Magazine of DLR, the German Aerospace Center · www.DLR.de/en · April 2012

DLR magazine 133

'Rumble in the jungle'

Europe's Spaceport in French Guiana

Watching whales for better flight
Making helicopters more agile

Unveiling the 'invisible'
The potential of nanoparticles

DLR magazine 133

24

'Invisible', yet full of surprises

In spite of their size – sufficiently small to be invisible to the human eye – nanoparticles are making a big impact. Researchers are imbuing these tiny particles with desirable properties, thus creating significant benefits. Be it in medicine, civil engineering, chemistry or – as at DLR – in the aircraft and vehicle construction sectors, little 'nanos' are on their way to becoming the 'next big thing'.

Dear readers,

As 2011 came to an end, a bright trail lit the skies and then vanished in the Indian Ocean. It was not a shooting star; it was ROSAT, re-entering the atmosphere at a time and place dictated by the laws of nature, rather than with control from the ground. In the words of our chairman, this was not a sign of the end of the world – rather, a reason to continue to identify problems and work on finding solutions for them. Once again, DLR is leading the field in this respect.

To perhaps avoid uncontrolled re-entries from occurring in the future, our researchers are devising in-orbit satellite servicing concepts with the Deutsche Orbitale Servicing Mission, DEOS, and they used their involvement in the PRISMA mission to refine their techniques. The idea is to perform robotic maintenance and extend the operational lives of satellites that remain fully functional but are close to exhausting their station-keeping propellant supplies. It may also prove practical to capture and de-orbit satellites that lack the systems to perform controlled re-entry.

But research at DLR reaches beyond Earth's orbit, extending out into our cosmic neighbourhood with involvement in NASA's Dawn mission, which continues to acquire spectacular images of and data about asteroid Vesta, and the OSIRIS-REx mission. Upon its arrival at asteroid RQ_{36} in 2019, OSIRIS-REx will send a sample of the regolith back to Earth, part of which will be analysed at DLR.

Back here on Earth, nature holds the biggest wonders. The humpback whale, among the largest of the marine mammals, is one of these. Nature and technology go hand in hand. Through observation, we have learned that they are extremely agile as a consequence of bumps on their pectoral fins. What would happen if this idea were applied to aeronautics? DLR researchers have mimicked these bumps on helicopter rotor blades, with impressive results.

Inspiration for the field of aeronautics does not just come from studying the largest creatures on Earth, but also by looking into the smallest things – so small as to be nearly invisible. Nanoparticle research at DLR is breaking new ground, and 'nanos' are on their way to becoming the 'next big thing'.

The year 2012 brings with it many possibilities and exciting moments, such as the launch of the Automated Transfer Vehicle 'Edoardo Amaldi' and two more Galileo satellites from Europe's Spaceport in French Guiana. An extension of Europe in South America, this gateway to space is a very special place, the location from which missions to study Earth and our cosmic neighbourhood will continue to depart for many years.

Sabine Göge
Head of DLR Corporate Communications

Perspective

Specks of land

Lost in the expanse of the Indian Ocean – the largest of the Maldives islands as seen through the eyes of TerraSAR-X from an altitude of 514 kilometres. While the 1807 islands would be revealed as brightly outlined dots in images acquired with optical satellites, only that which rises above the water is visible to the radar satellite, showing that the habitable land area is extremely small. Clearly visible at the upper edge of the image is the capital island Malé, inhabited by around 100,000 people.

Mayan Zodiac Circle. Credit: wikipedia/flickr/theilr

The end of the world is not near

By Johann-Dietrich Wörner

Johann-Dietrich Wörner, Chairman of the Executive Board

www.DLR.de/blogs/en/janwoerner

The year 2012 began with a certain amount of hype. As is often the case when people have to deal with challenging situations – I want to avoid overusing the word crisis here – doomsday scenarios have been spreading across the press, radio, TV and the Internet. Legitimate concerns are mingled with sombre prophecies; then, fear arises. I have been asked 'Are you worried?' – directly and indirectly – by media representatives, and anyone who has been keeping an eye on the media knows my answer.

It is not just the optimist in me that rejects thoughts of the end of the world; it is my deep conviction that we must work on solving problems ourselves. Thanks to global advances in scientific knowledge, we know that the asteroid Apophis will approach Earth in 2029. Though it is certainly a cause for concern, this early discovery gives us the opportunity to determine the implications, to consider the consequences and, most importantly, to decide what we can do about it.

