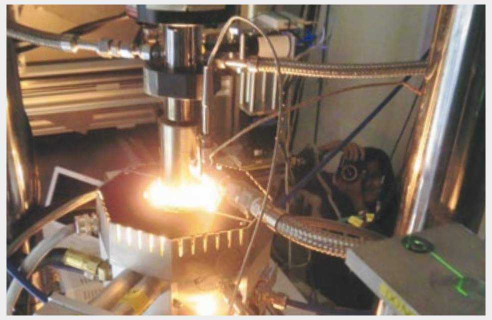
**Experiments in microgravity**
On board the ZERO-G 14

**The small all-rounder makes it big**
Gyrocopter conquers the skies 18

**Next-generation gliders**
A 'saintly' mission in the Nördlinger Ries 20

**Forced to vibrate**
Putting the A350 XWB through its paces 26

**Watching strain with X-ray vision**
Mechanicals materials testing at DLR 28



**In brief** 32

**A family-run rocket business**
Launch of MAPHEUS-4 34

**Portrait: Holger Hennings**
The man who set forth to capture the wind 40

**Mobility in Chad**
Transport research in the desert sand 44

**Please change lanes now**
Driver assistance systems 46

**DLR_School_Labs**
Ten years of excitement and wonder 48

**Free-falling scout**
The MASCOT asteroid lander 54

**At the museum**
Among seagulls and windmills 58

**Reviews** 62


**Dear readers,**

We believe in children. These are not just the words of an expectant mother, but also the creed of a research establishment whose daily work is dedicated to the future of our society. Without a doubt, children are our future and, in view of this, we must invest a lot of time, energy and intellect in both.

Over 10 years ago, DLR took an important step in this direction by setting up the first laboratory specifically aimed at school children. An ingenious idea and the unrelenting perseverance of one DLR employee resulted in the establishment of the first DLR_School_Lab in Göttingen. Today, we run 12 of these extracurricular places of learning, spread across Germany, and the trend is showing no sign of abating. Conducting research like scientists, awaiting results with bated breath, not just having theory drummed into one's head but trying it out for oneself – today the school laboratories are more popular than ever. Back at the start, there was no way of knowing how successful they would be, and for that reason, securing the necessary long-term funding was no easy matter. Today, fortunately, there is no longer any doubt, as the benefits are recognised. If just two children in a class who once visited a DLR_School_Lab go on to take a degree course in science or mathematics, we can be proud.

But at the same time, we actively contribute towards the further development of our knowledge-based society through new research approaches, ambitious collaborative projects and technological investigations. What will happen when the MASCOT asteroid lander reaches its destination in 2018? Equally exciting is the question of the aerodynamic properties of the new A350 medium-range airliner. DLR is testing the aircraft to determine whether its flight characteristics meet the predictions of the developers and manufacturers. DLR even performs highly precise scientific studies into gliding; with our brand-new measurement glider, the flow researchers, aerodynamicists and flight experts of tomorrow are testing their developments.

At German Aerospace Day, being held at DLR Cologne on 22 September 2013, there will be an opportunity to experience the knowledge of tomorrow in person. With good reason, we will once again be focusing on children and adolescents. Just as we did two years ago, we will be treating them as very important guests, our VIPs. We have increased the number of site tours specifically targeted at them as well as the number of people acting as hosts – guided tours, no queues and scientists who devote their time to the youngsters and to explaining everything that they are eager to know. We are creating opportunities for these young researchers and discoverers, and we are hoping for many curious visitors – a guarantee for our future.

Sabine Hoffmann
Head of DLR Corporate Communications


The European Ariane 5 – a symbol of success in scientific and technical research in a united Europe.

Image: ESA

Dr Angela Merkel, Chancellor of the Federal Republic of Germany

# Personal greetings on the occasion of German Aerospace Day 2013

**By Angela Merkel**

Germany is a land of ideas, rich in places where curiosity and creativity, knowledge and skill can work well together. The German Aerospace Center DLR is, without doubt, among these places. Drawing on interdisciplinary connections between aeronautics, space, energy and transport research, this organisation develops new perspectives for the mobility of the future, satisfying in equal measure the need for security and high standards of resource efficiency and environmental protection.

It is thanks to places of innovation such as this that Germany is one of the leading international research locations – and it should stay that way. This is why, in our daily work, we place special emphasis on education and research, and with our High-Tech Strategy, pool the forces of politics, science and industry.

To secure our prosperity and maintain our ability to innovate, it is important that we continue to attract young people to mathematics, the natural sciences, technology and engineering. I am therefore delighted that DLR's doors are open once again, offering an insight into the exciting world of its various research fields.

Aeronautics and space have always been in our dreams. Much of what initially appeared utopian has become real thanks to outstanding, cutting-edge research. Progress – this is DLR's calling. I therefore invite everyone to make use of the opportunity that German Aerospace Day offers, and take a look into the future. ●

# Perspective

## Lonely search for a landing site

The Moon is getting closer and closer. Instead of human eyes, a camera looks out for distinctive landmarks to orient the spacecraft and find a safe place to land. Its software must draw the correct conclusions from what it sees. The trip to Earth and back for a radio signal will take too long. Long before a spacecraft approaches a body in space, the final descent will be simulated in the laboratory. Here, a scale, three-dimensional image of the Moon plays the part of the planned target of the exploration mission; a spotlight simulates the Sun, so the shadows can be depicted realistically. The camera plays the lead role. Together with its software, it must determine where exactly the spacecraft is and where it can land. Here, Hans Krüger, Head of the TRON (Testbed for Robotic Optical Navigation) laboratory at the DLR Institute of Space Systems in Bremen, only has a secondary role.

www.DLR.de/IRS/en

# ... is it worth it?

## Research and the question of costs and benefits

**By Johann-Dietrich Wörner**

Johann-Dietrich Wörner, Chairman of the DLR Executive Board

www.DLR.de/blogs/en/janwoerner

The question of 'return on investment', or the gains to be derived from funds made available, is no longer restricted to the accounting departments of industrial companies. It is now a part of many aspects of life, and people try to make investment decisions under the dictate of benefit. The matter of 'whether it is worth it' seems especially justified when it comes to the use of public funds. In this case, 'central' standards are used to measure the benefits and associate them with the cost.

This practice is not new. Even Columbus solicited funding for his expeditions based on the expected benefits – as did other explorers. Many examples in research show that the desired association between investment and return can often only be accounted for after a long period of time. When Faraday, who discovered that electricity can be generated by induction, was asked about the practical worth of electricity, he said: "I do not know, but there is every probability that you will soon be able to tax it!" The revolutionary and fundamental theoretical work of Albert Einstein on relativity only delivered its practical benefits several decades later in satellite navigation, where a failure to take into account the dependency of time on speed and gravity would lead to unacceptable location errors. When researchers were studying Venus in detail (why exactly, lawyers asked of the benefits, when we have enough problems here on Earth), they discovered the greenhouse effect. A similar phenomenon was later found on Earth. How can we know in advance what the possible benefits of our study of Dark Matter or Dark Energy, which together make up 96 percent of the Universe, will be?

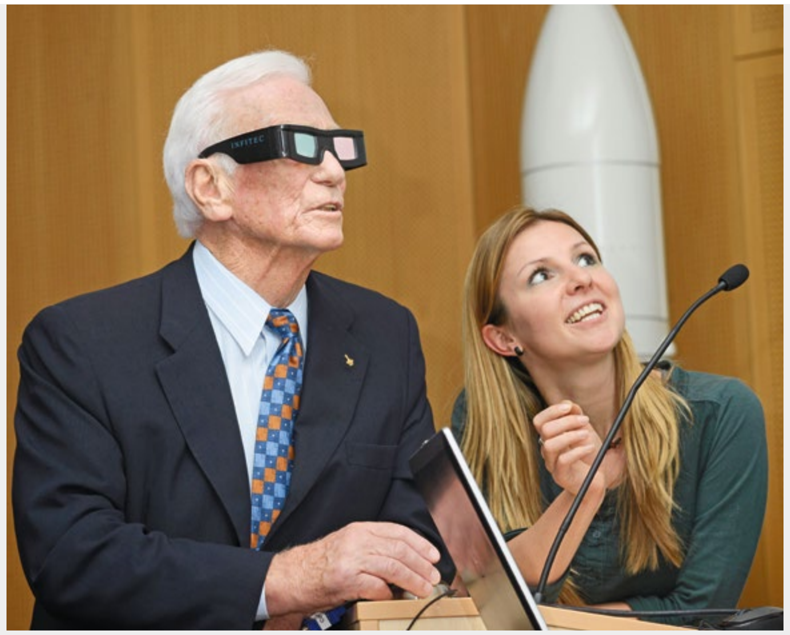
The purpose of this observation is to point out the need for a broad understanding of research; from basic research to applied research and through to product development – it is sometimes a long and time-consuming journey, but one that is well worth embarking on. At DLR, we are trying to make the innovation chain as seamless as possible, from invention to innovation, from an initial idea to a groundbreaking new product. In doing so, we also collaborate with partners to develop ideas into products, for example, or to transfer technologies from one of our research areas – aeronautics, spaceflight, energy, transport and security – to a completely different field of application, such as agriculture or medicine.

However, research has an additional advantage – it encourages people to support a cause. The Apollo Moon programme gave scientific activities in the United States an enormous boost and, in particular, fascinated and inspired a generation of young people.

With German Aerospace Day, we want to, with our partners, demonstrate to everyone – but especially women and young people – the accomplishments we have to show now. Investing only in research where the benefits can be determined in advance is not worthwhile in the long term. ●

# In brief

## Moonwalker soars through the chasms of Mars

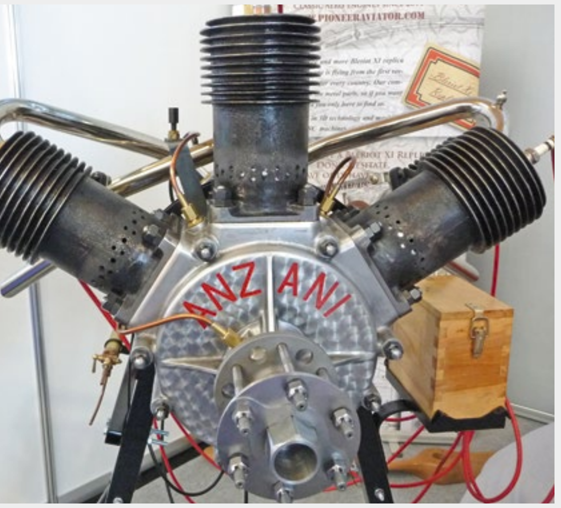


Astronaut Eugene Cernan at DLR Berlin

Even an experienced astronaut can find flying into new territory a challenge. Captain Eugene Cernan, commander of NASA's Apollo 17 mission in 1972, experienced this during a 3D-flight through the chasms of Mars. Cernan, the last man to walk on the Moon, visited DLR Berlin in the early summer of 2013. Thanks to the friendly assistance of Daniela Tirsch from the DLR Institute of Planetary Research, he enjoyed the virtual flight. "I would rather leave the first landing on Mars to one of these motivated youngsters," the 79-year-old said afterwards. He talked excitedly about his space flights with Gemini IX, Apollo 10 and Apollo 17, and explained in moving words the importance of striving for ambitious goals in space exploration. There is no doubt that the fire is still burning brightly in him. During his stay, Cernan handed over a lunar rock to the Technik MUSEUM SPEYER. The loan was arranged through the DLR planetary researchers' NASA contacts.

**www.DLR.de/PF/en**

## Inspired by aviation history




Good ideas simply last longer – the same is true of aircraft engines. Fans of historical aviation equipment have always been in awe of the small, reliable Anzani engine that carried Louis Blériot across the English Channel in his fragile monoplane in the summer of 1909. The three-cylinder engine in a W-construction that ran reliably at almost 1200 revolutions per minute and had an output of 25 horsepower was clearly enough to successfully haul Blériot's monoplane over the mighty cliffs of Dover.

At this year's AERO Friedrichshafen, which is now the best-established event for general aviation, Hungary's Pioneer Aviator Company presented a fully functioning replica of this small aircraft engine. It also produces 25 horsepower, operates at around 1500 revolutions per minute and weighs 65 kilograms.

The Anzani engine – a piece of technological history.

**www.pioneeraviator.com**

## New start for the Junkers F 13 project

After a long delay, the project to reconstruct a flying Junkers F 13 is once again up and running. The Swiss company Ju Air, the Association of Friends of Historical Aircraft (Vereines der Freunde historischer Luftfahrzeuge; VFL) and the company Rimowa have joined forces to reconstruct a working Junkers F 13 – the first all-metal commercial aircraft in the history of civil aviation. The reconstruction work has now started in Oberndorf am Neckar in Swabia.

First on the work schedule is constructing the wings and other basic structural elements. All the official requirements have been fulfilled, so the F 13 – under Swiss approval – is expected to roll out onto the runway for the first time in early 2015. The Junkers F 13 is being built by Kaelin Aircraftstructure GmbH. This company also played a significant role in the restoration of a Breitling Super Constellation.

The Canadian Junkers F 13 'City of Prince George' is the template for reconstructing a working model of this type.

## Augsburg: unique research institute for lightweight materials

Lightweight materials are among the most important futuristic technologies in aircraft, vehicle and machine manufacturing. Along with colleagues at the Fraunhofer-Gesellschaft, DLR scientists are working on automated manufacturing processes for carbon fibre reinforced plastics, CFRP, that are suitable for large-scale manufacturing. For this reason the Center for Lightweight-Production-Technology (Zentrum für Leichtbauproduktionstechnologie; ZLP) came into operation in Augsburg in May 2013.

The majority of components in aircraft and Formula 1 cars are already made of CFRP, albeit painstakingly by hand. CFRP components weigh only half as much as their equivalents made of steel, but are equally rigid, crash-proof and do not rust. The initial aim of DLR's research at the ZLP is to develop a consistent manufacturing process for CFRP components. Robotic systems play an important part in this; they are expected to reduce manufacturing costs and increase productivity and quality.

The ZLP in Augsburg is equipped with several special research facilities, making it unique in Europe. At its heart is a robot with a laying head: it grips the carbon fibres, which are coated with resin, and deposits them on the tool. The fibres are then hardened. This automated process is suitable for use in large-scale production and provides high quality. No waste is produced.

The robot with the laying head has an especially large range for picking up and depositing the thermoplastic sections

## Successful flight tests with helicopter external loads


The DLR EC-135 ACT/FHS (Active Control Technology/Flying Helicopter Simulator) research helicopter carrying out a flight test with an external load on the rescue winch

Researchers in Braunschweig working on the HALAS project (Hubschrauber-Außenlast-Assistenzsystem; Helicopter External Load Assistance System), have succeeded in using a small sensor to measure the swinging motion of an external helicopter load precisely. In collaboration with iMAR Navigation GmbH, they carried out flight tests over a period of several weeks.

The sensor, which was developed by iMAR Navigation, captures the motion of the loads in relation to the helicopter and sends the results to the cockpit. Based on the information from the sensor, the experimental system then accesses the helicopter's controls, if necessary, to take control of its flight movement and reduce the swinging motion of the load, finally bringing it back into position.

In future, the HALAS sensor technology will be used for both the transportation of objects and rescuing people. Another test campaign is planned for late 2013, to demonstrate the automatic external load stabilisation in flight.

# Robots enrich life in isolation

Collaborating with the DLR Space Administration, Bielefeld University has been running the SoziRob project on human-machine interaction. In two campaigns, eight test subjects spent three weeks in the isolation room at the DLR Institute of Aerospace Medicine in Cologne, shut off from the outside world. Under these circumstances humans and robots were put to the test.

During the first campaign, the human participants had to motivate themselves in games and sport. In the second campaign, they had the support of two robots. The first was the talking robot head Flobi, which played a few memory games with the isolated subjects every day. Flobi could respond minimally to the participants and move its eyes, eyebrows, eyelids and lips. The other robot was the 60-centimetre-tall Nao, which ran a daily hour-long spinning session for the participants to perform on their stationary bicycles. It gave them exercise instructions and provided feedback on speed.

As it turns out, both Flobi and Nao did a good job. With Flobi the participants played the memory game for much longer than with only other subjects. Nao was also accepted by the participants and even provided a slight increase in performance on the bicycle. Despite the mental strain, humans and machines tolerated each other well. Performance levels improved slightly and the test subjects' mood fluctuated slightly less than without the robots. Flobi and Nao have shown that interaction between robots and humans in space can be beneficial.

**Robot head Flobi plays a memory game with a test subject in the study**

# DLR solar researchers support Morocco's Solar Plan

**Parabolic trough facility at the Plataforma Solar de Almería, in southern Spain.**

Construction work for the first solar power plant in Ouarzazate, Morocco began this year. The project is a collaboration between DLR and the Moroccan Agency for Solar Energy, Masen. This will be a parabolic trough power plant with a capacity of 160 megawatts. By 2015 this capacity will be increased to 500 megawatts and the complex will then include a solar tower and a photovoltaic power plant.

The DLR Institute of Solar Research is currently developing a concept for a test centre that might also be built in Ouarzazate. This centre would research efficient, cost-effective solar power generators for energy and desalination plants. The long-term goal is to develop a competitive solar industry in Morocco. By 2020 power stations with an output of 2000 megawatts are expected to be in operation.

The heat energy produced by solar power plants has the advantage of being much easier to store than energy from other renewable energy sources. Thanks to special storage technology, solar power plants can work around the clock; they can continue to supply energy when the Sun has set and demand is particularly high.

**http://s.DLR.de/92ee**



# Alphasat I-XL is orbiting Earth

ESA's largest telecommunications satellite to date, Alphasat I-XL, has been orbiting Earth since 25 July 2013. It is being operated as a public-private partnership (PPP) between ESA and Inmarsat, a global operating company for mobile satellite communications services. This partnership gives the satellite the 'I' (Inmarsat) in its name. The Alphasat development project was carried out in the framework of ESA's telecommunications satellite programme (ARTES 8), and Germany is pursuing several objectives through the DLR Space Administration.

In addition to the commercial payload, Alphasat I-XL offers accommodation for technologies that are being tested for the first time in geostationary orbit. Of the four payloads that are flying for demonstration purposes, two are from Germany. A star tracker from Jena Optronik delivers highly accurate orbit and attitude information, and this supports the precise alignment of the optical Laser Communication Terminal (LCT), which was also developed in Germany.

**http://s.DLR.de/1u9r**

# Falcon tracks down desert dust

The effect of desert dust on cloud cover and the weather is one of the biggest uncertainties in climate forecasting. Therefore, DLR scientists have been carrying out measurements with the Falcon research aircraft on Cape Verde and in the Caribbean. The questions they are looking to answer are many. For example: how does the distribution of dust particles of different sizes change during transportation across the Atlantic into the Caribbean? What influence does desert dust have on Earth's radiation balance? How many large dust particles are lost during transportation across the Atlantic? How does the desert dust interact with clouds? Is there a connection between the presence of Saharan dust above the Atlantic and the formation of hurricanes? How well can Saharan dust be measured using existing satellites? Hopefully, the answers to these questions will be found in the data acquired during the Falcon research mission, which will be studied in detail at the DLR Institute of Atmospheric Physics, as part of the Saharan Aerosol Long-range Transport and Aerosol-Cloud-Interaction Experiment, SALTRACE.

**From DLR's Falcon research aircraft, dust and forest fire aerosol layers at Cape Verde are not only detected, but also measured using special instruments.**

**BUILDING CURIOSITY**

**http://lego.cuusoo.com/ideas/view/3431**

Designed by a mechanical engineer who worked on the actual Curiosity, the Mars Science Laboratory can now be recreated in Lego, including its mechanical arm, deployable mast and the suspension system that allows Curiosity to tread through the rocky Martian terrain. So dig out your Lego bricks and start exploring!

**SUN WATCH**

**www.helioviewer.org**

This exciting new scientific tool offers data from NASA's Solar Dynamics Observatory in an easy-to-use web interface. Explore the Sun and inner heliosphere for solar flares or coronal mass ejections from as far back as 1993, and share images and videos of them with your friends.

**SQUEEZE YOUR BRAIN**

**www.youtube.com/Headsqueeze**

Have you ever wanted to know whether we can build an elevator into space or whether time travel is possible? Check out the Headsqueeze YouTube channel, where James May and his team answer a range of quirky and interesting science questions from the audience.

**MARS: A PLANET FULL OF RIDDLES**

**www.mex10.dlr.de/index-en.html**

On the occasion of the tenth anniversary of the Mars Express mision, join us on a trip to our planetary neighbour. See breathtakingly beautiful pictures of its surface. Find out more about its geology, climatic history and moons, and learn about the history of its exploration.

**GERMAN AEROSPACE DAY**

**www.DLR.de/en/tdlr**

Every year, DLR opens its doors for German Aerospace Day, to present the latest in high-tech research in aeronautics, energy, transportation, security and space technology to the public. To find out more about this exciting event, visit the special website.

**HOPPING IN MICROGRAVITY**

**http://s.DLR.de/b8fw**

What will happen when MASCOT lands on asteroid 1999 JU3 in 2018? How can scientists ensure that everything will go as smoothly as possible? Take a look at the research conducted at DLR to make sure all systems work properly at the right place, at the right time.

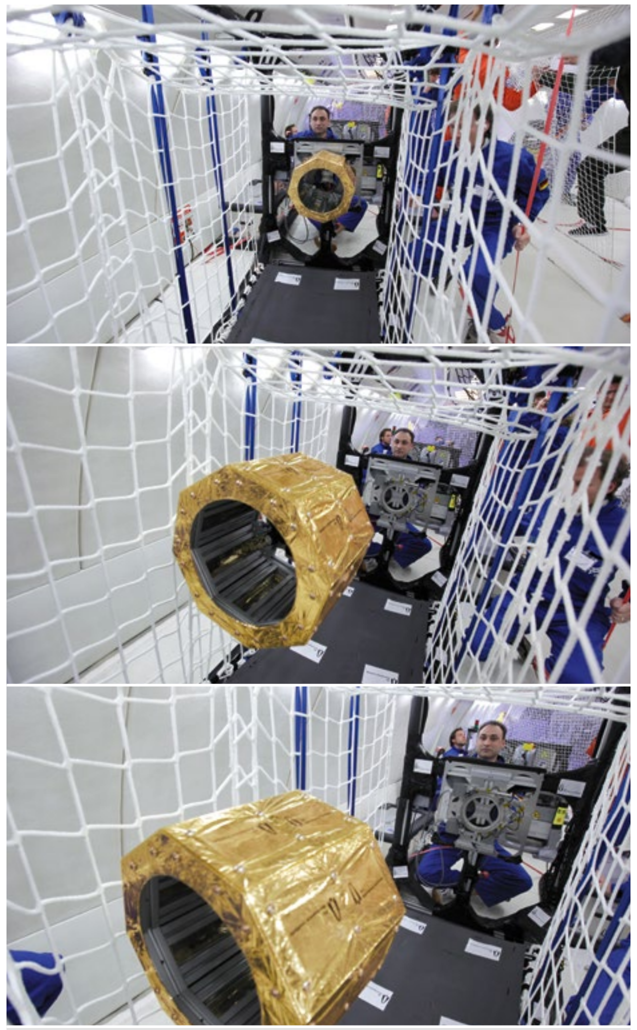
DLR researcher Peter Gauger monitors the heart rate of astronaut Hans Schlegel as he floats

# Palpable heartbeats and floating cell cultures

**The scientists had prepared for their zero gravity flight for weeks – filling out applications, developing experiments and instruments, adhering to strict safety requirements for constructing their systems. And then the moment comes; the start of three days of flights during which to conduct their experiments in the fields of biology, materials physics or medicine, while all the time cheating gravity. A report.**

## Beyond the constraints of gravity – scientists conduct experiments on DLR parabolic flights

**By Manuela Braun**



**What should be done smoothly in space later on, will be thoroughly tested during the parabolic flight – here, the separation of a satellite from its launch vehicle.**

Eyes closed and with his face completely relaxed, Hans Schlegel floats towards the aircraft ceiling. Slowly, his body rotates, rises, and then drifts gently back down. Around him, the aircraft levels out at the apex of its ascent before plummeting back down, diving from 8500 metres to 7600 metres. Maximum concentration grips the cockpit. The pilots are seated close together, strapped into their seats. Around them, everything floats – their hair, their uniform collars. The pilot's countdown echoes through the aircraft's public address system: "40, 30…" Schlegel opens his eyes. Unless he gets his feet on the aircraft floor quickly, he will experience a 'rough landing'. "Pull-out." Captain Stéphane Pichene begins to level the aircraft. In an instant, zero gravity is turned on its head. Arms, legs – everything is suddenly twice as heavy as it would be on Earth. Previously effortless movements become a laborious struggle against gravity. Hans Schlegel wrenches himself back to a standing position. The first parabola is complete. The astronaut participating in the study on board the 'ZERO-G' has now completed 20 seconds of double gravity, followed by 22 seconds of zero gravity, and another 20 seconds of double gravity.

### Between anticipation and scepticism

The first day of flights in the 22nd DLR Parabolic Flight Campaign is underway. Thirty-one will be the number of times that the aircraft will climb steeply to then dive back down towards Earth. Each time, the cardiac output of the floating test participants will be monitored, the plants observed as they respond to zero gravity, and the satellite model released from its launch vehicle. Granular matter will be X-rayed and dusty plasma photographed without gravitational interference. Some of the study participants spend the flight in a balancing act, while others are asked to demonstrate their fine motor skills under stress and in zero gravity. Already, at 07:45, the tension was almost palpable. "So – your first flight?" Past experiences were shared in the queue outside the doctor's office. The faces of the first-time fliers show anticipation, curiosity and perhaps a touch of scepticism. Will they manage to work under zero gravity conditions without feeling nauseous? Will they be able to execute the correct manual operations at the right time when experiments commence or samples need changing? Thierry Leraitre, the physician, carefully disinfects the participants' arms and proceeds to administer a scopolamine injection. "It helps to prevent motion sickness." One after the other, the scientists extend their arm to receive the helpful medicine.

Research without gravitation – while the subject performs various tasks on the screen, the researcher from the German Sport University drifts above his control laptop.

Balance in microgravity. The team from the University of Freiburg examines movement and balance control to help astronauts and patients undergoing rehabilitation.

On the dot of nine, the doors closed behind the scientists and the ZERO-G took off on its parabolic flight. The European Space Agency, ESA, and the French Space Agency, CNES, have conducted 120 parabolic flight campaigns since 1984. The German Aerospace Center has been doing this since 1999. In total, they have completed 1400 experiments in 28 years while flying in zero gravity in the aircraft. This time, there are 11 experiments on board the ZERO-G.

**A weed as test specimen**

The second parabola begins. Svenja Fengler has anchored herself to the aircraft using the foot restraints – both gloved hands in a box of specimens. *Arabidopsis thaliana* is set to receive an injection of chemicals. The unprepossessing weed is almost predestined for parabolic flights: "The genome has been fully sequenced," says the scientist from the University of Tübingen. Biologists are well acquainted with thale cress – which is why it is perhaps best suited to revealing the genes

The extraordinary manoeuvres are carried out in specially designated areas

responsible for the perception of gravity and where, for instance, the calcium in its interior – the level of which rises dramatically during periods of zero gravity – comes from. This is why 36 bottles full of cells are on board during the steep climb and subsequent dive. A crop plant is also along for the ride to permit comparisons with the weed; a Brazilian scientist is on hand to look after the sugarcane cell cultures. Svenja Fengler now sits motionless on the soft mats covering the floor. "Pull-out." She braces herself with one hand against the soft foam wrapped around the edges of her equipment to protect the system. Before the flight, a team of 12 safety officers thoroughly checked each individual instrument one last time. Are there any stray components that could just float off during zero gravity? Have all the sharp edges been protected to make sure no one is hurt, even during the transition to double gravity? Each of the experiments has been fitted with a red emergency button. With just one push the experiment will stop – a precautionary measure in case electricity, X-rays or liquids are in danger of spiralling out of control.

While the cell cultures are experiencing their first taste of zero gravity, Hans Schlegel, an old hand at weightlessness, floats through the cabin once more, just a few metres away. He flew on the Spacelab D2 mission back in 1993, and delivered the European research laboratory Columbus to the International Space Station in 2008. "Your body always remembers weightlessness," he will say later, once the parabolic flight aircraft is safely back on solid ground. But for now, he is entirely focused on what astronauts are so familiar with – floating without fear.

**Heartbeat by heartbeat**

Now, the only thing picking up pace is his heart rate. Anchored to the floor, Peter Gauger from the DLR Institute of Aerospace Medicine stands next to the astronaut, and gently guides him away from the ceiling, in preparation for the transition to double gravity. The sensors on Schlegel's body can only record the force with which his heart pumps blood into the large vessels with each beat if he is allowed to float entirely free of outside interference. He has already completed this experiment once, in Spacelab during the D2 mission. The plan now is to optimise the simple technique of ballistocardiography for use on the International Space Station, ISS. Several countries are represented on the scientific team; United States, Belgian and German researchers work hand in hand. "Next, we want to, on the ISS, verify whether spending several months in space affects the way the heart works," says Gauger.




After 31 parabolas, each with 22 seconds of microgravity, the first of three flight days comes to an end. The team of scientists, volunteers and pilots are more than satisfied with the research results of the 22nd DLR parabolic flight campaign.

A break comes after the sixth parabola. For five minutes, the ZERO-G will fly like a normal airliner. Restlessness spreads across the aircraft. Specimens are exchanged, procedures improved and for just a moment, preliminary conclusions are drawn. For some on board, these five minutes offer a precious break allowing their bodies to recover. It is practically impossible to influence how one's balance organ responds to the ups and downs. The first scientist in Alexander Piehl's team is lying flat on the floor. "It's far better this time than in previous flights," he asserts. Another five parabolas and he will ask the on-board doctor Thierry Leraitre to administer a further injection to combat nausea – before spending the subsequent 20 parabolas examining the behaviour of nonlinear waves in dusty plasma during weightlessness. "It is important to conduct experiments in microgravity," he says. "And it is still fun, even if it leaves you feeling a bit sick."

It is a rare thing indeed for anyone to refuse the opportunity to conduct experiments in circumstances that are so rarely on offer. The ZARM drop-tower in Bremen can offer four to nine seconds of weightlessness, while a high-altitude research rocket delivers six to 12 minutes. All that comes after that to obtain weeks or even months of weightlessness are satellites and the International Space Station. "Parabolic flights are a good occasion to conduct experiments in the absence of gravity for multiple periods of 22 seconds, without needing long periods of preparation," says Ulrike Friedrich, Project Manager for Parabolic Flights at DLR. So anyone wishing to be on board has to convince a jury of outside experts. "Many scientists devise a whole series of experiments and fly with them on several campaigns."

**Treacherous exercise in balance control**

Ramona Ritzmann from the Albert Ludwig University of Freiburg is one of these researchers. The sport scientist is floating professionally while her test subject in zero gravity balances on one leg. The board he is standing on is designed to surprise; sometimes it lurches forward, other times it slips to the side. Astronauts living and working in space experience deterioration in the control of movements and balance. Upon their return to Earth, they find they are barely able to walk or stand upright without assistance. "You lose a lot of skills in space," says Ritzmann. The test subject, Yannik Kupfer, struggles for stability. Each attempt to maintain balance on the treacherous, freely oscillating board provides the sport scientists with data on his muscle activity and reflex pathways. The phase of double gravity begins. Yannik flops back into his seat while Ritzmann hops cumbersomely up and down. Novices are urgently advised to rest during these hyper-G phases, and most certainly without moving their heads. "Thankfully, it doesn't bother me at all," says the sport scientist. In future, people undergoing rehabilitation will benefit from the results of this experiment.

The 31 parabolas are over faster than expected. The red digital display in the aircraft records each single parabola. Finally, the last cycle comes and goes. Everyone on board returns to their seat. Like in any airline flight from Cologne to Berlin, passengers are required to fasten their seat belts. Zero gravity conditions prevailed for a total of 682 seconds. Back in the arrivals hall, conclusions are drawn. One team experienced difficulties exchanging the specimens between the individual parabolas, while another team had found the first parabola to be too fast. The crew from the University of Freiburg had struggled with a defective cable, while the team from the DLR Institute of Materials Physics in Space had encountered difficulties with the new X-ray system, X-Rise, on their maiden flight. And the scientists who spent the flight monitoring the weeds can look forward to months of evaluating tens of thousands of genes back in their home university. Hans Schlegel's heartbeat is revealed to the scientists as a zigzag line. He will spend the following day breathing in and out in regular patterns, instead of on board the aircraft. The plane itself now stands parked in front of the hangar, its door closed. A new day of flights begins at 06:00 the next morning – the X-ray device will get to work, another test subject will try to keep his balance, and dusty plasma will once more form clouds, waiting to be photographed. •

**More information:**
http://s.DLR.de/3xsc

# The small all-rounder makes it big

**It has come surging back onto the scene, just like in the title sequence of the James Bond film 'You Only Live Twice' that popularised gyrocopters 46 years ago – but this time the main focus is in the world of science. This rather odd-looking flying machine is a rotary-wing aircraft. However, it is not an engine that turns its rotors, but rather the air streaming past. The rotor on the gyrocopter, also known as an autogyro, thus enters a state of 'autorotation'. This principle of flight is as simple as it is ingenious. Juan de la Cierva developed the first rotary wing aircraft as far back as the nineteen-twenties. Its success story, however, did not begin in Germany until roughly 10 years ago. Since then, registrations have risen consistently. Nevertheless, the ultra-light aircraft still poses many unanswered questions, making it an enticing object of research.**

## Back in the spotlight – the gyrocopter conquers the skies

**By Frauke Engelhardt**

Small gyrocopters are real all-rounders: they are quick to deploy, inexpensive and are considered sturdy aircraft due to their comparatively simple technology. They offer promising flight characteristics, such as the ability to fly very slowly when needed or to take off and land in extremely small spaces. Gyrocopters can be operated safely in unfavourable weather conditions such as strong winds or poor visibility, making them ideal for use in air surveillance.

Since 2012, DLR, together with the German Federal Agency for Technical Relief, THW, has been researching the advantages of using gyrocopters during rescue operations. Catastrophes always demand rapid response times. This is where gyrocopters enter the equation – from the air, they can shed light on the situation, for example to gather information regarding the extent of damage or the number of persons requiring rescue as well as their location.


**The new gyrocopter of the type Cavalon of the company AutoGyro is ready to be put throught its paces at DLR Braunschweig**

In September 2012, a gyrocopter transmitted live video images to a ground station during an earthquake drill. "The aerial images provided by the gyrocopter were an extremely effective way of getting a quick, general picture of the extent of the damage, allowing us to tailor our assistance accordingly," says Ulf Langemeier, Director of Operations during the earthquake drill.

### New flight system supports the pilots

A new gyrocopter, the AutoGyro Cavalon – D-MGTD – has been used for joint research conducted by THW and DLR since April 2013. The new gyrocopter, based in Braunschweig, is to be fitted with a special infrared camera, to be controlled from the cockpit, and intended for aerial reconnaissance. Moreover, there are plans to develop a flight system to assist gyrocopter pilots in complex mission situations. Once complete, it will be unrivalled. Finally, the unusual flying machine will be put through its paces in test flights to confirm its suitability for everyday use and operational deployment.

The DLR Institute of Flight Systems aims to establish itself as the leading institute in the field of autorotation research. Of interest, for example, are better training simulators as well as flight performance and flight characteristics. The researchers also aim to improve flight performance and handling qualities of gyrocopters, ensuring that the 'small one' will soon be a 'great all-rounder'. New licensing regulations will also be needed to govern the commercial use of gyrocopters, which DLR is developing on the basis of scientific analyses of their in-flight properties. Stefan Levedag, Director of the Institute, adds: "We have, by no means, fully explored the inherent potential of gyrocopter technology; we are excited and looking forward to a bright future with this flying miracle." ●

**More information:**
www.DLR.de/FT/en

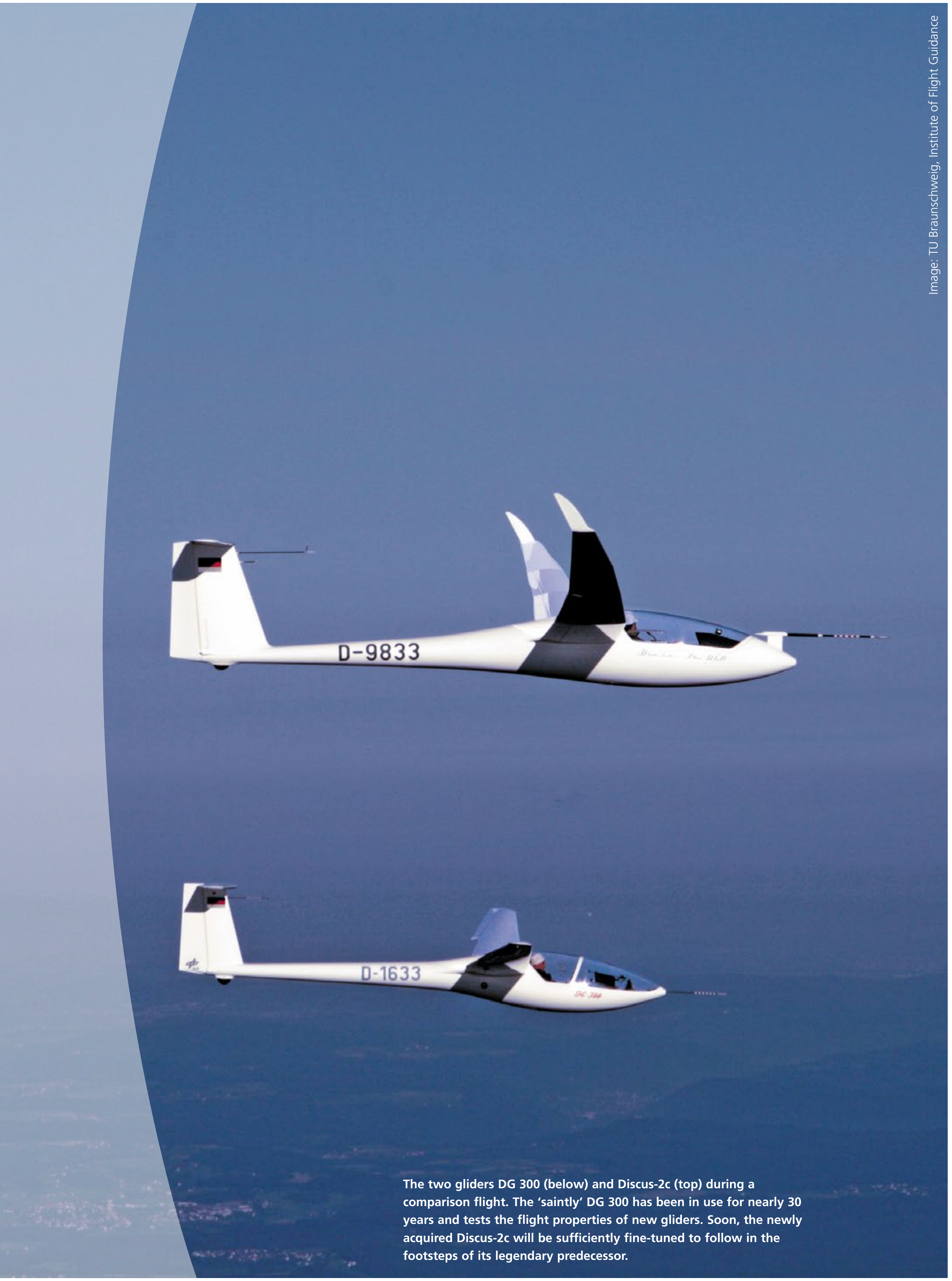



Image: TU Braunschweig, Institute of Flight Guidance

The two gliders DG 300 (below) and Discus-2c (top) during a comparison flight. The 'saintly' DG 300 has been in use for nearly 30 years and tests the flight properties of new gliders. Soon, the newly acquired Discus-2c will be sufficiently fine-tuned to follow in the footsteps of its legendary predecessor.

# A 'saintly' mission in the Nördlinger Ries

**Young aviation enthusiasts are building gliders, learning to fly them and preparing to become the aerodynamics researchers and aviation experts of tomorrow. At their summer camp, they had the support of two gliders and an aerotow plane from DLR.**

## The DG 300 and Discus-2c measure the properties of next-generation gliders

**By Falk Dambowsky**

**The student glider pilots carry out a variety of measurement projects. Threads and cameras on an aerofoil document flow separation (above). A probe on the aircraft wing is used to measure the angle of attack (bottom).**

From the air, the Nördlinger Ries district looks like a huge expanse of fields surrounded by a fringe of trees. From 1000 metres up you can barely see the trees that form the vast ring around the Ries. Right in the middle is the almost circular town of Nördlingen, with its red tiled roofs. A huge meteorite impact formed this landscape over 14 million years ago. This district, in Swabia, with its rolling hills and excellent thermals, is one of the most popular gliding areas in Europe.

As you cross over the wooded slopes of the ancient crater and fly westwards, the A7 motorway soon comes into sight, here running between Ulm and Würzburg. In front of it lies a narrow airstrip, in a much larger area of grassland and surrounding fields. As you make your approach, the flight path takes you directly over the motorway. On touchdown, you roll past dozens of glider trailers. Numerous hangars are filled to the brim. There are even small, powered aircraft packed close together and hanging from the roof, almost like items displayed in a museum.