In January 2012, DLR launched NEOShield, a project that will investigate measures to prevent collisions of near-Earth objects, such as asteroids and comets, with Earth. But the grounds for my optimism go beyond this; with the launch of two more satellites, the European Galileo satellite navigation system will grow to four, enabling the first position determinations to be performed. The completed network will give Europe navigation possibilities that will provide more security in any area dependent on precise positioning – be it transportation or disaster relief. Another building block is Alert4All, A4A for short, where, together with 11 European partners, we are working on alerting the population during emergencies and communicating effectively with each other.

In its capacity as the German space agency, DLR is responsible for the safe operation and disposal or controlled re-entry of its own satellites. Collision-free spaceflight is no easy task in light of the estimated 700,000 pieces of space debris: our researchers are developing a laser-based method to detect this debris and catalogue it systematically.

Energy is another field that continues to receive the attention of our researchers. Changes in energy policies have given us cause to reinforce our efforts towards effective solar power plants; a new test facility is being built at the Spanish research centre in Almería. We are also combining our expertise in aeroelasticity, aerodynamics, materials and structures to make better use of wind energy. Electric mobility will be further investigated in 2012.

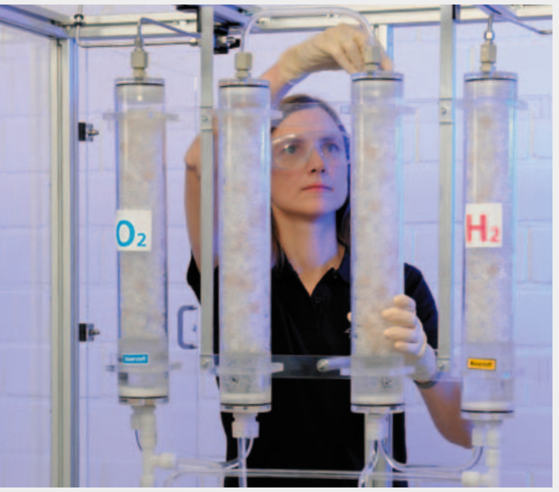
We take the protection of our environment very seriously. In this regard, biofuels for aircraft are just as important for the aviation industry as is the connection between weather and flying. The first major test campaign for environment-friendly airport approach procedures – involving air traffic controllers – as part of the flexiGuide project will begin this summer.

Many more examples allow me to look upon 2012 with great confidence. In times of economic difficulty, it is important to show that we are not carrying out our activities in 'ivory towers', without regard for society and the economy, but rather in ways in which it is possible to think about and work on practical applications, be it within our own institutes or with external partners. In this way, invention leads to innovation. For me, the end of the world is not near – at least, not in 2012! ●

In brief

Hydrogen production from surplus wind energy

Storage systems are necessary to enable greater use of renewable energies. Representatives from industry and research, including DLR, now want to show the potential of hydrogen for storing energy from wind in sufficient quantities. They are demonstrating the production of hydrogen in large-scale facilities and how it can be used as storage for the energy industry.



The wind does not always blow at times of high electricity demand. There are also times when wind turbines produce more electricity than is required. Instead of feathering the blades, this surplus energy could be used to produce hydrogen that can be stored for later use.

As part of the 'Performing Energy Alliance for Hydrogen from Wind' initiative, the participants from industry and research want to investigate the technical feasibility and economic viability of large-scale wind-hydrogen systems and develop the technologies required for market launch. The objective is to generate more hydrogen with the same amount of power and develop electrolysis systems with greater flexibility that can produce more or less hydrogen depending on the strength of the wind.

http://s.DLR.de/upf4

Electrolysis test bench being used to conduct research into more efficient processes for the production of hydrogen through electrolysis

Improving space weather prediction through collaboration with Norway

Space weather influences people and technology. Solar eruptions and the solar storms they trigger can compromise the use of modern technology on Earth to a great extent and lead to the temporary malfunction or failure of satellites, telecommunication and navigation systems, as well as power supply networks. The commonly used Global Positioning System (GPS) is also susceptible to the complex influences of space weather.

DLR and the Norwegian Mapping Authority, NMA, recently signed a memorandum of understanding in Neustrelitz on long-term collaboration in ionospheric research. This opens up excellent opportunities to significantly improve the accuracy of space weather forecasts. DLR and NMA will work together on a more precise and reliable space weather service, and contribute to predicting solar storms and the effects associated with them as reliably as possible. The collaboration between the two experienced institutions means that there is now a broad database available for the rapid identification and analysis of ionospheric disturbances.