Aalen-Elchingen airfield is a long-standing gliding Mecca. For 41 years, Idaflieg (Interessengemeinschaft deutscher akademischer Fliegergruppen; the Association of German Groups of Aerodynamics Students), an affiliation of the 10 groups of aerodynamics students (Akafliegs), has been hosting its three-week summer camp here. During this meeting, new gliders are tested exclusively by students, and complex measurement flights are conducted. Time and again, alumni come to the meeting, having been local aerodynamics students (Akaflieger) themselves, now working in aviation research, the aviation industry or national aviation bodies. They allow the young flyers to share their wealth of experience, offer advice, and help out as towing pilots for a few days. The support provided by DLR has been a part of this for almost as long as the traditional meeting.

Image: TU Braunschweig, Institute of Flight Guidance

Cockpit view of the Discus-2c

## Discus-2c and DG 300 – the two DLR gliders

The Discus-2c glider is a brand new member of the DLR research aircraft fleet. It will be used as the comparison aircraft of the future, to measure the gliding properties of new types of glider under development. The DG 300 has been fulfilling this task for almost 30 years. The new high-performance glider will answer questions concerning aeroelasticity. Stress measurement strips and fibre Bragg sensors are integrated into the wings and fuselage of the Discus-2c to measure distortion. An integrated enclosure in the fuselage enables a wide range of scientific applications for the research aircraft. The pointed mast on the nose carries a five hole probe for measuring the airspeed and angle of attack.

## Technical data

**Discus-2c DLR:**
Wingspan: 18 metres
Weight: approx. 290 kilograms
Maximum take-off weight: 565 kilograms
Maximum speed: 280 kilometres/hour

**DG 300-17:**
Wingspan: 17 metres
Weight: approx. 293 kilograms
Maximum take-off weight: 550 kilograms
Maximum speed: 270 kilometres/hour

The gliders line up – on peak days, more than 50 young pilots get together at the Idaflieg summer meeting on the Aalen-Elchingen airfield.

DLR staff member Johannes Anton is a seasoned former Akaflieger from Munich. Initially, the slender figure and unpretentious glasses appear almost unremarkable, but his powerful voice and clear pronunciation make him appear all the more self-assured. Anton completed his studies in mechatronics at the University of Munich a year or so ago and joined the DLR Flight Facility in Braunschweig. At the summer camp, his former Idaflieg classmates know him only as 'Pünktchen'. There is a tradition at the summer camps that everyone is given a nickname: "Mine was from 'Pünktchen and Anton', so there we are," says the 30-year-old.

At the DLR Flight Facility, he is now focusing on the collaboration between DLR and Idaflieg. DLR has two gliders, the DG 300 and the recently acquired Discus-2c. "We have brought both aircraft to the summer camp. They are used by the students as measurement aircraft." The DG 300 has been in use for almost 30 years and is known by the students as 'The Saint'. It is packed very carefully and kept in the hangar – the wings and fuselage are clothed in protective covers. "The DG 300 must not be scratched," reveals Anton during an inspection of the hangar. "This is because we use it as a reference aircraft." He pulls one of the covers back and brushes his hand over the smooth wing. "It's a bit like the standard metre – the DG 300 is the most precisely characterised glider in the world in terms of its flight characteristics, so it is something of a 'saint'." He grins. "We only ever use it for comparison flights early in the morning – the DG does this by flying with another glider in a shared parcel of air – only about one wingspan apart." Afterwards, the young researchers study the flight performance of the glider being tested so it can be precisely compared with the DG. "When we do this, we pay special attention to measuring the polar curves of new gliders, which compare sink rate with horizontal speed. This tells us how well a glider sustains flight or, alternatively, how much it descends in a section of the flight path," explains the enthusiastic small aircraft researcher. "We have to carry out at least three reference flights to measure the gliding properties of a new model."

Riding a bicycle on the airfield. This is where one can find George Mitscher, a test pilot at the DLR Flight Facility. He is wearing an aviator's cap and shorts – comfortable clothing for hot days at the airfield. He immediately welcomes you with a beaming smile. Normally, Mitscher flies the DLR Do 228-101 research aircraft from the DLR site, but for three weeks in August he has travelled to Aalen-Elchingen at the controls of 'Victor Echo', the four-seat DLR aerotow plane. Here, he is known as 'Schorsch'. The 30-year-old fits in well among the ranks of young flight enthusiasts; he joined DLR two years after completing a university degree in aerospace engineering. He learned his aeronautical skills as a glider pilot in the club before becoming a professional pilot.

"We flew in a dual formation from Braunschweig to the airfield at Aalen-Elchingen," Mitscher tells me in a break between two towing flights. As he does so, a group of Akafliegers push a glider that has just landed back over the grass to the take-off point. "We were able to use another aerotow plane that we have on loan to tow the DG 300 and the Discus-2c over Germany right next to each other, side by side," reports the DLR pilot. "It was good practice for the numerous towing manoeuvres I will have to fly here." He takes a drink from a water bottle. "The early morning comparison flights are especially nice. We take off in dual formation, the DG 300 on one tow line, a new model on the other, and climb up to 3000 metres above the often mist-covered landscape."

The DG 300 is still on this 'saintly' comparison mission, but in less than two years, if it has been sufficiently fine-tuned, the Discus-2c will be climbing into the early morning sky with the new prototypes to measure their flight performance. The DG 300 will then be able to have a well-deserved retirement.

Dual formation in the early morning: the glass canopy offers a fantastic panoramic view. Below and left or centre, the aerotow plane can be seen. The cockpit canopy reflects the light of the rising Sun. On the right, the second glider and its aerotow plane are visible.

After a weather briefing for the rest of the day, Kai Rohde-Brandenburger from the DLR Institute of Aerodynamics and Flow Technology reveals that the Discus-2c will be capable of doing something more: "A comprehensive set of measurement sensors was integrated into the glider when it was built. For example, we will be able to capture the smallest strains in the fuselage and wings."

The 30-year-old is a strong, friendly person, a real 'guy's guy'. Like his colleagues, he is lightly dressed for summer. You can immediately tell that he is a Braunschweig Akaflieger – on his T-shirt, 11 white glider silhouettes are arranged in a circle surround the lettering. He proudly points to it and says: "These prototypes were developed by the Braunschweig Akaflieg over the past 90 years." Underneath it is a silhouette with conspicuously large wings. "That is the SB10 from 1972, the largest glider in the world – with a 29-metre wingspan."

Student aerodynamics clubs have a long history in Germany, and are almost unique in the world. In 1918, after the First World War had been lost, aviation research in Germany was forbidden under the Treaty of Versailles. "But there was one exception," the Braunschweig researcher says. "Aircraft with no engine were not covered by the ban, so student gliding groups thrived and started a tradition that has been maintained until today."

In July this year, Rohde-Brandenburger moved from the Braunschweig Akaflieg to the DLR Institute of Aerodynamics and Flow Technology. Alongside Johannes Anton, who is a member of the DLR Flight Facility, maintaining contact with the aerodynamics students and supervising the gliders and small aircraft, Rohde-Brandenburger looks after scientific projects in this area. The engineer's work is focused on the DLR Discus-2c research glider. With gleaming eyes, he lists the capabilities of this unique aircraft, while he explains the displays in the cockpit: "There are acceleration sensors and magnetic field sensors on board. In the fuselage there is a large enclosure for a wide range of measurement instruments."

The researcher is particularly proud of the integrated fibre Bragg grating: "In this experiment, we send light of various wavelengths through the structure of the new research glider,

## Aerodynamics Student Flying Groups

Braunschweig, Munich and Berlin are just some of the cities in which academic trainees demonstrate their enthusiasm for gliding. In 'Akafliegs' (Akademische Fliegergruppen, or Aerodynamics Student Flying Groups), they learn all about this traditional sport and more – they fly, build and research gliders. Volunteers play a large part in this. Alumni who are now working in industry and research support the young aviation enthusiasts. DLR test pilots have also come from among their ranks. The summer camp held by Idaflieg (Interessengemeinschaft deutscher akademischer Fliegergruppen; the Amateur Association of German Groups of Aerodynamics Students) in Swabia is the annual high point in the lives of the student flight pioneers. This summer, DLR was there too, with an aerotow plane and two measurement gliders.

# Two new faces in small aircraft research at DLR

**Johannes Anton, DLR Flight Facility in Braunschweig**

Johannes Anton first climbed into a glider at the age of 14. His father, himself a glider pilot, had taken him to the local flying club in Erlangen. Several months later he was already being allowed to sit at the controls alone above the clouds. Youth gliding club and secondary school were followed by a degree in mechatronics at Munich University, where he soon became a member of the local student flying group. He took part in numerous projects with the group, including testing the Munich Schlacro-Mü30 motorised aerobatic aircraft. The enthusiast became increasingly interested in flying small aircraft in Idaflieg (the Amateur Association of German Groups of Aerodynamics Students). Since August 2012, Anton has been working for the DLR Flight Facility in Braunschweig. He is responsible for glider and small aircraft research and for coordinating the collaboration between DLR and Idaflieg.

**Kai Rohde-Brandenburger, DLR Institute of Aerodynamics and Flow Technology**

Kai Rohde-Brandenburger actually intended to use his degree in mechanical engineering from TU Braunschweig to follow in his father's footsteps and go into the automotive industry straight after graduation. But at university, he met a fellow student whom he followed into the workshop of Braunschweig Akaflieg, filled with curiosity. From then on, he could not leave flying alone and finally completed an engineering degree in the aerospace sector. For his degree and beyond, he carried out development work for the Braunschweig SB-14 glider, which was given new curved wing tips specifically as a result of his calculations. Since July 2013, Rohde-Brandenburger has been responsible for scientific leadership of glider and small aircraft research at the DLR Institute of Aerodynamics and Flow Technology, where he is in close contact with the managers of Idaflieg and the associated student flying groups.

DLR test pilot George Mitscher in the cockpit of the DLR aerotow plane 'Victor Eco'. Normally, Mitscher flies the DLR research aircraft Do228-101. For three weeks in August, he is a tow pilot at Aalen-Elchingen.

Community spirit is very important amongst the students – after landing, everyone lends a hand to push the glider back to the take-off position.

which is reflected according to the strain." He points to an almost nine-metre-long wing that ends in striking, raised winglets. "Together with the DLR Institute of Flight Systems, we want to use the Discus to investigate the possibilities of elastic aircraft."

Uncharted territory has never been a foreign phrase to the Braunschweig-born scientist. You can tell that he has experience in his field, and so he says of the responsibility that the flights in a prototype entail: "Occasionally, we practice parachuting from the cockpit at the summer camp," pointing to the slim blue backpack that every glider pilot carries like a thin cushion. "But not to worry, this is just a dry run on the ground, mainly involving getting the proper technique for climbing out."

Every evening, the participants at the summer camp, who number up to 50, convene in the restaurant at the airfield. From the terrace, they can enjoy a view across the green grassland of the airfield and, behind it, the Sun on the horizon. Before eating comes the daily debriefing, led by Anton Dilcher, chairman of Idaflieg. In the style of a student get-together, it is somewhat casual, but nonetheless purposeful. Dilcher, who has short hair, a beard and aviator sunglasses, is known as 'Mr Bean' in these circles. The 24-year-old has a slight English accent, which, together with his likeable sense of humour, has led to him being nicknamed after the English comedian. Anton Dilcher, or Mr Bean, originally came from Halifax in Canada. Five years ago, he came to Germany to study and joined the Akaflieg in Braunschweig.

"We have just been talking about the flights that took place today," the aerospace engineering student explains over chicken drumsticks and chips. "This time, many of the trainee pilots were concerned with 'Zachering'." This process, which goes back to aviation pioneer Hans Zacher, involves using simple tools to measure the flight properties of gliders that go beyond straightforward gliding. A stopwatch, a tape measure, a hand-held dynamometer and a somewhat unusual-sounding device called a 'PhiPsiTheta' are in the experimenting students' toolboxes. "We use the PhiPsiTheta to determine angular positions relative to the horizon," explains Dilcher, as chips are brought to the table. "To do this, you just need a hand-sized piece of transparent plastic on which to mark various angular positions with lines." This small device hangs in the cockpit, in the pilot's field of view. In the event of non-level flight, the pilot can then simply read off the angle to the horizon. Dilcher has an amazingly simple explanation for the device's curious name: "Phi, psi and theta are the three angles used in the coordinate system. These are angles we measure with the PhiPsiTheta."

In addition, the students are investigating the rudder effect and manoeuvrability when 'Zachering'. "We just need a hand-held dynamometer on the control column," the glider pilot says. At the end the flight, properties are painstakingly documented by the students in a Zacher log. There are also numerous special measurement projects for the ambitious trainee researchers. "For example, we can fit a probe on the wing of the glider that measures the angle of attack, or we can use filaments bonded to the wing surface and cameras to reveal flow separation."

Even after the evening meal, the participants all still have jobs to do – the flight logbooks must be filled in and the gliders put into the hangars. There are instructions regarding new gliders that are being brought to the meeting at short notice. "Community and community spirit are especially important to us at the Idaflieg summer camp," the chairman emphasises on the way to the hangars. "Everyone here at the airfield and in the camp site makes a personal contribution to the big picture." Some of the young aviation enthusiasts will surely belong to the next generation of aviation researchers – and some may even join DLR soon. ●

**More information:**
http://s.DLR.de/96cl



# Eight questions concerning gliding

**1. What is the minimum age at which a person can fly a glider?**

You are allowed to start training to become a glider pilot from the age of 15, even 14 with a special exemption. You can then receive your pilot's licence on your 16 birthday at the earliest.

**2. What altitude/speed can a glider reach?**

The normal range for a flight above land is an altitude of around 3000 metres and a speed of up to 180 kilometres per hour. In central Europe, the record distances travelled in a glider – depending on the category – are between 1500 and 2000 kilometres. The altitude world record is 15,447 metres, set by Steve Fossett and Einar Enevoldson in 30 August 2006 on a flight over the Argentine Andes along the Chilean border.

**3. How many gliding clubs are there in Germany?**

There are around 900 gliding clubs in Germany, run by the German Aeroclub. Fifteen of these are aerodynamics student groups, called Akafliegs.

**4. When was the first glider built?**

The first glider was also the first aircraft: the first glider flights go back to Otto Lilienthal in 1891, but Albrecht Ludwig Berblinger carried out the first short hops and flight tests in 1811.

**5. How popular is gliding?**

Worldwide, there are almost 120,000 active glider pilots, almost a third of which live in Germany (source: DAeC).

**6. What materials is a glider made of?**

Modern gliders are made almost exclusively of carbon fibre reinforced composites. This material enables low structural mass and large aerodynamic advantages in the structural shape.

**7. What is 'Zachering'?**

'Zachering' involves the investigation of the flight properties of gliders. It is named after Hans Zacher, who established pioneering processes during his time at the DFS (Deutsche Forschungsanstalt Segelflug; German Glider Research Institute, which later became the DFVLR, the German Research Institute for Aviation and Spaceflight).

**8. How long can a glider flight last?**

For as long as the Sun is shining and thermals are being produced, or the wind is blowing strongly enough for ridge lift to be generated on a mountain. A glider can only be flown during the daytime, so the maximum duration is from sunrise to sunset.

# Forced to vibrate

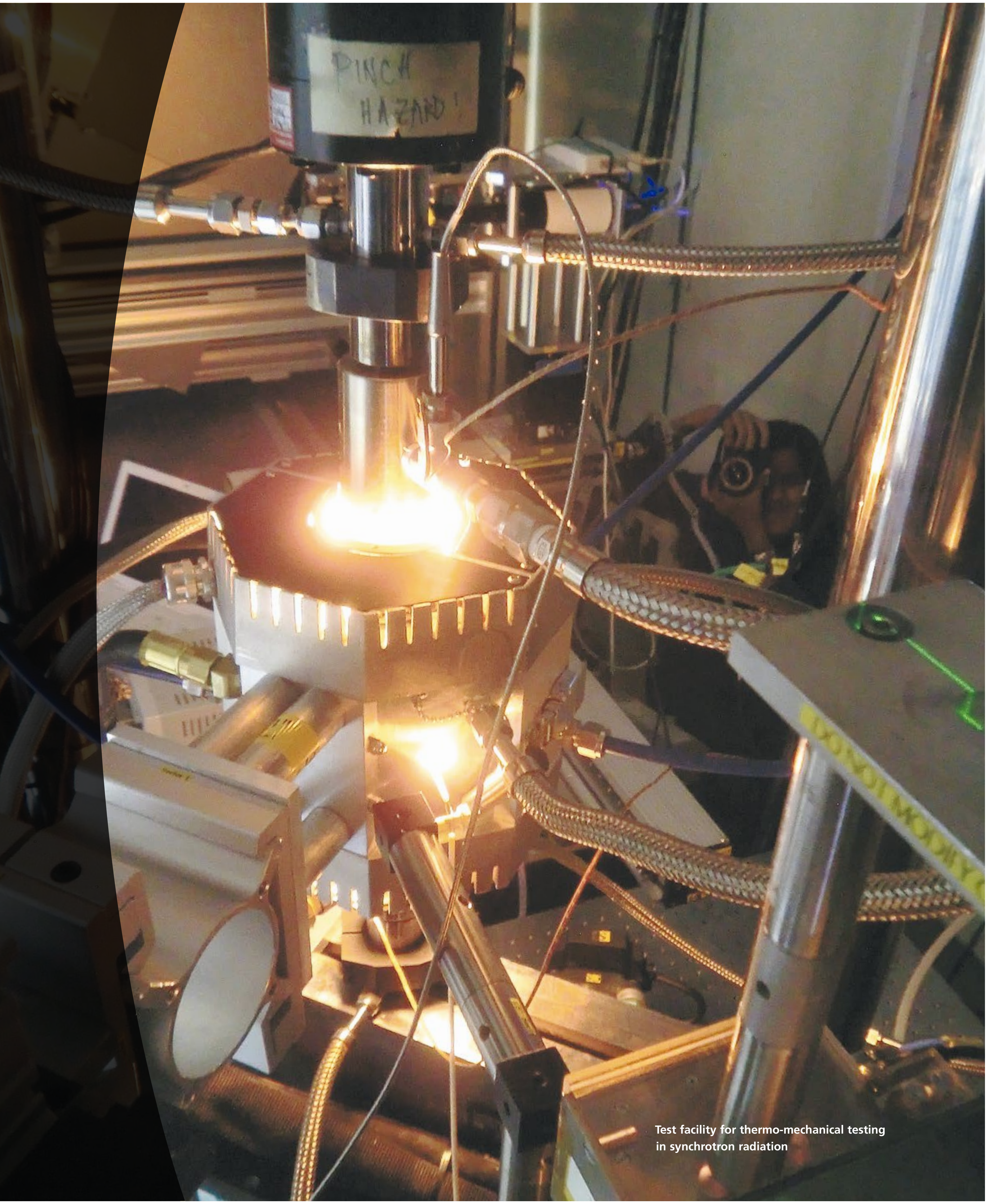
A ground vibration test is an important milestone in the final stages before a new aircraft type is approved. Its purpose is to reveal whether the first built sample of the aircraft will indeed behave in the way its engineers want it to and the simulation models predict. So engineers engage in a series of experiments to determine the prototype's actual vibration properties, hence permitting a mathematical description of vibration responses and providing validation of the simulation models the engineers applied. In turn, these validated models can deliver computational predictions of how the aircraft will respond in certain operating conditions, for instance when encountering a wind gust, if the pilot initiates abrupt flight manoeuvres or under shock loads when the undercarriage touches ground during landing.

The DLR Institute of Aeroelasticity in Göttingen is a world leader in the field of ground vibration tests. To meet the stringent requirements of the contracting entity, in this case Airbus, with regard to test duration, deployment of human resources and test equipment, the French Aerospace Lab ONERA requested DLR's cooperation to put the A350 XWB through its paces. The engineers installed 530 acceleration sensors throughout the machine to ensure precise detection of the complex, dynamic deformation.

Different states of vibration were deliberately induced at 25 points in the aircraft, while the 530 sensors measured how the aircraft responded to stimulated vibration. With the results from the ground vibration test, the experts reviewed the computational model of the A350 XWB. Subsequent aeroelastic analyses simulate how the vibration characteristics will change across different flight conditions. Flutter analysis is used to predict whether the surrounding flow field can induce vibration during flight. To get certification, it must be demonstrated that the A350 XWB possesses a sufficient margin with respect to any critical ranges of induced vibration (fluttering) across the entire flight envelope for which it was designed.

**More information:**
www.DLR.de/AE/en

Image: AIRBUS S.A.S. 2013 – photo by e*m company / A. Doumenjou



Test facility for thermo-mechanical testing in synchrotron radiation

# Watching strain with X-ray vision

**The best way to get between measuring stations is by bicycle. A complete circuit of the storage ring is over one kilometre long. Thirty-five stations are available for scientists to work with high-energy, or hard, X-rays, permitting unique images of technical materials and biological structures at the atomic dimension. Researchers granted measurement times here are the chosen few, and a team from the DLR Institute of Materials Research was among them. In cooperation with the University of Central Florida and the Argonne National Laboratory near Chicago it was analysed, using synchrotron radiation, what happens in very thin protective layers of turbine blades, which are under severe mechanical load and exposed to temperatures exceeding 1000 degrees Celsius.**

## Very thin layers under thermal mechanical load

**By Marion Bartsch and Janine Wischek**

Turbines in modern aircraft engines have to cope with extreme conditions. Combustion gases at temperatures of up to 1600 degrees Celsius enter the turbine, where they are guided by alternating rows of fixed and rotating turbine blades, driving the turbine and generating the aircraft thrust. The higher the turbine entrance temperature, the greater the thermal efficiency. Despite being made of high-strength nickel superalloys, the turbine blades are only able to withstand these temperatures because they are air cooled via internal labyrinthine ducts and protected by an insulating ceramic coating on the outside. The high temperature difference between the cool interior and hot exterior produces a complex multi-axial state of stress in the turbine blade wall. The rotor blades are exposed to centrifugal forces that cause the material to creep, elongating the turbine blades with exposure time. Furthermore, the alternating thermal and mechanical loads during aircraft take-off and landing also produce fatigue damages.


Team from the University of Central Florida together with Marion Bartsch, Carla Meid and Janine Wischek from DLR (from the right).

At the DLR Institute of Materials Research in Cologne, laboratory specimens are used to analyse these complex operating conditions in a specially developed test facility, allowing the reproduction of the thermo-mechanical fatigue stresses, a turbine blade and its protective coating are exposed to during flight. It is therefore to be expected that these laboratory tests will produce realistic damage. The purpose of this work is to estimate the service life and damage characteristics of the coated materials used in the aircraft turbines. If the protective coatings of turbine blades fail, the blades are at risk of breaking, which might lead to total engine breakdown.

### When the protective coating system fails

Protective coating systems in turbine blades typically fail by spalling. The transition between metal and ceramics is particularly at risk. The protective coating system consists of multiple layers, including an approximately 200-micron thick ceramic thermal barrier coating made of zirconium oxide above a roughly 100-micron thick metallic oxidation protection layer. The zirconium oxide layer is highly porous, designed to provide good thermal insulation. Its porosity renders it permeable to oxygen contained in the hot combustion gases. For this reason, an oxidation protection layer made of an aluminium-rich alloy is applied. A thin layer of aluminium oxide forms during coating and slows down any further oxidation. The aluminium oxide layer initially possesses a thickness of between 0.3 and 0.5 microns, but it grows during flight operations, producing mechanical stresses that ultimately cause the coating system to fail.

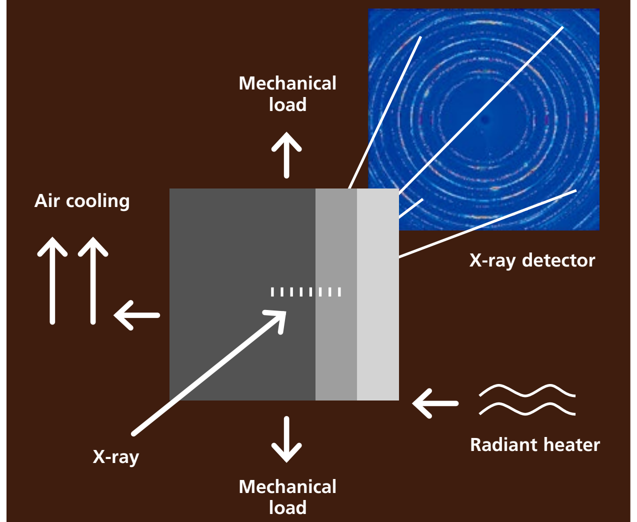
### At the boundary of the directly detectable

The damage that occurs in the test specimens after several hundred to a few thousand thermo-mechanical load cycles, particularly in the coating system, is examined microscopically after the test is completed. However, the precise genesis of the damage observed can only be explained once the local stresses and strains during the course of a load cycle are known. Calculations are used whenever direct measurements are not possible. To do this, a geometric model of the test specimen or a section of the coated specimen is created and converted into a numerical simulation model. This computer model is used to simulate the effects of thermo-mechanical loads.

Provided that the properties of the different materials of the coating system are known across the entire temperature range, the local stresses and strains in the material can be calculated. But a few unknown variables still remain in this calculation; a large number of material properties are not available, specifically for these thin layers with a thickness of just a few microns. Further, as the material is exposed to high temperatures and a rising number of load cycles, the properties of the layers change with time. Chasing down the unknowns in the system, we cooperated with a team under Anette Karlsson from the University of Delaware to initially estimate the unknown material data and then evaluate the calculated results with respect to the damage pattern observed under the microscope. Varying the material data, further calculations helped us determine the data yielding the greatest correspondence between the experiment and the results of our calculations. But although this provided us with a plausible set of data concerning the material properties in the layer materials, we had not yet, by means of measurement, obtained direct verification of the strain in the layer system when exposed to complex conditions.


**Aerial view of the synchrotron source in Argonne near Chicago**

## The principle of strain measurement with synchrotron radiation




**The X-rays are diffracted by the atoms of the coating material. A detector registers the diffracted X-rays. If thermal and/or mechanical loads strain the coating system, the atomic spacing changes – and with it the diffraction pattern.**

### An unexpected suggestion

The 35th International Conference of the American Ceramic Society in January 2011 in Daytona Beach brought an encounter that would help us move forward. Seetha Raghavan from the University of Central Florida in Orlando introduced to the discussion the synchrotron source at the Argonne National Laboratory and proposed that, there, we build a modified test facility, similar to the one already developed at DLR. The high-energy X-rays emitted by the synchrotron would enable us to penetrate the layers, and hence use the interactions between the radiation and the material to determine the strain, and thus the stress, in the individual layers. This was the missing link to validate our calculations with direct measurements.

After developing a preliminary concept for the new test facility, and once Seetha Raghavan achieved approval for measurement time for our project on the advanced photon source, APS, in Argonne, her postgraduate students Kevin Knipe and Albert Manero travelled to our institute in Cologne for two months in the summer of 2012, where we jointly designed the new facility. We essentially needed a compact furnace with high heating power and grips with ducts for efficient inner cooling suited to the tubular specimens. The furnace had to fit in an existing mechanical test machine at the Argonne National Laboratory and needed windows at the right positions to let the X-rays through. The entire test machine is mounted on electro motors, which are used to position the specimen to the fine X-ray beam with a precision of microns. During measurement, the beam penetrates the layer system and is diffracted. A detector registers the diffracted radiation, and the resulting pattern can be used to identify the materials, which are present.


**After many long-distance flights, sections of the white ceramic thermal barrier coating on the left blade have spalled.**



In principle, this works as follows: atoms in crystalline systems like those found in the coating systems are arranged in a three-dimensional regular lattice structure. Given that the lattice spacing is characteristic to individual materials, the diffraction patterns emerging from the interactions between X-rays and the crystalline planes are characteristic as well. The spacing between the crystalline planes change as thermal or mechanical stress deforms the material, and these changes correspond to the altered diffraction patterns. By reverse logic, the diffraction patterns tell us the extent to which the material is strained. So in terms of our layer system it means that we take the strains relating to different thermo-mechanical loading to identify the mechanical properties of the individual layers.

### Approaching the finish line

So, finally, the moment arrived in November 2012. The teams from Orlando and Cologne packed up the furnace components and the specimens coated in Cologne and set off for the Advanced Photon Source, APS, in Argonne. The APS is a particle accelerator, used to speed up electrons to almost the speed of light. Electro-magnets then compel them to follow a circular path in a ring-shaped, stainless steel tube – the storage ring – causing them to emit high-energy X-rays. The storage ring at APS has a circumference of 1104 metres; 35 laboratories, referred to as 'beam lines', are housed in the experiment hall, arranged around the ring. These beam lines divert some of the X-rays produced and use them for various test purposes.

Scientists at APS run the laboratories, cooperating with external users from all over the world to build experiments and test facilities and offering scientific support during the experiments. Use of the APS as well as the scientific support provided are almost priceless, but they cost us a thoroughly reasoned research application. The approved measurement times are therefore correspondingly valuable, and so initially we assembled the test setup in shifts operating around the clock and then proceeded to conduct our actual tests with as little interruption as possible. The yield at the end of four days of measurements was one hard disk containing a terabyte of raw data. Analysing it all will take a few months, but we can already confirm that the measurements were a success.

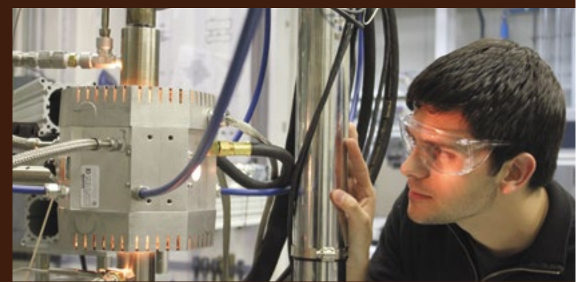
For instance, the thin aluminium oxide layer that forms between the ceramic thermal barrier coating and the metallic oxidation protection layer is visible in astonishing detail. The diffraction patterns also reveal that this layer is under mechanical strain and – something that surprised us – the crystallites that the layer consists of displays a clearly perceivable, preferred orientation. We have already presented the initial results at the 37th International Conference of the American Ceramic Society in Daytona Beach – the exact place where the whole cooperation began two years earlier. ●

**About the authors:**
Marion Bartsch is Head of the Experimental and Numerical Methods Department at the DLR Institute of Materials Research in Cologne. She is also Professor for Materials used in Aerospace at the Ruhr University in Bochum.
Janine Wischek is Head of the Mechanical Testing of Materials Group.

**The international team:**
Janine Wischek, Carla Meid, Marion Bartsch – Institute for Materials Research in Cologne; Anette Karlsson (now Cleveland State University); Kevin Knipe, Albert Manero, Sanna Siddiqui, Prof Seetha Raghavan – University of Central Florida in Orlando; Jonatan Almer, John Okazinski – Advanced Photon Source in the Argonne National Laboratory.

**A close-up of the specimen (white in the image)**

**Janine Wischek sets up the test system**



**Keeping an eye on the special furnace – Albert Manero from UCF**

**Kevin Knipe and Albert Manero during data acquisition**

**More information:**

www.DLR.de/WF/en
www.aps.anl.gov
http://mmae.ucf.edu/Faculty/Raghavan

# In brief

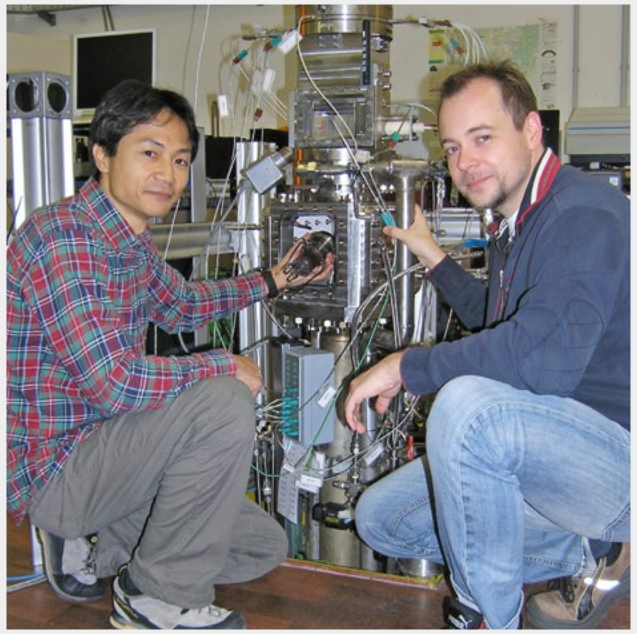
## German-Japanese collaboration for improved engine burner

**DLR and the Japanese Aerospace Exploration Agency JAXA have been collaborating in the area of aircraft engines since 2010. This collaboration has recently been extended for another three years.**

Determining the right proportion of air and fuel is one of the big challenges facing engine manufacturers. The ratio of the two components is critical to the stability and efficiency of the combustion as well as the amount of pollution produced. Fuel and air are mixed in the burner. Conventional burners are built in such a way that they ensure stable combustion under any operating conditions. This is because an aircraft engine is expected to function reliably under any circumstances. However, the functional range of an aircraft engine has to be very large. It includes rolling out onto the runway with low engine output; the take-off process requires maximum engine output. This involves a compromise in the burner design that has previously meant that better use of exhaust gases occasionally had to be sacrificed.

This is the issue now being addressed by JAXA and the DLR Institute of Propulsion Technology. The scientists are attempting to influence the distribution of air in such a way that the stabilisation limits for the combustion are extended. The scientists want to achieve this by discharging the air through small channels at specific points in the burner in a targeted manner. This process is known as fluid control and has the potential to make future generations of engine more effective and less pollutant.

www.DLR.de/AT/en



DLR engineer Denis Schneider and his Japanese colleague Seiji Yoshida have a common goal: that the burners of the engine will produce less exhaust fumes.

## :envihab opens its doors

This summer, :envihab was inaugurated at the DLR site in Cologne. Now, DLR scientists can offer international space agencies and universities a globally unique research facility. Human health is studied in its eight modules, which are spread over 3500 square metres, and include a centrifuge, a hypobaric chamber and a positron emission and magnetic resonance tomography unit. Another unique feature is the capacity to perform an ultrasound screening on a test subject during a session at the short-arm human centrifuge using a robotic arm. A one-of-a-kind combination of resources.

Here, the scientists will not only focus on the effects of living in space, but on life on Earth as well. For instance, the measures the scientists have developed to counteract the effects of weightlessness in space will also help with bone and muscle deterioration following a lengthy confinement to bed or in old age. To better understand these effects, a two-month bedrest study will soon be carried out in the Sleep and Physiology Laboratory at :envihab.

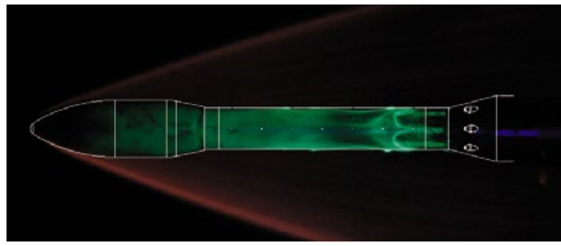
http://s.DLR.de/cu3z

:envihab will be open to visitors on 22 September 2013. The research facility serves as a communications centre as well.

## Vega rocket model in the wind tunnel in Cologne

The European carrier rocket Vega has already been launched to space twice to carry satellites to their destinations. At DLR, it has completed such a flight over 50 times – albeit as a miniature version in a wind tunnel. Seventy-five centimetres long and made of steel and titanium, the model is used by the DLR engineers to simulate the separation of the lower and upper stages in the hypersonic wind tunnel in Cologne. This is one of the most critical moments in such a flight, and staff in the Supersonic and Hypersonic Technology Department at the Institute of Aerodynamics and Flow Technology are aware of this.

Under contract to the European Space Agency, ESA, the engineers have been using the wind tunnel to investigate how the flow around the rocket varies during the stage separation. They have used a highly accurate set of instruments to measure the forces and momentum that affect the rocket during the stage separation. To make the change in flow along the rocket visible – it had previously only been calculated in computer models – they also put oils with different viscosities on the model throughout the measurement sequence, and recorded the changes in this film of oil. The most important finding was that the flow field around the rocket is disturbed enormously during the stage separations. Asymmetrical vortices are generated that separate the flow. The measurement data can now be used to better define the optimum time for stage separation.

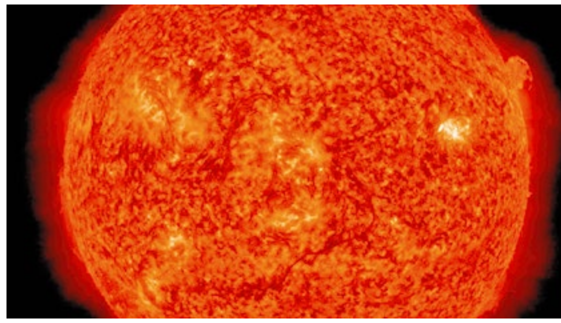


To record the variations in the air flow, engineers placed a film of oil on the model of the Vega rocket. The images show how the oil particles are distributed when subjected to various experimental conditions.

## Solar activity reduces radiation exposure in the air

When the surface of the Sun is covered in sunspots, the eruptions of material and solar wind blowing towards Earth are stronger. This has caused many people to wonder about the effect of radiation at aircraft cruising altitudes. Surprisingly, radiation exposure levels decrease. DLR scientists confirmed this in a measurement campaign in early summer 2013. Using the DLR Falcon research aircraft, they flew over Bavaria and southern Norway. The measurements showed that the exposure to radiation at cruising altitudes, when compared to similar measurements taken in late 2007 – close to solar minimum – was actually around 10 percent lower as a result of increased solar activity.

The Radiation Protection in Aviation working group at the DLR Institute of Aerospace Medicine in Cologne has been investigating this problem since 2004. The solar wind clearly does not contribute to the radiation field at cruising altitudes, as the radiation of particles from the Sun generally lacks the energy necessary to penetrate deep enough into the atmosphere. High-energy cosmic radiation, on the other hand, encounters various air molecules in the upper layers of the atmosphere, at an altitude of around 10 kilometres – high above normal flight corridors. This gives rise to secondary particles. The DLR scientists used detectors to study the interaction with matter.



The crew of the Falcon flight campaign confirmed: the solar wind does not contribute to the radiation field at cruising altitudes.

http://s.DLR.de/4093

## New DLR_School_Lab in Aachen

Learning while playing: the 'energy-smart' city.

The twelfth DLR School_Lab in Germany will be open to students at RWTH Aachen University as of the coming school year. The subjects range from the areas of aerospace, energy and transport research, with a special focus on robotics and artificial intelligence. An 'energy-intelligent' town will be controlled, a quadrocopter will be flown using bodily gestures, driver assistance systems will be tested, and industrial and humanoid robots programmed. One unique experiment is 'A Walk on Mars'. In the Holodeck in the laboratory, students can go on a virtual treasure hunt through Gale Crater on Mars.


# A family-run rocket business

**Over the last 45 years, the team at the mobile rocket base, MORABA, has launched more than 500 rockets and balloons around the world – sometimes in Norway, others in Australia, Antarctica or in Brazil. The campaigns in remote rocket launch sites generally last several weeks. "We are almost like a family – it wouldn't work otherwise," says Wolfgang Jung from MORABA, part of the Space Operations and Astronaut Training Department. This time, the 'family' has travelled to the rocket launch site in Esrange, located roughly 40 kilometres from Kiruna, Sweden's northernmost city. With the microgravity research rocket MAPHEUS-4, the DLR Institute of Materials Physics in Space expects to conduct two experiments in microgravity. But the mission will take a different turn…**

## The MORABA mobile rocket base is the 'flight ticket' to scientific experiments

**By Manuela Braun**

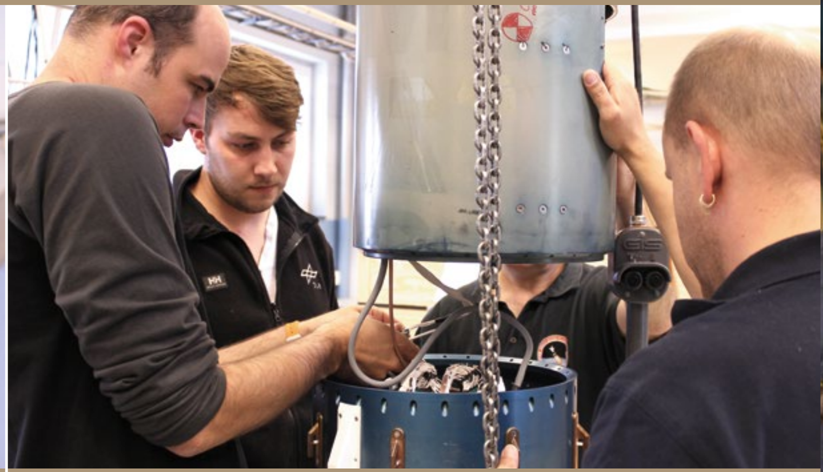

**At MORABA, safety comes first: the motor's igniter is blocked during preparations.**

**The traditional family portrait – the engineers from MORABA, scientists and Swedish colleagues strike a pose with the MAPHEUS-4 payload.**

The MORABA team has been at the rocket launch site in Esrange for several days now, but no one has put on the MAPHEUS-4 T-shirt yet. Nobody will until the payload and engine are ready. Superstition reigns, so although the mission emblems for MASER 12, MAPHEUS-3, REXUS/BEXUS and SHEFEX II are present at the 08:30 meeting with the Swedish colleagues, MAPHEUS-4 remains unseen. The mission is proving difficult. Already a few steps behind schedule, the experiments are proving a challenge. The MORABA team has no option but to wait while the scientists from the DLR Institute of Materials Physics work through strength-sapping night shifts.