© Stefan Meiners

Euphoria at Europe's first Space Tweetup

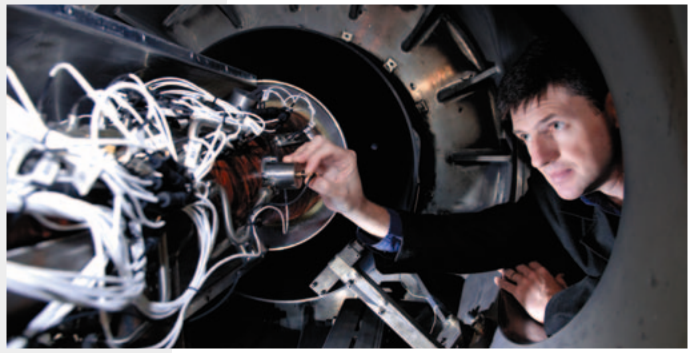
"Awesome!" was called out excitedly by many space enthusiasts as the astronauts of shuttle crew STS-134 entered the Tweetup tent at DLR in Cologne during German Aerospace Day. Enthusiasm for space travel dominated the first European Space Tweetup organised jointly by DLR and ESA on 18 September 2011. Figures demonstrate the spread of the first event of this kind in Europe – in total, almost 22,000 relevant social media contributions were identified, which were reflected in 19.3 million potential impressions (number of contributions times the reach, such as 'followers' of the respective channels).

Sixty international DLR and ESA followers were invited to the Tweetup. In an attractive programme, the Twitter followers were presented with interesting information and facts about European aerospace, met researchers and astronauts, visited DLR facilities and aircraft, and were the first to tweet their impressions from the Tweetup tent directly to the world. A new genre of science communication is here – this Tweetup will certainly not be the last one.

www.DLR.de/en/tweetup

Australian scramjet in Göttingen for testing

DLR researchers are testing the propulsion system of the Australian SCRAMSPACE 1 experimental spacecraft in one of Europe's leading hypersonic wind tunnels at Göttingen. They are investigating whether new types of propulsion systems can make the journey to space lighter and more cost effective.



Inspection of the scramjet model in the High Enthalpy Shock Tunnel, Göttingen. The flight of the spacecraft at an altitude of about 30 kilometres is simulated in the 62 metre-long wind tunnel.

The Australian spacecraft is what is known as a scramjet (Supersonic Combustion Ramjet), a propulsion system intended to make hypersonic flight up to Mach 15 possible. In contrast to normal jet engines, it has no moving parts; a scramjet must first be accelerated to hypersonic speed before it can function.

Experts are placing great hopes in such a propulsion system for future space travel. Ultimately it is to be combined with a multi-stage rocket, which could make space propulsion more efficient, reliable and inexpensive. SCRAMSPACE I is scheduled for launch at the Woomera Test Range, in the Australian desert, during March 2013 with the support of DLR Oberfaffenhofen's mobile rocket base, MORABA. The 1.8 metre-long spacecraft will be transported to an altitude of 340 kilometres by two rocket stages. After leaving the atmosphere, the scramjet will separate from the launcher and control rudders will stabilise it for the return journey. During the return flight, the vehicle will be accelerated to Mach 8.