Frank Scheuerpflug, responsible for the mission with MORABA, goes through the status checklist. "The rocket motor is complete," says Wolfgang Jung. "So is the recovery system," adds Marcus Hörschgen-Eggers. "We are still having a bit of trouble with the X ray tubes," explains Florian Kargl, Principal Investigator of MAPHEUS. Silence falls for a few moments. Some members of the MORABA team travelled directly from the launch of the WADIS rocket in Norway, and have been away from home for several weeks. A swift, uncomplicated launch would have been welcome, but life is not a box of chocolates and the complex payload needs another while before it is ready. This is the first time that an X-ray system will record the diffusion of molten material specimens during flight. "Ok, so we'll move the bench test to this afternoon," Scheuerpflug decides. Communication between the experiments and the MORABA service module must be spot-on, and the afternoon test is intended to put it through its paces. Until then, Florian Kargl, Jörg Drescher, Christian Neumann and Michael Balter will check the X-ray system software and conduct some final tests.

Johann Pfänder carefully tightens bolt after bolt. Here, precision is of utmost importance.



Making of a rocket: little by little, the individual elements are connected with the experiment modules.

### Meticulous and focused

In the meantime, Wolfgang Jung, Johann Pfänder and Alexander Kallenbach stow their mobile phones safely away in the wooden shelf at the door to the engine hall. The rocket motor is filled with solid propellant – any electrical discharge close by must be avoided as it could trigger premature ignition. Jackets, trousers, shoes – everything is antistatic; polyester is taboo. Wolfgang Jung holds his code card up to the reading device. Only members of the launch team responsible for the rocket motor have access to this room. A red strip of fabric dangles from the still-blocked igniter: 'Remove before flight'. The stabilising fins have already been fitted and it is now time for the adapter, used to connect the rocket motor with the payload.

Completely focused, Pfänder and Kallenbach get to work. Bolt after bolt is tightened to a precise torque. Twenty years ago, Pfänder was working with three colleagues on a launch pad when a test device accidently detonated the rocket. The rocket fired horizontally, skimmed along the launch rail and smashed into the building opposite. A Swedish colleague working in the narrow launcher building was struck by a fin and died. Pfänder came away with first- and second-degree burns and a broken kneecap. But he stayed at MORABA nevertheless. "You don't give up driving after a car accident." Pfänder only gets annoyed when high-risk tasks are pending and there are too many people standing around the colleagues as they work. "First of all, concentration can slip quite easily and, secondly, it puts more people at risk than necessary."

### Don't slip into routine!

The team's work is rarely without risk. "We are familiar with the risks and know how to deal with them," says Jung, Deputy Head of MORABA. "And we never slip into routine – it wouldn't be a good idea." Each mission is different; each combination of rocket, payload and recovery system is new. Even the sequence in which the rocket is prepared in the launcher for lift-off is discussed with everyone involved, each time anew. The team goes through each stage one last time on the white board. "New colleagues ask questions and those with experience must deal with it." MORABA engineers and technicians come from various disciplines: aeronautics and spaceflight, electrical and mechanical engineering, and physics. Although the Head of MORABA, Peter Turner, believes that each member should work in their specialist field, he is firmly convinced that: "They must all look beyond their own horizons and should be as versatile as possible." The team must function as a unit.

Jung knows his colleagues: "We MORABISTs are all a little bit maverick," he says with a chuckle. "But it works." Nicknames are commonplace. With two Marcus, the nicknames Hörschi and Pinzi have come into play; then there is a Hasi, an Andi and an Alex. The team members come from all over Germany – from Berlin and Hamburg down to Nuremberg, although Bavarians are now quite scarce. In the evening, the team gathers in the shared kitchen to prepare meals. A repurposed red cabbage jar stands on the table, black lettering in permanent marker declaring: 'Rocket Propellant'. Jung has prepared a fiery marinade for this evening's barbecue. The rocket business is always close by – even after office hours.

### The launch draws nearer

Several tests later, the time has come: "Everything fits, we can get started," Florian Kargl calls. The two experiments are finally running smoothly. Until now, the MORABA team had been on standby. Andreas Kimpe and Frank Hassenpflug took the opportunity to make some small adjustments to the five-metre telemetry antenna on the adjacent hilltop. The brackets used to move the rocket to the launch ramp have been carefully adjusted. The previously tranquil hall is now a teeming anthill. Tobias Ruhe moves the crane across various sections of the payload; Jürgen Knof, Marcus Hörschgen-Eggers and Philipp Koudele drive the tool truck to the centre. The nose tip, interstage ring, recovery system with parachute, service module – the metre-high tower that will later fly on the rocket almost 160 kilometres into the sky rises up in the hall. "Let it down! A bit to the right! It fits!" Command after command echoes through the building. At times, in the metal structure, up to eight hands grapple with the elements, pulling cables into place, holding bolts and fitting components.

MAPHEUS Project Manager Martin Siegl attaches labels. In an instant, the shimmering blue payload elements display the rocket's name. Siegl and Knof stroke the adhesive lettering until the last air bubble has disappeared. Finally, the rocket has a name – time for the mission shirts and the traditional group photo with the Swedish colleagues. Tomorrow, the rocket motor and payload will be driven to the launch ramp and assembled. The only steps remaining before the red launch button is pressed are the countdown test and the weather forecast.

### High-altitude flight ticket

MORABA issues 'flight tickets' for eight to 12 missions each year. Some of them are particularly memorable. "SHEFEX II, that was one of them," says Wolfgang Jung. He still gets goose

The rocket motor and payload are attached to the launch ramp. Wolfgang Jung (left) checks the connection to the ramp.

Before launch, Alexander Kallenbach lets the ballons rise so that the rocket's trajectory can be adapted to the prevailing weather conditions.

Last tests on the telemetry antenna: Andreas Kimpe and Frank Hassenpflug check the receiving system.


bumps at the thought. "It was extraordinarily complex, yet worked so perfectly." The experiment had risen into the skies with its sharp-angled tip one year before. "Moments like that make working at MORABA worthwhile." Missions under the midnight Sun or during the deep icy winter, months of preparation for Antarctic rocket launches or even birthdays spent with MORABA colleagues instead of back home with the family – field missions leave a mark. The rest of the time, the team works at DLR Oberpfaffenhofen – with the exception of the rocket motors, all flight systems, ground support systems and telemetry stations are developed there. "The development side of things has grown significantly," Turner emphasises. "Sometimes we are able to use components from our 'toolbox', but we frequently develop and qualify new systems for upcoming missions." This combination makes MORABA the only one of its kind in Europe, with clients that include DLR, the DLR Space Administration, as well as international space agencies and universities.

**The tension rises behind thick protective walls**

The alarm clock rings in the middle of the night of 15 July 2013 – the countdown will commence at 03:30. The test run was successful; the weather forecast for the morning hours is favourable. Alexander Kallenbach sends the first weather balloon up in the dark. Frank Scheuerpflug, responsible for flight control, sits at the console in the main building on the range. Frank Hassenpflug, Thomas Jahnke and Andreas Kimpe are seated in the mobile telemetry station. The rocket will be tracked along its flight path from here. "Take-off certainly sets your heart racing," says Andreas Kimpe. Markus Pinzer and Nils Höger sit behind thick protective walls in the control room that is located in the blockhouse, close to the launch ramp. Roughly two hours prior to take-off, only Wolfgang Jung, Johann Pfänder, Marcus Hörschgen-Eggers, Tobias Ruhe and Jürgen Knof will leave this protected space; they will prepare the igniters on the launch ramp for take-off. Large numbers on the screens count down the seconds to lift-off. The launch ramp now stands tall, pointing to the sky. At 07:00 the lines to the igniters are activated. The heavy steel doors are shut 15 minutes later. Take-off is tantalisingly close; the furnaces in the payload section now begin to heat the specimens at up to 900 degrees Celsius, to melt them completely. The final 10 minutes are here.

The air folds in on itself in the control room. Wind measurements could still put paid to the whole enterprise. A staccato "Go!" comes from the loudspeaker. Every station signals a green light. 10, 9, 8… The Swedish colleague lets his finger hang heavy over the launch button. He must keep it pressed for five long seconds for the computer system to trigger ignition. 3, 2, 1. A bass rumble swirls up from outside, rolling in on the building and the control room. 07:53 and MAPHEUS-4 has lifted off. But nobody speaks.

Everyone is crowded around the screen displaying the images from the camera in the recovery system. The rocket motor must first burn out, the payload stabilise in flight and then, suspended from its parachute, land safely – only then can they celebrate. The rocket motor slowly falls back above the blue planet while the payload continues to ascend into the sky. The experiment will be subjected to roughly four minutes of microgravity. "Told you!" Spellbound, all eyes are on the film. "What's that?" Tobias Ruhe stares at the camera images, horrified. "Damn it, the parachute is opening too soon…" But it doesn't open too soon – it actually doesn't open at all, it rips. The main parachute will thus no longer unfold. A single strap dangles back and forth in front of the camera lens. "Did the thermal shield open too early?" "What altitude are we at?" All of this is interspersed with the sound of Tobias Ruhe and Marcus Hörschgen-Eggers cursing under their breath. They all know by now that the sections containing the experiments will touch down at almost full speed. An appalled silence has replaced the



"Go" for the rocket launch: Andreas Kimpe receives data during the flight at DLR's telemetry station.

A rough landing: the payload was found on the marshy ground and cleaned. Fortunately, most of the data survived the impact.

joy of a successful launch. At this moment, it is not at all clear whether the mission will be successful at all. In the worst-case scenario, the payload will shatter on impact.

**A rough landing in the marsh**

The recovery helicopter sets off a short time later with members of MORABA and scientists. The data received has revealed the precise location of the since-landed payload. For half an hour they fly over trees, lichen, rocks and lakes before catching sight of the shimmering blue microgravity research rocket, impacted lengthwise in the soft morass of the marshy ground and shattered to pieces, now buried in the soil. Perplexed, Jörg Drescher and Christian Neumann from the team of scientists gaze at the remains of their experiment. Did the memory cards with the crucial images withstand impact? Or has all the data been lost? One by one, the team drags the dirt-encrusted pieces to the helicopter. On the way back, they see the orange rocket motor underneath the helicopter with its fins sticking out of the marsh. The burnt-out rocket has rammed itself into the ground almost vertically.

Esrange comes into view after just over half an hour in the air. The rest of the MORABA team is gathered at the helicopter-landing site. It takes five minutes to unload all of the pieces and drive them to the launcher hall. Cordless screwdrivers start to whir, and the pounding of hammers echoes through the room. A constant flow of clumps of earth falls from the experiments. Tobias Ruhe, Marcus Hörschgen-Eggers and Jürgen Knof take a look at the module with the failed recovery system. Screwdriver in hand, Florian Kargl is busy with a module one table down. "The camera is fine," he calls. Packed on three tables, everything that survived the rough fall is taken to pieces, one bit at a time. Although everyone has been up and about since 03:30, a break is completely out of the question. A few hours later, it is known that the vast majority of data has been recovered. Florian Kargl comes into the hall carrying his laptop, two pictures of the X-ray tubes visible on the screen. "Perfect images," he calls. "What more could you ask for? Great!" Finally the tension subsides. Science worked, and the data is available for analysis.

"We'll have to go back to the drawing board with the recovery system," says Tobias Ruhe, finally able to smile again. It appears that the heat around the rocket was so high that the thermal shield opened prematurely. A detailed analysis will be conducted at the Oberpfaffenhofen site. The recovery system for missions such as MAPHEUS will have to be replaced with a more powerful one. "We build prototypes," says Scheuerpflug. It is never routine. ●

**More information:**
**www.DLR.de/RB/en**

Holger Hennings has had a feel for wind and water since he was a child in Dithmarschen in northern Germany. Understanding wind energy turbines better and improving them is what still motivates the engineer.

# The man who set forth to capture the wind

**Holger Hennings was one of the first people to show an interest in wind power. He followed the failure of the large Growian science project and saw how wind power turbines went on to become a surprising success. Today, Hennings works at the DLR site in Göttingen, making wind power turbines safer and more efficient to operate.**

## Holger Hennings – a man with a feel for wind and science

**By Dorothee Bürkle**

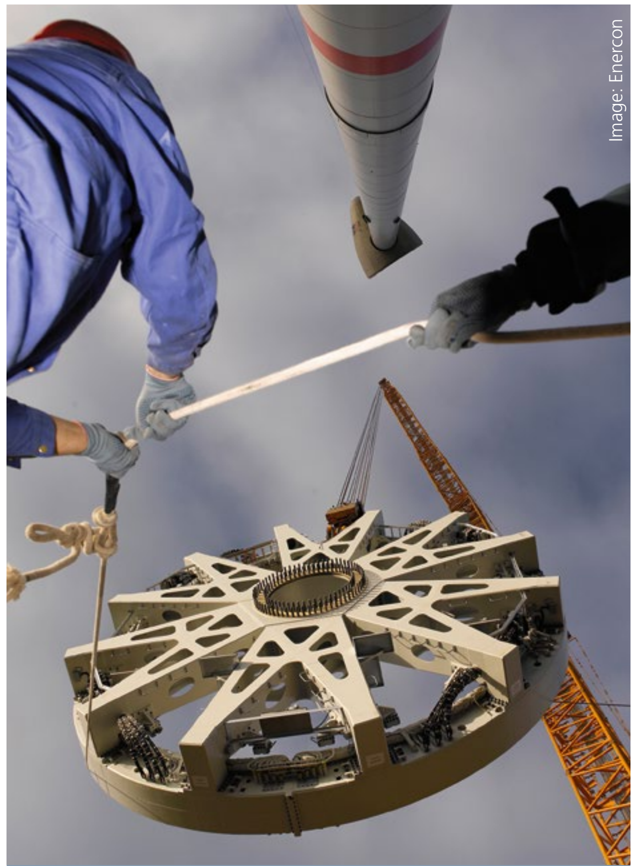


Image: Enercon

Mounting the stator on a wind energy turbine: today wind energy is an important pillar in energy generation – using hi-tech turbines from listed companies.

"I have had a feel for wind and water since I was a child. I grew up in Dithmarschen on the coast of the North Sea, 11 kilometres from the dyke." At first glance, Holger Hennings is a quiet, contemplative man, who likes the open, unbroken landscape of north Germany. From the age of nine he had the North Sea wind in his sails and has loved the interplay between wind and water. Generating electricity from power in the air caught his interest at 14. During a holiday on Sylt in 1976, he discovered aircraft construction engineer Hans-Dietrich Goslich's pioneering equipment. "That was the spark – a unit with a counter-rotating rotor – still a technical challenge today," recalls the qualified mechanical engineer with accuracy. Hennings sought out literature on wind power turbines and devoured the few books available at the time on the subject of renewable energies.

### Pioneer spirit and shattered dreams

At the same time – at the end of the seventies – scientists at the research centre in Jülich were planning the construction of Growian (GRoss-WIndANlage), the large wind turbine, under the leadership of the German Federal Ministry of Research – a response to the oil price shock in the early 1970s. In 1983, at the Kaiser-Wilhelm-Koog in Dithmarschen, with its 100.4-metre-diameter rotor and three megawatt nominal output, Growian was the largest wind energy facility in operation in the world. However, it was very soon apparent that a facility of this size could not be controlled using the technology of the day. Growian did not once achieve sustained test operation and was ultimately more of an argument against the use of wind energy.

But not all the pioneers or those involved were discouraged, recalls Hennings. At that time, a couple of mechanical engineering companies were manufacturing wind energy turbines in manageable dimensions, including MAN (Maschinenfabrik Augsburg-Nürnberg). In parallel with Growian, the company was developing AeroMAN, a significantly smaller machine with a rotor diameter of 12 metres, of which several hundred examples had been built worldwide and were being operated successfully.

**Advanced training in wind energy in 1984: seminar participants in Vlotho test a converted light flux machine.**

## History of DLR wind energy research

**1959** Professor Ulrich Hütter becomes head of the newly founded Department of Applied Flight Physics at the German Research Institute for Aviation and Space Flight (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt; DFVLR) The father of modern wind turbines, Hütter had previously constructed wind power turbines for Swabian company Allgaier. Under his leadership the first German test field for wind turbines was established in the Swabian Alps in 1956.

**1974** Following the oil price shock, Hütter was commissioned by the Federal German Government to sound out the potential of wind power.

**1990** DLR terminates its activities in wind energy research at the Stuttgart site. This research was due to be extended to other facilities in northern Germany, including the Kaiser-Wilhelm-Koog near Marne, site of the large Growian wind turbine.

**2012** DLR begins collaborating with IWES and Forwind; the Merwind research project starts.

**2013** Start of the Smart Blade research project


Image: Jan Oelker

**Wind power turbine DEBRA 25 in the Ulrich Hütter test field in Stötten/Schnittlingen. It was assembled and erected on 13 July 1984.**

By the time he left school at 18 and was training to be a machine fitter, Hennings was part of a small group of wind power enthusiasts. "They were pioneers, and numerous experiments were conducted." This circle was very straightforward at the time; you could become personally acquainted with the 10 facilities that were then in operation in Germany. "Wind energy projects were being operated in a niche, and many of their supporters came from the ecology scene." Hennings describes the feeling among the wind pioneers as a cautious spirit of optimism: "All those involved were sure that significant amounts of power could be generated with wind. On the grid operator side, however, there were concerns that instabilities could occur if as much as three percent wind energy was fed into the network."

Hennings followed developments closely. In 1983, a farmer in Cecilienkoog in North Frisia purchased a facility belonging to Danish wind power turbine manufacturer Vesta and became the first private producer of wind energy to feed into the Schleswig-Holstein network. It was a milestone. "Of course, in the 1980s, it wasn't at all obvious to those involved that there would be the kind of explosive development that we have seen since then."

Holger Hennings studied mechanical engineering at the TU Braunschweig and attended a lecture on aeroelasticity by professor Försching from DLR Göttingen. By 1990, he had completed his thesis on the subject of vibration in wind power facilities at the Institute of Aeroelasticity. In doing so, he spent four months in the university city at DLR. As rooms there are hard to come by, DLR offers its graduates accommodation on the DLR campus itself, with the 'tower room' on the first floor, the shower in the cellar, and the toilet in the hallway. Hennings enjoyed the freedom that the research and the proximity to his place of work offered. "It was the most efficient period of my life. It was really interesting to get so much motivation and help from experienced scientists. I applied new computer processes in fluctuation science involving data from wind facilities that I had previously only approximately understood in theory."

At the same time, DLR terminated its involvement in wind energy research. Nevertheless, Hennings decided to stay at DLR Göttingen and continue working on aeroelasticity, where he was part of the group investigating the aeroelasticity of turbo machines. After gaining a doctorate in the field, he later held the position of Head of Department of aeroelastic experiments at the Institute and, since 2012, Head of Department of Aeroelastic Simulation.

"I have learnt a great deal about structural dynamics, unsteady aerodynamics and aeroelasticity, and how to model them, and I have continually received new input from experienced colleagues," he says, looking back on his two decades at DLR. He wants to pass on this experience of intensive exchange to his younger colleagues and enjoys the culture of debate that has been established in front of the blackboard and around the tables in the coffee kitchen. His family – his wife and three daughters – also make him happy. Like him, they find the environment in Göttingen ideal to live in.

Holger Hennings has continued to follow events in wind energy and travels to meetings and conferences in his spare time. In 1990, three years after the demolition of Growian, there was a lively debate in the wind energy community about a law on the sale of electricity to the grid. This was passed in the same year by the Federal German Government of the day, and came into force on 1 January 1991. "This law, which was a forerunner of the Renewable Energies Act, meant guaranteed current pick-up for a set price for operators of wind power turbines for the first time. This was the critical breakthrough," recalls Hennings. The energy suppliers had to pay 16.61 pfennigs for each kilowatt hour of wind power fed in. Investors and entrepreneurs in the



**Debate culture at the Institute of Aeroelasticity: Holger Hennings places great store on intensive exchanges with younger colleagues.**

wind energy sector finally achieved a degree of planning certainty with this law. Among these was Aloys Wobben, who had started to construct wind facilities in 1984, working part-time in his garage. Today, the company he founded, Enercon, is among the top five in the world with a turnover in the range of billions.