http://s.DLR.de/508v

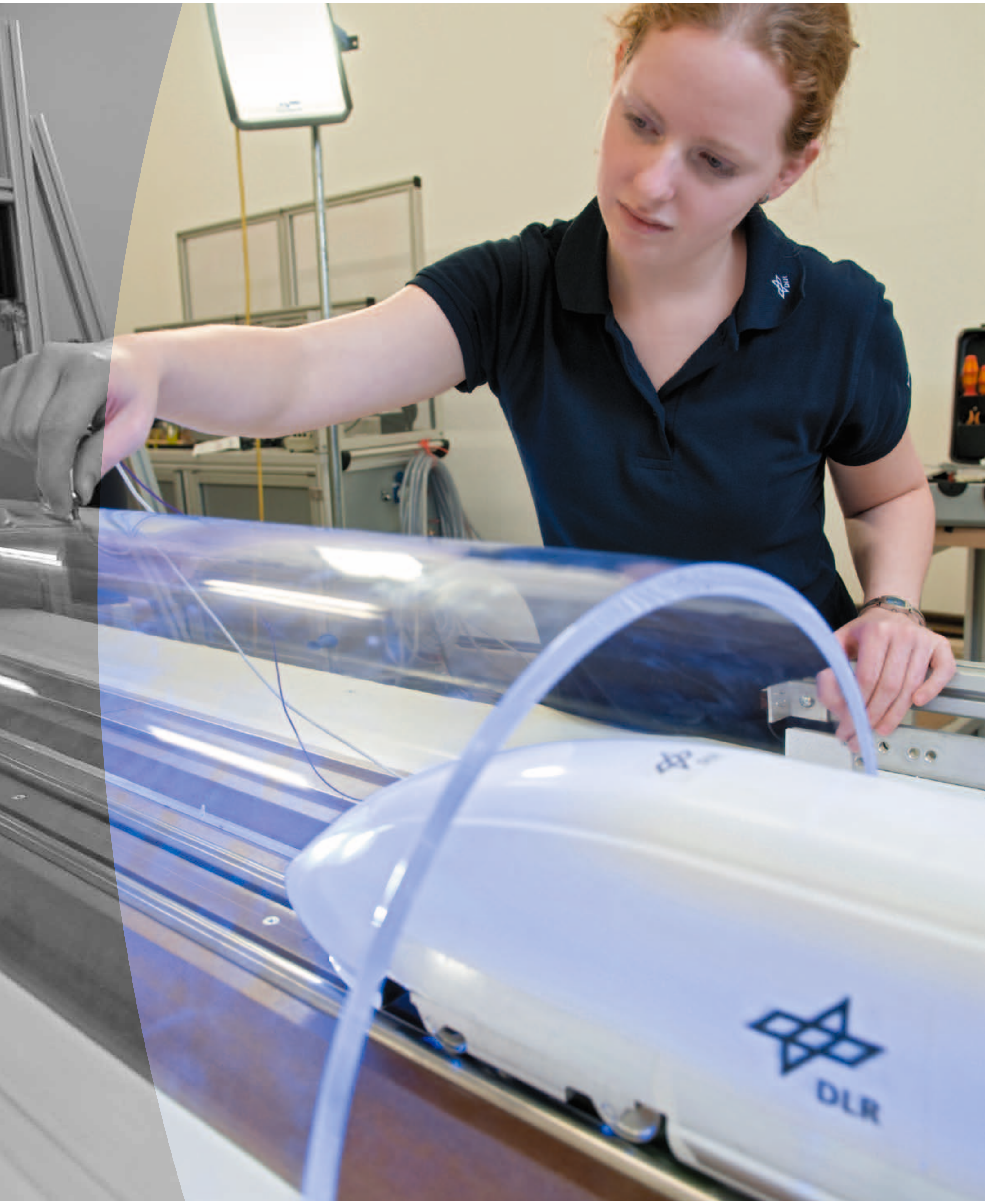
Monitoring traffic from the air

DLR researchers are developing a new technique for monitoring traffic using laser beams to send large quantities of high quality image data from the air to the ground. The images, each 63 megapixels in size, are acquired with a special camera on board the DLR Do 228-212 research aircraft. The camera can obtain up to five photographs per second, covering an area of about 25 square kilometres in one minute. The scientists established a data link from the aircraft to the ground station at the DLR site in Oberpfaffenhofen, near Munich, to be able to send the image data from the aircraft to the ground station. To this end, they installed a special communication terminal on board the aircraft. DLR is currently developing a mobile version of the receiving station so that the communication system can be used in all conceivable locations.

This technology is also of interest to DLR traffic researchers. Precise and comprehensive information about the traffic situation at any given time is necessary to be able to recognise and deal with congestion at an early stage. Using these aerial images transmitted without time delay, DLR researchers can automatically record the traffic situation or people flow to give effective support to emergency and relief services.

http://s.DLR.de/8vnk

The DLR Do 228-212 research aircraft is being used as an experimental vehicle for the transmission of high resolution image data to the ground station at the DLR site in Oberpfaffenhofen. Such a transmission has now been successfully completed for the first time over a distance of 120 kilometres. The overall system, consisting of a camera and optical data transmission by laser beams, has thus reached an important milestone. The very first time that the DLR scientists succeeded in sending data via a laser beam was in November 2008.