### Expertise from aviation for wind energy projects

Nowadays, wind energy provides over 10 percent of the net energy consumed in Germany, and Holger Hennings is now attending meetings and conferences in a professional capacity. In 2012, DLR started researching wind energy once again. The Institute and Holger Hennings' department are involved in these research projects, because scientists can transfer a great deal of knowledge from aviation research to wind energy research in the field of aeroelasticity. At the age of 50, Hennings still wants to be a wind energy researcher. "What is different for us about this research area, and what also makes it attractive to collaborative partners, is our expertise and the useful tools from aviation."

In a video from 1987 that focused on lightweight turbines and left an impression on him, Holger Hennings remembers how important a profound understanding of aeroelasticity is. At first, the facility runs smoothly and you can see how the rotor is turning. But then one rotor blade in the unit fails between one frame and the next. "At the time, this meant that the turbine had a stability problem. When I look at the video today, it's obvious: it was flutter. But clearly, that was still not properly understood at the time."

Understanding and improving are what motivates the engineer in wind energy research and in aviation. As head of the department of aeroelastic simulation, Hennings mainly investigates flutter in helicopter rotors. Flutter is a mechanism whereby blade vibration is increased by movement-induced aerodynamic forces; in extreme cases, so much so that the rotor blade breaks. With his experience of helicopter rotors, the engineer can now simulate the vibration behaviour of large rotor blades. "In today's wind turbines, a rotor blade breakage through flutter is impossible. But the trend is towards larger, leaner turbines. With these, the manufacturers must take into account that such phenomena will start occurring again." In his field of aeroelasticity, Hennings is investigating how a rotor blade vibrates both experimentally and digitally. As an aerodynamicist, he also observes which aerodynamic movements are induced through the rotor blade. "In order to understand flutter correctly, you need precise knowledge of the complex processes of structural dynamics and aerodynamics. If we want to prevent the occurrence of flutter, we need to change at least one of the two complex processes on the rotor blade."

In Hennings' opinion, the turbine manufacturers are not far from the ideal rotor blade. Like most experts, he believes that rotor blades will be lighter and be able to use active elements to adapt to the wind in future. "However, active elements in the rotor blade also mean more maintenance work, and they do not reduce the risk of flutter," he warns. He still sees a need for a great deal more research here.

"Perhaps I've missed a trick, especially when you see how companies of pioneering individuals always become bigger and better," says Hennings retrospectively. As an engineer, he is an analytical person and has already considered this: "But it's not a major problem for me. In my field I've worked with many inspiring scientists and have been able to introduce new approaches and implement ideas of my own." And now he can pass on his experience and knowledge to an inquisitive and receptive new environment. ●

**More information:**

http://s.DLR.de/4gz3

http://s.DLR.de/88rg


Over one million people live in N'Djamena and move through its streets. There are hardly any local public transport systems directly supported by the city or the state.

# Transport research in the desert sand

**Chad – a country in the heart of Africa, home to nearly 10 million people. To the north, it is bordered by the extreme aridness of the Sahara desert, while the south is densely covered in forests. One of the poorest countries in the world, Chad has no railway system, and the entire network of paved roads totals just 270 kilometres – the length of the A14 motorway connecting Potsdam and Hamburg. The contrast could hardly be greater. Nevertheless, Chad has attracted the interest of DLR transport researchers. In February 2013, Berlin-based transport researchers visited N'Djamena, its capital city, as part of their scientific activities.**

**Melanie-Konstanze Wiese interviews Barbara Lenz, Head of the DLR Institute of Transport Research, about a very different type of mobility.**

**What makes the transport system in Chad so scientifically appealing?**

As transport researchers, we are of course not only interested in how the transport system in Germany is shaped and will develop in the future. Here, we have a tightly knit network of various means of public transport. So we switch quite naturally between them, taking the train to work, going shopping by car, and taking a taxi home after an evening out. In countries like Chad things are very different; the only regular bus services available are for inter-city traffic. Within cities, minibuses and motorcycle taxis are operated by small private businesses, and there are no fixed prices or consistent timetables. What would seem like an adventure to us is established everyday practice there, and it works. Transport research is interested in describing every facet of transportation. We want to know how a system relying almost exclusively on informal options functions. What dependencies arise as a result of this?

## Mobility in rapidly growing cities

As with many other cities in sub-Saharan Africa, the population in N'Djamena has increased rapidly in recent years. While in 1960 there were no cities of over one million inhabitants, by the mid-1990s there were already some 100 cities with 100,000 or more inhabitants. Today a number of cities are home to several million people, including Lagos, Abidjan, Dakar, Nairobi and Douala. As a result of this fast growth, the metropolitan areas have been constantly expanding as well. Local public transport systems are insufficient, so significant accessibility problems are arising for the population in newly developing suburbs. Not least, the lack of public transport services and the large distances within the cities means that access to work, education and healthcare is made more difficult or even impossible for inhabitants of the peripheral neighbourhoods.

**This transport situation is also present in other countries in Africa and South America. How did this country come to be chosen?**

Coincidence played a part. A colleague from Chad worked with us in Berlin. He was our initial contact with the Department of Geography at the University of N'Djamena. We had almost a year of exchanges with colleagues there via telephone and email. In February, it was time to establish personal contact and intensify the collaboration.

**What did you experience and learn during your stay in Chad?**

Our hosts at the University received us very warmly and introduced us to leading personnel, such as the President and Dean of the University, as well as important administrative figures. We were able to get a picture of the sometimes-difficult working conditions of the researchers and of various efforts in the country to improve the living conditions of the population. Naturally, we also discussed the large number of traffic accidents – one of the biggest problems of transport in the city. Vulnerable road users, such as pedestrians and motorcyclists, are especially at risk here.

**What comes next?**

We are just at the beginning. We have made contact with local scientists and have an initial picture of the transport scene in N'Djamena. In future, one of the things we want to do is establish a mutual student exchange programme. It would be a very positive thing that would benefit both institutions; there is a lot we can learn from one another. For the DLR Institute, this will offer the opportunity to address international issues and enhance the existing expertise. ●

**More information:**
www.DLR.de/VF/en/

At the MoSAIC laboratory of DLR Braunschweig, test drivers steer cars through a shared virtual landscape.

# Please change lanes now

**Driver assistance systems can do more than just inform, warn or intervene – they can also cooperate with other cars. Such cooperative assistance systems are the subject of research in the new MoSAIC Laboratory at the DLR Institute of Transportation Systems in Braunschweig.**

## MoSAIC – a modular and scalable application platform for driver assistance systems

**By Julia Förster**

At first glance, it looks like an Arcade racing game: test drivers are seated in the driving simulators at the MoSAIC Laboratory, steering their cars through a shared virtual landscape. The feeling, Gerald Temme confirms, is not dissimilar to interactive video games – but the purpose of the laboratory is, of course, entirely different. The laboratory driving simulators do not place much emphasis on brilliant graphic renditions, but are more concerned with traffic jams at the right time and realistic driver behaviour. The test drivers are also less prone to spontaneous bursts of racing fever; they are behind the wheel to conduct transport research. Their behaviour will be incorporated in the development of future driver assistance systems.

The pivotal question that Gerald Temme, developer and manager of the laboratory, poses together with his colleagues from the fields of engineering, computer science, psychology and ergonomics is not 'who's fastest?', but rather 'how and when do drivers cooperate?' Temme describes a situation that most of us are familiar with: "You're driving down the slow lane of the motorway, completely relaxed, and you see a lorry far ahead. The overtaking lane is fully occupied". In the simulation, the assistance system recognises this situation and it asks whether it should create a gap. If you reply in the affirmative, it looks for someone in the overtaking lane who would just have to decelerate for a moment so that you can change lanes without obstructing the flow of traffic. "The assistance system in the other vehicle receives the query and enlarges the gap if the driver consents. Our assistance system then gets back to us with the report: "There is space for your vehicle; please change lanes now." This is the scenario considered in the European research project D3CoS, in which the Braunschweig-based Institute is putting the 'cooperative lane change assistant' through its paces.

The MoSAIC Laboratory has offered this possibility since 2012. Its three networked driving simulators are available, in particular, for studies relating to the socio-psychological aspects of structured interaction – those that tackle the question of whether drivers display greater willingness to allow others to switch lanes if they are asked directly. "Our MoSAIC software opens up completely new possibilities. Before MoSAIC, we would simulate behaviour of one participant and then on the other. But our test candidates behave differently now that they know that real people are in the other vehicles. They even flash their lights."

Another project that the Institute is involved in is UR:BAN. Among other things, it is investigating driver assistance systems in urban traffic. Suppose that intelligent traffic lights inform vehicles fitted with a suitable assistance system, and still at some distance from the lights, that if they proceed at a speed of 30 kilometres per hour, they will arrive at the signals during a green phase; further assume that these cars decelerate from that point. What happens to the flow of traffic? Will it change positively or perhaps negatively? This is the type of situation simulated in the MoSAIC Laboratory before research is carried out using real vehicles; in Braunschweig, for instance, the 'Application Platform Intelligent Mobility (AIM)' offers opportunities to test this.

The transportation of tomorrow needs to be safe, low-emission, energy-efficient, comfortable and free flowing. Assistance systems can contribute to all of these goals. But people have to want them, and sometimes it is mere details that help their acceptance: "It could even be the mere option of switching off a function," says Temme. But he is not overly concerned about the future of cooperation between mankind and machines in the long-term: "Cars will ease the burden on drivers by providing support or perhaps even taking over in certain traffic situations, tailored to suit the individual needs," he explains, adding: "What's important is that the driver and the vehicles understand and trust each other." ●

**About the author:**
Julia Forster, a physicist and journalist, has been working as a freelance science journalist for 15 years. She is currently based in Hannover.

**More information:**
www.DLR.de/TS/en/

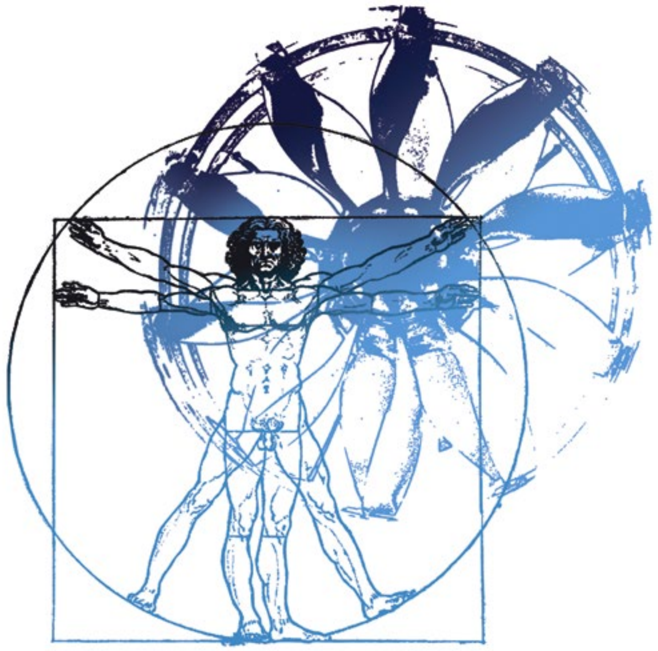

Leaping with excitement after a great day at the DLR_School_Lab

# Why the apple falls and the Grätzel cell provides electricity

**'Out of school and into the lab' has been the call to students from around Berlin, Cologne and Oberpfaffenhofen for 10 years now. The instructors at these three DLR_School_Labs do all they can to impart knowledge and excitement to the children by exposing them directly to science, and they have elicited many a hidden talent from the visiting groups of young researchers. Each DLR_School_Lab focuses on a specific theme that children can experiment with and hence gain new insights. The DLR Magazine visited these three School_Labs on the occasion of their tenth birthday.**

## This year, three of 12 DLR_School_Labs turn 10.

**By Sarah Lange**



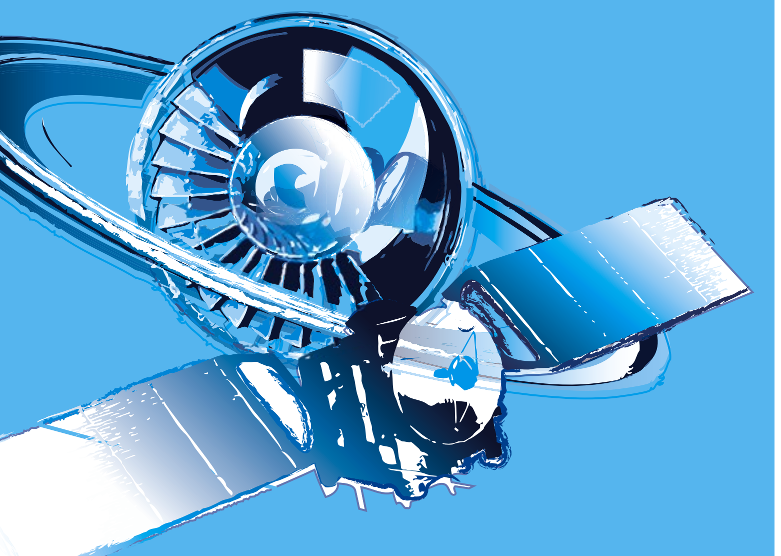
### Weightless in Cologne

Jan-Niklas gazes avidly at the screen, his eyes tracking a full glass of water as it hurtles down the miniature drop tower. Along a free fall stretch of 2 metres, 0.6 seconds of weightlessness are achieved. In addition to water, the glass contains air, so a bubble should form in its centre during free fall. But a squirt of detergent destroys the magic – the air stays on top and the water below, as the detergent reduces the water's surface tension. A video system records the events in slow motion, allowing everyone to see what is happening. The 15-year-old grabs his pen, and begins to scribble his observations. His classmates are just as captivated by the experiment dealing with weightlessness. Questions follow. What is weightlessness, actually? And what is gravity? Why does an apple fall to the ground on Earth yet simply floats away when released by an astronaut on the International Space Station? The children are not short of questions to ask the instructors, but the answers all come, and fast, in the practical demonstrations. It turns out that gravitational force determines the orbits of the planets as well as the structure of the Universe. And soon the students realise that investigating weightlessness will give them clues about life here on our planet.

Jan-Niklas and more than 20 of his second-year classmates from Martin Butzer Grammar School are here at the DLR_School_Lab in Cologne for the day. After a brief stroll, from the entrance gates to the building that houses the School_Lab, the children take a seat in front of the small stage where Richard Bräucker, Head of the DLR_School_Lab, stands and welcomes his visitors. The students are then divided into three groups, and the young scientists immediately begin discussing the experiment 'Mission to Mars'.

The balloon is sprayed with cold water. Using the thermal imaging camera, Jan-Niklas can then reveal how the energy is distributed over the surface.

Wearing 3D glasses, the students at the DLR_School_Lab in Cologne marvel at the size of Mars in a computer simulation.



In recent decades, numerous spacecraft have orbited Mars, transmitting images of the planet's surface back to Earth. Today, we are able to purchase Mars globes, similar to those of Earth. But observation from lofty heights has its limits. For this reason, the Mars rovers were sent to the surface. The most recent one, Curiosity, was sent in August 2012 and is the largest so far. Over the course of the eventful day, the students learn how the robots are controlled – and it's not that easy! This experiment replicates the rover's movement across the Martian surface to help the boys and girls relate to what it is like controlling the vehicle in uncharted terrain. "I want to go first," Jan-Niklas calls. But, before he can take control of the rover, he has to calculate the turns and the route. The vehicle will not begin moving until this is complete, and even then it will move with a delay. "It is amazing all the things you need to be aware of to drive on Mars. Not an easy task," Jan-Niklas realises. "I'm going to become a pilot. A DLR pilot," he adds with an air of conviction.

**Mobile in Berlin**

The Solar System is also a topic covered at the DLR site in Berlin. But here, the focus is on developing the required optical sensors to facilitate scientific analyses on the formation and evolution of Mars and other celestial bodies that will, in turn, improve our understanding of Earth. In addition to planetary research, DLR Berlin places great emphasis on the study of traffic. Solving everyday issues such as congestion or the best use of various means of transport of people and goods are in the spotlight to keep things running smoothly in the future.

The students ask each other: "How do you get to school?" Some respond that they cycle, while others travel by public transport, and a few even go to school on their skateboards. The experiment 'Youth Mobility' helps students at the Käthe Kollwitz Secondary School Prenzlauer see everyday issues from an entirely new perspective: "What is traffic? What do we transport in traffic? What paths can traffic research take?" Each student completes a questionnaire. By the end, many of them have seen the light: traffic research can contribute to improved mobility.

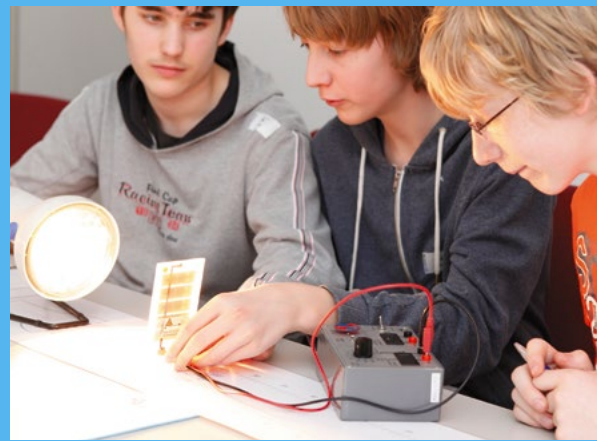


Enough theory – it's now time to get to work, hands on. The students are asked to construct a Grätzel cell; to do this, they take a seat around a large, round table. Nguyen Hoang Thanh Loc, aged 14, asks: "What is a Grätzel cell, anyway?" To explain, the instructor gives an example. Almost everyone has seen a solar power cell: glinting in the Sun, they cover entire roofs and smaller areas of land. Although their production is a technical feat, today the students will learn how to construct this kind of solar cell using nothing but everyday household items. For this, they need duct tape, a hair dryer, clips, a hot plate, titanium dioxide (found in toothpaste, for example) and a few other things. First, the students mix the titanium dioxide solution and apply it to small, thin slides of glass. A thin layer of graphite is then added to the conductive surface, followed by the dye. The students are so concentrated you can hear a pin drop in the room. The strips of glass are then coated with an electrolyte solution to enable the flow of electricity. Finally, the children stack the glass slides and fix two clips to the Grätzel cell to keep it together. "All done," Nguyen calls. "This is fun! It's a shame we don't get marked," he adds cheekily. His Grätzel cell now produces electricity. "I had no idea you could produce electricity this way with a solar cell," he adds.

More than a few jaws drop during the third experiment. A small group gathers around the two instructors. The energy provided by their newly constructed solar cell varies – as if by magic, the light dims or brightens, depending on the distance between the solar cell and the light source. The lights in the room are switched off and miniature lamps switched on. "That's spooky," one of the girls whispers, as she holds on to the student next to her. The students gingerly connect their solar cells to the measuring device and position them on the measurement section. Now, they can read the intensity of the current and measure the distance. The school teacher enters the room: "Just checking up on you," he says, as he grins. No one hears him. One of the girls notices him and says: "I never understood this in class, but now that I've done it myself, I get it. I guess you could call that a sense of achievement."

**Researching and learning at DLR**

The German Aerospace Center is one of Europe's largest and most modern research institutions. Here, the aircraft of tomorrow are being developed, pilots are trained, rocket engines tested and images of far-away planets analysed. High-speed trains are put through their paces, eco-friendly methods to produce energy are being devised and much, much more. The social impact of these projects is immense, and they are very appealing to students. The DLR_School_Labs were specifically established to provide school-age students with insight into what DLR is about, and to promote their interest in the natural sciences.



Brighter or darker? It's all a matter of distance. The students understand this while performing a solar cell experiment at the Berlin DLR_School_Lab.

Revealing the secret of the Grätzel cell – Nguyen takes a few drops of titanium dioxide solution and applies them to small thin glass slides. A flow of current is established between the joined glass slides.

Annika was fascinated by the robot kit activity. At last, they can drive their robotic car.

In addition to the robotics experiments, students are also captivated by the infrared experiment at the DLR_School_Lab in Oberpfaffenhofen.

## On the road with robots in Oberpfaffenhofen

The DLR_School_Lab in Oberpfaffenhofen is known for its exciting experiments in infrared, laser and radar measurement technology, environmental surveying, satellite data analysis, weather and climate studies, planning research flights, robotics and simulation. In the laboratory, the students have access to high-tech instruments such as sensors, a robot, archives of satellite data and professional simulation and analysis programs. Dieter Herr Hausamann, Head of the DLR_School_Labs in Oberpfaffenhofen, is busy with the final preparations for today's guests. It's time for the last minute tweaking – the lights are dimmed and the DLR Video, created specifically for the school classes, stands ready to start playing. Glimmering stars appear on the ceiling. The first students stumble into the room at around nine in the morning. One student says: "Cool. That's what it must look like in space". Hausamann welcomes his young guests and introduces the three instructors. "Today we will spark your curiosity," he says. The school class from the Johann Sebastian Bach Grammar School in Windsbach will have the opportunity to acquire knowledge actively and playfully in a few simple experiments. The class is divided into four groups. Laser technology, ASUROnaut, robotics and infrared measurement technology are on the agenda.

The first group, the infrared measurement technology team, marches up to the instructor. Today they will make the invisible visible. Scratching the side of his head, one of the boys asks: "How does that work?" The instructor remains unperturbed by the feisty kids and starts explaining in a lively voice: "The human eye perceives the world in visible light. But this light represents only a small fraction of the electromagnetic spectrum; most of it is invisible. Infrared radiation lets us see differently and helps us understand the world better." Then he shows the children the infrared cameras. "Have a go yourselves!" Requiring no further prompting, the students grab the infrared cameras, point them at each other and observe how thermal radiation is converted into visible images. Fascinating!

### Powerful places

Gravitational biology, solar water purification, Mars exploration, mobility research, robotics, weather and climatology – these are among the topics that school classes investigate at the DLR_School_Labs, under the auspices of scientists and experienced students from the fields of natural science and engineering. Through hands-on experiments, carried out at real research facilities, the laboratory becomes a place of wonder, learning and inspiration.

Over 100,000 school-age students have attended the DLR_School_Labs since the project's inception, and experienced the 'fascination for research' by conducting interesting experiments themselves. A survey in which several hundred school-age students participated, conducted for a doctoral thesis completed at the University of Kiel, has revealed that, even long after visiting a School_Lab, the interest in the natural sciences continues to a far greater degree than before. The DLR_School_Labs actually inspire children and young adults to pursue study or work in the field of natural science. The manifold responses among students and teachers alike also confirm that School_Labs make an important contribution to the development of an exciting and varied curriculum.

The first DLR_School_Lab opened its doors at the DLR site in Göttingen back in 2000. There are now DLR_School_Labs at the DLR sites in Berlin, Braunschweig, Bremen, Cologne, Göttingen, Neustrelitz, Oberpfaffenhofen, Lampoldshausen/Stuttgart and at three affiliated universities: RWTH Aachen, TU Dortmund and TU Hamburg-Harburg. One more laboratory is currently being constructed at TU Dresden.

The third group is hiding behind partition walls, focused entirely on the experiment. Working in a team, the boys and girls are asked to assemble the ASURO robot kit, a robot car. Fifteen-year-old Annika Flock was one of the lucky ones to draw a place on the robotics team. "This is exactly the team I wanted to be on because I think computer science is great, and here we can do some programming and put the kit together ourselves," she says afterwards. "It's a perfect mix". The numerous components that make up the robot kit look complicated, but the students have no problems putting it together. Asking if he can be of any assistance, the students greet their instructor with no more than a parrying "Shhh!" Just a few hours later, the various robot cars are dashing round the room and the young scientists are beaming with pride.

"The DLR_School_Lab is very much hands-on, and that makes it particularly excellent. In physics class at school we learn formulae, and maybe once in a while the teacher will demonstrate one or two experiments while we watch. It's totally different in the School_Lab. They give you the materials, explain how it works and then you go ahead and build it," says Annika appreciatively at the end of the experiment.

"I really enjoy motivating the students and getting them thrilled about science," says the young instructor, and full of enthusiasm she proceeds to tell the children: "There are plenty of intelligent machines around us in everyday life. Robots weld cars and bake bread. They can do the work that is too dangerous or strenuous for us. But they can only perform these tasks because they are told precisely what to do." She starts off by explaining how a Mars rover is controlled or what happens when it gets stuck. The visitors in the School_Lab listen attentively to the implications of using a robot to explore a landscape when you can only 'see' through its eyes. A tiny delay of less than a second has serious consequences, so precise control is imperative. Then, the students proceed to the practical side. Refusing to give up, they try to steer the Mars rover in the right direction again and again. "It's not that easy," says one of the girls, "but it sure is fun!"

This is precisely what the DLR_School_Labs set out to do – to awaken an interest in experimenting and demonstrate the joy of learning. As the day comes to an end, a student from Berlin asks one final question: "How can I build my own life-sized robot? It could clean my room and my mum could stop fussing about the chaos!" ●

**More information:**
www.DLR.de/schoollab/en

Controlling a Mars rover with a time delay requires great deal of concentration.


What goes up must come down. DLR engineers follow the path of the metal cylinder in which the MASCOT asteroid lander descends 110 metres to the ground.

# Free-falling scout

**In 2014, the Japanese Hayabusa-2 spacecraft will begin its journey to asteroid 1999 JU3. On board will be the Mobile Asteroid Surface Scout, MASCOT, an asteroid lander. The main excitement for DLR engineers will begin in 2018, when the lander detaches itself from the mothercraft, touches down on its target, moves across the surface by 'hopping' and contributes to the first ever measurements on the surface of an asteroid. First, however, MASCOT must undergo numerous tests to prove that it is capable of completing the trip through space and the separation from Hayabusa-2. The DLR Magazine was in Bremen when MASCOT was 'launched' and, shortly afterwards, separated from its mothercraft – on a smaller scale, but as realistically as possible.**

## Testing the MASCOT asteroid lander

**By Manuela Braun**

The testing of the MASCOT separation mechanism is taking place inside the drop tower at the Center of Applied Space Technology and Microgravity (Zentrum für angewandte Raumfahrttechnologie und Mikrogravitation; ZARM) at the University of Bremen. A capsule containing the asteroid lander will be dropped from the top of the tower. As the experiment falls towards Earth, it will experience a few seconds of microgravity. One of the most critical moments of the lander mission will take place in the human-sized metal capsule. The release mechanism must gently push MASCOT away from Hayabusa-2, overcoming any friction in the separation process, and out towards the surface of the asteroid.

Christian Grimm from the DLR Institute of Space Systems examines a small black plastic component. As he presses on the part connecting two small plastic arms, there is a gentle click. "Actually, it is a fairly simple spring," says the Test Manager. Nonetheless, this spring will determine whether or not a lander will touch down on an asteroid and acquire data on its surface – data that will allow researchers to learn more about these celestial bodies and the evolutionary history of the Solar System.

Many things might go wrong; for example, MASCOT could tilt and become stuck as it separates from the Japanese mother craft. This was the case during the first test in the drop tower. Grimm smiles and shrugs his shoulders. You can only learn from such mishaps. As a result, the second test run on the following day was much better – everything went perfectly. Today, the model of the shoebox-sized lander is back in the cylinder, ready to descend to Earth in free fall once again.

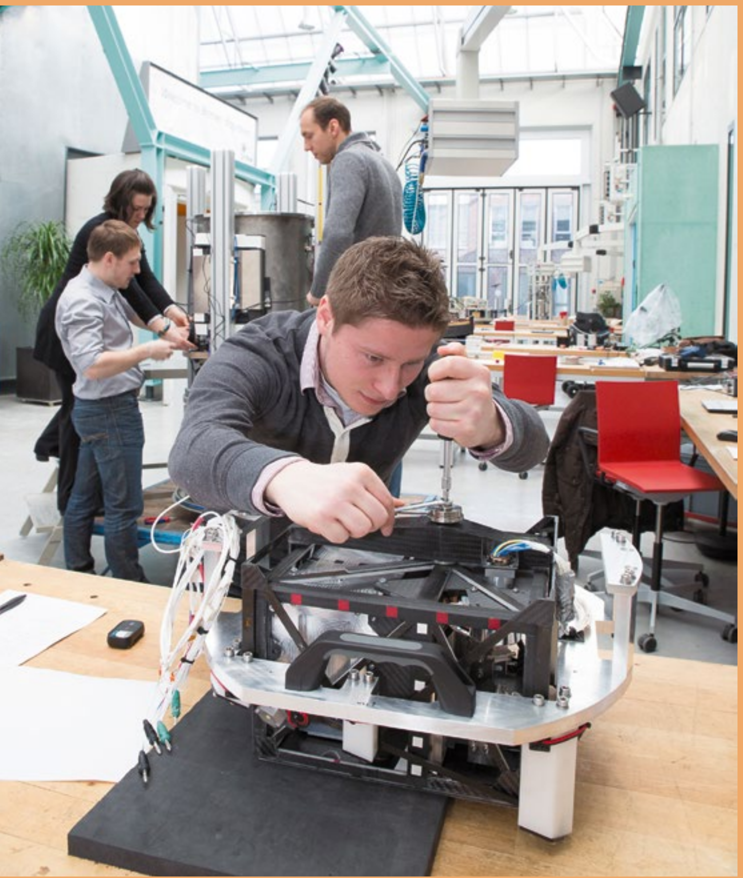
A small team is simulating the flight over the asteroid. Christian Grimm, Artur Hass, Maria Talapina and Christoph Freukes work calmly and with intense concentration. Grimm and Hass carefully measure the lander. The black struts give it the look of a tiny half-timbered house. The Test Manager writes down number after number on a list. The more precisely the model's centre of gravity is calculated, the better the test results can be compared with the computer simulations. Grimm taps on the black structure that protects the interior of the lander. "You could, of course, make this out of aluminium as well, but carbon fibre reinforced composite is much lighter and yet extremely stable – and with this compact lander, every gram counts." The container that will carry four instruments to the asteroid's surface measures just 30 by 30 by 20 centimetres.

### Under close observation

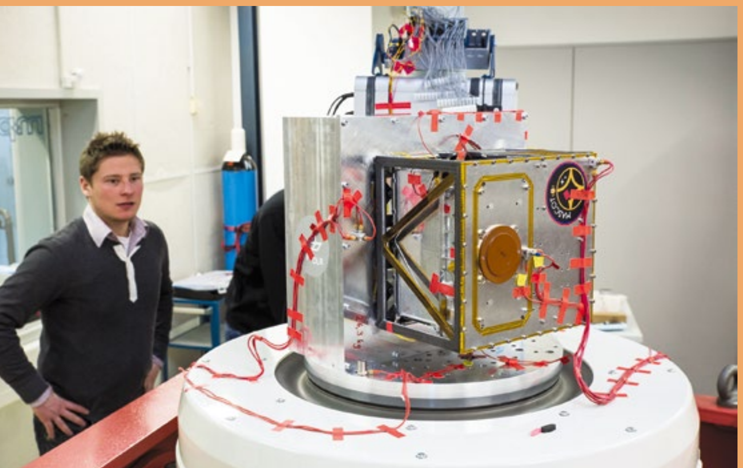
In the meantime, Maria Talapina and Christoph Freukes prepare the capsule. At the base of the metal container, padding ensures that MASCOT is not damaged during the abrupt deceleration following the rapid descent. Four small cameras will monitor the lander from every direction during the flight in microgravity, and will record the events taking place inside the capsule. Two additional high-speed cameras on the outside of the capsule will also be transmitting the first live pictures during the descent – these will be displayed live on a screen in the control room. Bundles of fine cables and connectors are wound along the cylinder's exterior. Christian Grimm and Artur Hass mount the supporting structure on the lander. In free fall, this part will simulate the spacecraft from which MASCOT will be ejected at a height of 100 metres.

Everything is ready. Four pairs of hands gently slide the asteroid lander into the cylinder. Maria Talapina lets the heavy cover slide downwards on its hoist. Metal contacts metal. It is now time for the DLR engineers to make the final adjustments before leaving their valuable cargo in the hands of the team operating the drop tower. Screw after screw is tightened. The first data from the lander is displayed on the screens. "Something is not right," shouts Freukes. And then it happens – one of the wires on the exterior of the cylinder breaks off. Christian Grimm rummages in the drawers looking for a tool. Together with Artur Hass, he works his way through the cable harness to the damaged wire. They both completed training as electrical technicians before going on to study aerospace engineering, and this is now being put to good use on the asteroid lander. Tension dominates the atmosphere for a few moments. The test must proceed, but the defective wire is holding everything up. Ten minutes later the wire is repaired and the cylinder is ready to be handed over.

As of this moment, the fate of MASCOT lies in the hands of drop tower operators Torsten Lutz and Dieter Bischoff. The DLR engineers must get used to standing on the sidelines. When the asteroid lander touches down on 1999 JU3 in 2018, the distance to Earth will be too great for real-time radio commands, so MASCOT will have to carry out its mission completely autonomously. Lutz and Bischoff roll the test unit to the drop tower, seal the capsule and raise it to the top using a chain. Eighteen powerful pumps spring to life with a hum.



Test Manager Christian Grimm prepares the asteroid lander for the test in the drop tower



On the shaker, MASCOT demonstrates whether it will be able to survive the loads it will be subjected to during a rocket launch.

The metal cylinder, with its valuable contents, is recovered from a sea of polystyrene spheres.

Within two hours they will create a vacuum in the entire tower – air resistance cannot be allowed to interfere with the free falll.

**Launch conditions on a shaker**

At the same time, in another building, another test item is being 'launched into space'. An indefinable sound comes from a room in which a model of MASCOT is mounted on a shaker table. What seems like a mix of grinding and screeching penetrates through the glass in front of which Olaf Mierheim sits with his team. The researcher from the DLR Institute of Composite Structures and Adaptive Systems is subjecting the lander to the mechanical environment it will experience during launch. MASCOT must be capable of withstanding the vibrations from the launcher's engines as well as acoustically induced vibrations in this environment without suffering any damage. Japanese colleagues at the JAXA space agency have supplied detailed information about the loads that MASCOT will be subjected to during the launch. A wide range of frequencies will affect the asteroid lander simultaneously – loads that will push the materials to their physical limits. Test Managers Christian Grimm and Olaf Mierheim put on ear protectors and enter the room containing the shaker table. The unpleasant noise gets louder for a moment. But MASCOT seems unharmed. The two colleagues will soon see from the display on the monitor in the control room whether the interior of MASCOT and the swing arm that will be expected to make the lander 'hop' have survived without damage. Everything looks OK. The next test run can be prepared.

**Countdown to release**

In the drop tower, everything is set for the critical moment. Torsten Lutz sits at the console in the control room. On the large screen, the capsule can be seen 110 metres up. Christian Grimm and Artur Hass go to their control console. In the seconds that follow, Bremen will become outer space, as an asteroid lander separates from its mother craft and falls towards an asteroid. Project Leader Tra-Mi Ho has entered the control room, as have several other members of the MASCOT team, to follow the flight in microgravity. Although there is no rocket launching this time, the tension in the control room is palpable. "Three, two, one!" With this short countdown, the Test Manager indicates that the capsule will begin its plunge. With the push of a button, the capsule on the screen hurtles towards the ground at 170 kilometres per hour. The experiment lasts 4.7 seconds, as the cylinder slams into the eight-metre-tall collector tube, where polystyrene spheres decelerate it. "This is like a car accident," says Lutz. In the control room, the tension among the engineers abates. "Yes!" says Christian Grimm, banging the palm of his hand on the table. Everyone exhales. The short film sequence from inside the capsule has shown that the release mechanism worked. In space, MASCOT would now be falling towards the asteroid from an altitude of 100 metres.

But there is still an unknown; how is MASCOT doing inside the capsule? Once air has been allowed into the tower, Torsten Lutz can open the huge doors. A metal ladder rises eight metres. A sea of polystyrene spheres covers the capsule in the collector tube. It is slowly pulled up with the chain. A waterfall of polystyrene cascades from the slowly emerging container. Lutz uses a high-pressure blower to remove the last spheres from the capsule. As soon as the package has been safely recovered and lowered down to the floor, the DLR team can inspect the asteroid lander closely.

**Successful separation**

A few moments later, the time has come; Christian Grimm, Artur Hass, Maria Talapina and Christoph Freukes loosen the final screws and the cover is free. They are able to look inside, where

The MASCOT team monitors the fall in microgravity via camera images

Tension following the test – how well has the lander withstood the descent?

## Participants in the MASCOT mission

The MASCOT (Mobile Asteroid Surface Scout) asteroid lander is being developed at DLR. It will arrive at asteroid 1999 JU3 on board the Japanese Hayabusa-2 spacecraft in 2018, where it will study the celestial body, which is approximately 4.5 billion years old, and has a diameter of roughly one kilometre. On board the lander are a magnetometer (TU Braunschweig), a near infrared microscope for hyperspectral imaging (IAS – CNES), as well as an optical wide-angle camera and a radiometer from DLR. Involved in this mission for DLR are the Institute of Space Systems, the Institute of Composite Structures and Adaptive Systems, the Robotics and Mechatronics Center (RMC), the Institute of Planetary Research and the Institute of Space Operations. CNES contributes to the system by providing the antennae, the power subsystem and performing the mission analysis. MASCOT's communication unit is provided by the Japanese Aerospace Exploration Agency, JAXA

MASCOT rests on its padding. "When it was released, it fell straight down, perfectly," the Test Manager says with delight. The asteroid lander is sitting on the square pattern of the padding, absolutely in line with the pattern. Grimm and Hass gently extract the lander from the cylinder. A ripping noise can be heard – the engineers have had to use a trick; Velcro underneath MASCOT has ensured that the asteroid lander was not thrown back out of the padding and against the upper support structure during the impact. "It would not have withstood that." The Test Manager slowly turns the unit from left to right. Four pairs of eyes look enquiringly at the lightweight structure. Nothing bent, nothing damaged? All of the struts on MASCOT look OK. The mechanism for ejecting the lander has worked, and the asteroid scout has survived the test.

In space, the encounter with the surface of the asteroid will hopefully be gentle. Landing on asteroid 1999 JU3 is a challenge – there, the gravity is 60,000 times lower than that at Earth's surface. If the lander is going even a little too fast, it will bounce off the asteroid and drift into space. But if everything goes according to plan, MASCOT will use its sensors to check whether it has landed the right way up, and its hopping mechanism to correct its attitude if necessary. The on-board autonomy will then put the scientific instruments into operation. Over the following 16 hours – two full asteroid days and nights – MASCOT will move to various measurement sites using the hopping mechanism. These jumps across 1999 JU3 will range between a few metres to 100 metres in length.

Here on Earth, for the asteroid lander, the end of one test means it is time for another. Once again, MASCOT will be released from the mother spacecraft and fall through microgravity. Once it has survived that fall, the next challenge follows – will it survive the extreme temperatures in space? At Bremen, space will once again be simulated to answer this question – in the thermal vacuum chamber at the DLR Institute of Space Systems. ●

**More information:**
http://s.DLR.de/0q75


Hands on the levers of the Boeing 747 – today a child's dream, tomorrow, maybe a reality. The Boeing 747-200 on display is one of the top attractions at the Aviodrome.

Image: Aviodrome

# Among seagulls and windmills

**The Netherlands, with its sweeping expanses of polder landscapes around the Ijsselmeer, devoid of landmarks for the eye to rest on, is domed by a canopy of blue skies and fluffy clouds. Only the occasional windmill, scattered farmyards and a line of wind-beaten trees interrupt the panorama as they jut out beneath the frequently dramatic, cloudy sky that once captivated Vincent van Gogh. Suddenly, a jumbo jet comes into view near the city of Lelystad – and it is no mirage. Perched seemingly right on the polder meadows, a full-size Boeing 747 greets motorists on the main N302 road, glowing in the bright blue and white colours of Royal Dutch Airlines, KLM.**

## The Aviodrome in Lelystad, The Netherlands

**By Hans-Leo Richter**



The faithfully reconstructed terminal building at Schiphol Airport as they were in 1928. From the former control tower, visitors overlook the extensive Aviodrome.

Upon closer inspection, visitors spot other aircraft – but how did they get here, in the middle of the polders? The signpost right in front of Lelystad regional airport soon solves the mystery – this is the way to the 'Aviodrome'. This neologism is the name of a remarkable aviation museum, a veritable adventure playground in the world of aviation. Numerous aircraft and myriad other exhibits from the world of flying pay tribute to the history of Dutch aeronautics – with a distinct and pleasing focus on the civilian sector.

The origin of the museum can be found in a collection that was exhibited back in 1960 at Amsterdam Schiphol, one of Europe's largest commercial airports and hubs. It is hardly surprising that the Schiphol premises soon became too cramped to accommodate any further additions, and in 2003 the museum moved to its excellent new site on the flat polders near Lelystad, in the province of Flevoland.

Visitors take off on a trip through time across more than 6000 square metres – from the heady days of the first ballooning adventures in the late eighteenth century to the cutting-edge jet aircraft of modern times.

The museum is divided into several sections. Naturally, the 'eye-catchers' are parked outside in the grounds, including the previously mentioned Boeing 747, a Douglas DC 4 'Skymaster', a Lockheed 'Constellation' and a Fokker 100. The main historic highlights are presented in a large, modern exhibition hall, protected from the elements. Other treasures of aviation history are on show in the adjacent T2 hangar, with the slight drawback that visitors can only take a look from the catwalk that runs around the building. This is the aircraft workshop, where one can watch the restorers hard at work – truly a distinguishing feature among aviation museums.

The ideal place to start in a logical, chronological sequence is the airy exhibition hall. Naturally, the first exhibits illuminate the dawning age of aeronautics, featuring a replica of the Lilienthal glider as well as a model of the Wright Flyer alongside the historical Bleriot monoplane from 1909, in which the Frenchman became the first person to fly across the English Channel.

It would hardly be the Netherlands if Anthony Fokker didn't enter the picture soon. From early childhood, Holland's most illustrious aircraft engineer, born in 1890 on the island of Java in Indonesia (then still a Dutch colony), developed a keen interest in technology, above all in the nascent field of aviation. He made a name for himself during the First World War developing versatile and high-performance fighter planes. He proceeded to develop the first commercial aircraft after the war, at times adapting previous designs. The company held on to its good reputation right into the 1990s, and the reliable short and medium-haul Fokker 50 and Fokker 100 airliners are still seen frequently today.

The Aviodrome is home to no less than 15 spectacular models from Fokker's former product range, among them the very first design, 'de Spin' (Dutch for 'the Spider'), a spidery monoplane with an Argus engine.

Of particular interest is the relatively advanced Fokker F.VII from 1924 – a sturdy-looking high-wing monoplane with struts, able to transport eight to 10 passengers just over 1000 kilometres. Pleasingly, the narrow cabin is open to visitors; the apparatus clatters gently – a landscape shot in black and white passes by the large windows, recreating the experience of passengers in bygone days.

The twin-engine Fokker F27 'Friendship' is pretty much essential for the exhibition; it was the first of the larg passenger aircraft constructed after the Second World War, designed for roughly 40 travellers. Outside, on the grounds, visitors will find more recent models – the F50 and the twin-jet F100, a 100-seater with a modern design.

There is, however, far more than just aircraft to marvel at. The museum management has been successful in acquiring additional exhibits from different eras to create an authentic atmosphere. For instance, an open De Dion Bouton two-seater car is parked in front of the Wright Flyer, presenting a charmingly contoured bonnet, while a timeless Renault stands in front of another classic plane, and even the diminutive Hanomag, the famed 'Kommissbrot' or 'army loaf', is there. Hidden beneath the comparably massive, four-engined Lockheed 'Constellation', a tiny Daf 600, the first compact car with fully automatic (V-belt) transmission, is almost completely overshadowed. Last but not least, resting next to the Fokker F.VII, visitors can admire a vertical fuel tank on wheels with a bulky hand pump – the first airfield tanker, from 1930.

Some of the aircraft are only shown as mock-ups or sections, while in other cases it is only the cockpits that convey a sense of the atmosphere in earlier days of aviation engineering, among them the Sud Aviation 'Caravelle', the elegantly proportioned medium-haul airliner constructed in France during the 1960s. An interactive area offers visitors the opportunity to put their skills to the test in a Boeing 737 flight simulator, even if it is a simple affair.

One of the true highlights in the extensive collection comprising over 80 aircraft is doubtless the world's last flying DC 2, 'de Uiver' (the Stork). It was the predecessor to the DC 3 Dakota, which would later become immensely popular – over 15,000 were constructed, making it one of the world's most recognisable aircraft. The DC 2 had two radial engines, accommodated 14 passengers and had quaint curtains at the windows – travelling in style. The Uiver on show is a tribute to the KLM DC 2, whose name and design it shares and which – as a scheduled airliner – competed in an air race from London to Melbourne in October 1934, coming in a sensational second place behind a specially designed de Havilland racer.

Some of the aviation old-timers in the museum remain airworthy and can even be booked for sightseeing flights. The Consolidated PBY 'Catalina', a twin-engined, long-range flying boat used primarily as a maritime reconnaissance aircraft in the Second World War, deserves a special mention. The most coveted seats – located in the two distinctive convex Plexiglas domes positioned along the sides – offer an unbeatable 180-degree panoramic view.

Finally, and we are still moving forward on our journey through time, visitors find themselves in a truly historic-looking building. This is the original passenger terminal at Schiphol Airport, dating from 1928 and reconstructed stone by stone. Visitors feel truly transplanted into this era, a time when travellers would look up flight connections scrawled in chalk on wide blackboards. For 20 August 1931, flights to 'Londen', 'Parijs', 'Berlijn', 'Praag' and even 'Batavia' – today's Jakarta – are announced. Huge barrows await mountains of baggage and, although the procedures in the terminal buildings back then were most certainly professional, they have little in common with the hustle and bustle and ubiquitous technology of modern-day practice.

Visitors are even invited to ascend the tower that was used at the time by air traffic controllers. Today, it offers a magnificent view of Lelystad Airport, the entire Aviodrome grounds and some of the aircraft exhibited there – a wonderful conclusion and the true highlight of the tour.

The Aviodrome is highly recommended and well worth a day-trip, perhaps as part of a visit to Amsterdam or tranquil holiday on the IJsselmeer. Even on a rainy day, when the North Sea beaches to the west are hardly inviting, the few kilometres journey to the aviation museum is definitely worth it. In any case, the relaxing drive from the city of Enkhuizen via the Markerwaarddijk – practically bisecting the IJsselmeer – is a fairly enchanting option in its own right … ●

Image: Aviodrome

Top: The Douglas DC 3 formed the backbone of many airlines in the post-war period – including KLM, the Dutch national carrier. Centre: the outdoor area. Bottom: inside the hangar. In the foreground, a Fokker F 27 'Friendship'; further back, a de Havilland 'Dove' commuter aircraft; on the ceiling, an MBB Bo 105, a very common multipurpose-and-rescue helicopter in the Netherlands.

Spartan cockpit of the de Havilland 'Tiger Moth', with its special, horizontally-installed flight compass. The image on the right shows a board with historical – and hand-written – departure times for 20 August 1931.

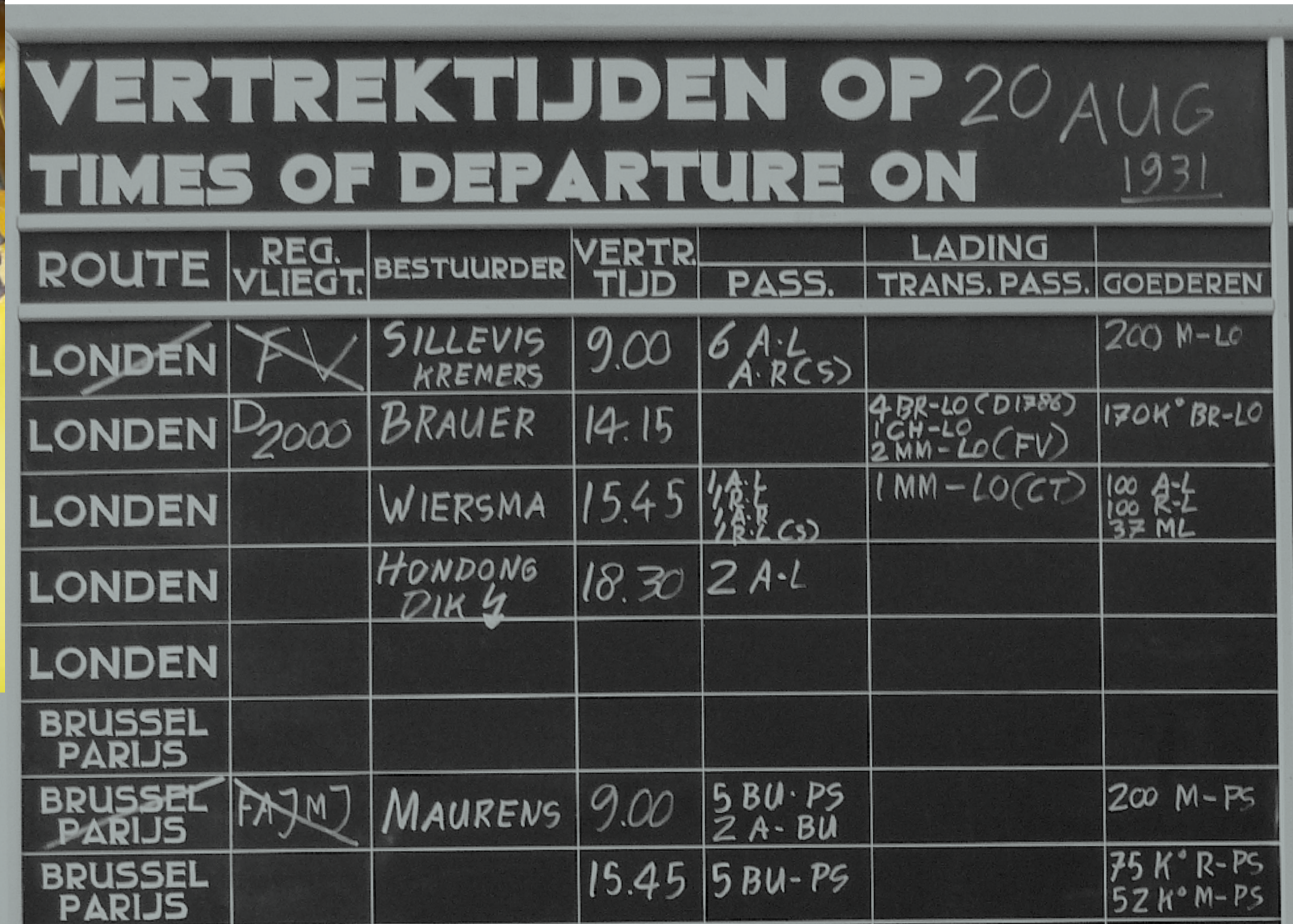



Image: Aviodrome

**Aviodrome Lelystad**
Pelikaanweg 50
8218 PG Luchthaven Lelystad

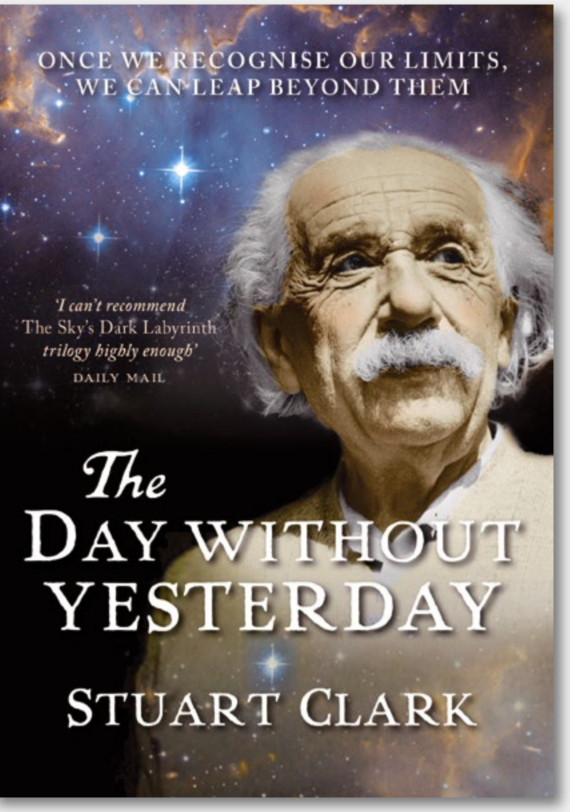
**Opening times**
Tuesday to Sunday
10 to 17 hours

**Admission**
Adults 16.50 €
Children 3-11 years 14 €
up to 2 years free of charge
(online-tickets 1 € off)

**www.aviodrome.nl**

Cockpit of the four-engined Lockheed L 749 'Constellation' long-range airliner, a precursor of the later and very popular 'Super Connie'. Numerous circular analogue gauges dominate the image. Just visible on the right is the flight engineer's console.

# Reviews




## The day without yesterday

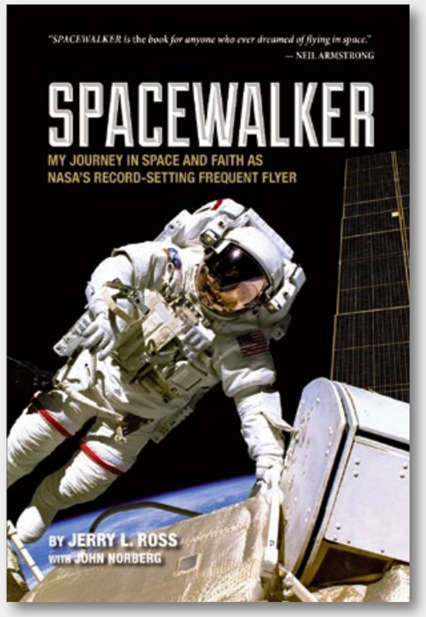
**The Day Without Yesterday**, written by Stuart Clark, brings to life the story of Albert Einstein and George Lemaître, whose scientific theories underlie today's understanding of the Universe.

Set during the First World War, Clark plunges the reader into the struggles of scientific endeavour in the context of a war-torn society. He charts the personal and professional clashes that Einstein faces as he works towards a major scientific break-through, and the fame that followed. Conflicts between his peers, and questions of morality face Einstein, from the concern of his colleagues working on poison gas to be used in the war, to the collapse of his marriage following an affair. Meanwhile, the young priest and physicist Lemaître confronts Einstein with the idea of 'a day without yesterday', and thus the seed for the Big Bang theory was planted.

Don't be deterred by the prospect of complex physics for this is not a textbook, instead this is a 'docudrama' style novel accessible to people with various backgrounds. But even the most devout cosmologist will not get bored; the story adds emotional depth to scientific theories so often taken for granted today.

This is the third novel in Clark's 'The Dark Sky's Labyrinth' trilogy that, together, provide a unique and engaging account of how the Universe was observed from the seventeenth century onwards. Each novel offers insight into the complex relationship between scientific discovery, religion and society, and the losses and frustrations faced by the scientists, along with their successes, which ultimately laid the foundations of modern physics.

**Emily Baldwin**



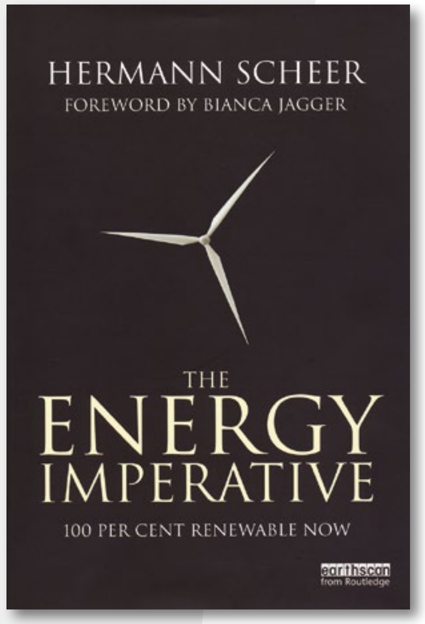

## A record-setting spacewalker

In **Spacewalker: My Journey in Space and Faith as NASA's Record-setting Frequent Flyer**, Jerry L. Ross, together with John Norberg, details his personal journey towards becoming an astronaut and a frequent 'space flyer'. From a very young age, Ross decided he wanted to be involved in the exploration of the Universe. He went on to obtain a degree in mechanical engineering from Purdue University, and later joined the United States Air Force. Finally, he embarked on what would be a long career at NASA.

This book offers an insider's account of the US Space Shuttle programme and the construction of the International Space Station, but also Ross's in-situ experiences of his multiple launches into space, nine spacewalks, observing Earth from orbit and witnessing the disasters of the Challenger and Columbia. The story is completed by accounts of Ross's life from the perspective of his wife and children.

This is a very informative book with the added inspirational story of a life following the stars, and a must-read for anyone who ever dreamed of flying to space. The book is available in print as well as Kindle edition.

**Merel Groentjes**



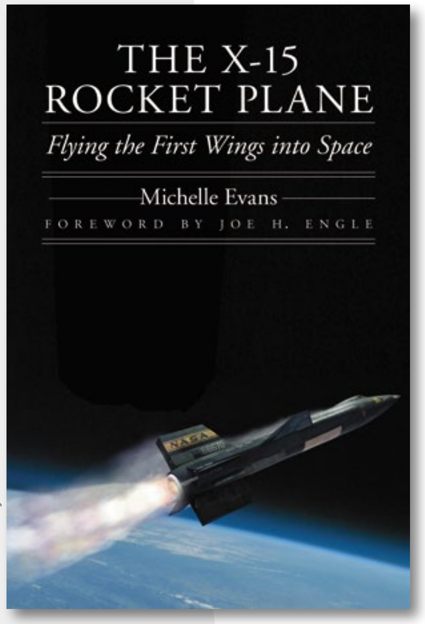

## The ultimate challenge

**The Energy Imperative: 100 Percent Renewable Now**, is one more of Hermann Scheer's contributions to the topic of renewable energies, and the last book he wrote before his death in 2010. Scheer will be remembered as one of the world's leading advocates of renewable energy. He was a firm believer that climate change is not just an environmental issue, but touches every part of our lives: peace, security, human rights, poverty, health, hunger, mass migration, economics …

With this in mind, in this book he lays out his vision for Earth – a planet 100 percent powered by renewables – and examines the fundamental ethical and economic imperatives necessary for such a transition. He introduces the topic of renewable energy, goes on to explain the challenges faced in achieving a 100 percent renewable world, the lack of alternatives to this type of energy, and continues through to the technologies that are working today, and the policy and market conditions that would allow them to flourish.

If you are an advocate of clean, safe, unlimited energy, this book is for you. The Energy Imperative gives a practical, inspirational map for the next stage of the journey, demonstrating why, in the words of Herman Scheer, the time for the energy transition is now.

**Karin Ranero Celius**




The University of Nebraska Press

## The first wings into space

When the Soviet Union launched the first artificial satellite in 1957, the Cold War intensified as the United States feared losing the space race. **The X-15 Rocket Plane: Flying the First Wings into Space** tells the story of the hypersonic X-15, the rocket-powered aircraft that paved the way for human spaceflight as the world's first operational spaceplane. The book commences with an inspiring foreword by Joe Engle, one of the most famous X-15 pilots other than the late Neil Armstrong.

Drawing on interviews with those who took part in the programme, Michelle Evans captures the drama and excitement of cutting-edge aerospace research – from the development of a variable-thrust rocket engine, to the dissipation of the heat generated at speeds up to Mach 7, through to how to safely re-enter the atmosphere and glide to an unpowered landing. This book tells the human story of the feats of science and engineering that went into the X-15 programme, many of them important for the later development of the Space Shuttle. We are introduced to the X-15 pilots. Twelve men flew this revolutionary plane, with eight of them reaching sufficient altitude to earn their astronaut wings. The X-15 Rocket Plane brings these pioneers, and the others who made it happen, back into the spotlight, and to their place in the history of spaceflight. All in all, this is an enlightening historical account that will be enjoyed by space enthusiasts, engineers and historians alike.

**Peter Clissold**


## The Sun at the tip of your fingers

Carry the Sun in your pocket! Developed in collaboration with NASA scientists, the **3D Sun Classic App** provides a unique window to the Sun's ever-changing surface. A 3D image of the Sun can be rotated manually, and shows the position of NASA's two STEREO (Solar TErrestrial RElations Observatory) satellites, which provide most of the spectacular material in the image and news galleries included in the app. Examine the surface of the Sun at different wavelengths, watch amazing videos of colourful magnetic loops, spectacular plasma rains, fiery solar tornadoes and stay up-to-date on current solar activity. Every day there's something new under the Sun!

**Merel Groentjes**

## 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 execution organisation.

DLR has approximately 7400 employees at 16 locations in Germany: Cologne (Headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Göttingen, Hamburg, Jülich, Lampoldshausen, Neu-strelitz, Oberpfaffenhofen, Stade, Stuttgart, Trauen and Weilheim. DLR also has offices in Brussels, Paris, Tokyo and Washington DC.

## Imprint

DLR Magazine – the magazine of the German Aerospace Center

Publisher: DLR German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt)

Editorial staff: Sabine Hoffmann (Legally responsible for editorial content), Cordula Tegen, Marco Trovatello (Editorial management), Karin Ranero Celius, Peter Clissold (English-language Editors, EJR-Quartz BV)
In this edition, contributions from: Emily Baldwin, Manuela Braun, Dorothee Bürkle, Falk Dambowsky, Frauke Engelhardt, Merel Groentjes, Sarah Lange and Melanie-Konstanze Wiese.

DLR Corporate Communications
Linder Höhe
D 51147 Cologne
Phone: +49 (0) 2203 601 2116
Fax: +49 (0) 2203 601 3249
Email: kommunikation@dlr.de
**www.DLR.de/dlr-magazine**

Printing: Druckerei Thierbach, D 45478 Mülheim an der Ruhr

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

ISSN 2190-0094

**To order and read online:**
**www.DLR.de/magazine**

The DLR Magazine is also available as an interactive app for iPad and Android tablets in the iTunes and Google Play Store, or as a PDF file.



DLR **Deutsches Zentrum für Luft- und Raumfahrt**
German Aerospace Center