A gentle pop instead of a loud bang

As they enter and exit tunnels, trains generate pressure waves of varying strengths, depending on their speed. Physicist Daniela Heine, from the DLR Institute of Aerodynamics and Flow Technology, is investigating how these pressure waves can be mitigated. The 25-year-old PhD student works with the only tunnel simulation facility of its type in the world, in a gigantic hall at the DLR site in Göttingen. DLR transport editor Elisabeth Mittelbach introduces us to the young researcher and her project.

Daniela Heine investigates pressure waves in railway tunnels

By Elisabeth Mittelbach

Daniela Heine remembers her first day as a PhD student at the DLR site in Göttingen like it was yesterday: "It was 16 May 2011," she says instantly. As a physicist, it is not surprising that the 25-year-old has a memory for numbers. On that day, she became acquainted with her workplace – the only tunnel simulation facility of its type in the world. "I was very impressed by the size of the facility. Although I had already heard about it, I had imagined it to be smaller," explains Heine excitedly. Since then, the trainee researcher has been making her way to Bunsenstrasse in Göttingen every day of the week. When she does not have to attend any events or appointments at Göttingen University in the afternoon, she often stays at the Institute a bit longer. "The good thing is that I can really focus on my research when I am here at DLR," she says excitedly. Her office is located directly above the tunnel simulation facility, so the PhD student is always very close to the core of her research project.

The young researcher is investigating the propagation of pressure waves in railway tunnels. She is looking into how they are created and wants to find out how the strength of the waves can be reduced. Though somewhat reserved at first, her commitment to her work and expertise in this research area becomes obvious during our conversation. During her PhD course, which will last three years in total, Daniela Heine will focus intently on the aerodynamics of high-speed trains such as the Inter-City-Express (ICE) and on the shape of tunnel entrances. "Smaller pressure waves on entering and exiting tunnels would make trains safer and more pleasant for the passengers – particularly at high speeds," Heine explains. As the pressure waves reach the tunnel exit, passengers can feel a sensation of blockage in their ears or, more rarely, varying degrees of popping.

The tunnel simulation facility at DLR Göttingen is the only one of its kind in the world. Before they enter the experimental Plexiglas tunnel, a 'catapult' can accelerate the model trains to speeds of up to 400 kilometres per hour on the 60-metre long test track.

The faster the train travels and the narrower the tunnel, the stronger the pressure waves. "Most passengers on the ICE have noticed the change in pressure upon entering a tunnel," says Daniela Heine. When the pressure waves reach the tunnel exit, the compression wave is partially reflected back into the tunnel. The successive reflections of the pressure waves inside the tunnel produce a complex wave interaction, causing aerodynamic loads on the train and tunnel structures, and affecting the passenger's comfort. To attenuate the transmission of pressure waves into the vehicle and protect passengers, the design of the ICE 3 is almost completely airtight and includes extra-thick walls. This means, for example, that the windows cannot be opened. "Ideally, all the windows in an inter-city train would have to be closed before entering a tunnel," the train researcher concludes. Since this is nearly impossible, conventional inter-city trains must travel through tunnels at lower speeds than the ICE.

But the trains of the future will travel even faster, and increasingly be double-deckers. An even stronger pressure seal would make the carriages heavier. "The costs would rise and the energy consumption would be greater," explains Heine. This has to be taken into consideration if modern high-speed trains are to partially replace aircraft in the future – such as for short-haul routes within Europe.

It is for this reason that Daniela Heine began to consider not the train, but the tunnel. Pressure waves are caused by a sudden difference in pressure, which then propagates as a wave. Heine's solution is a portal equipped with vertical ventilation slots in front of the tunnel entrance to reduce the strength of the pressure waves. "With this design, the pressure should build up more smoothly, so the negative side effects of entering and exiting tunnels are minimised," she explains. To achieve the most effective solution, she has conducted trials with different designs during the course of her research. "There must ultimately be an optimal configuration, and I will find it," she states with conviction.

The portal for the tunnel entrance is made from Plexiglas at a scale of 1:30, as is the 10-metre long tunnel itself. The two-metre long ICE 3, a 1:25 scale model, is made of carbon-fibre reinforced composite. "The train was built to a larger scale than the tunnel so it is a 'tighter fit'. This enables the pressure changes to be measured more accurately," the researcher explains.

Elementary work with room for experimentation

Daniela Heine has already 'catapulted' the model train along the 60-metre long railway track and through the tunnel around 200 times. "Sometimes I work with a longer train, and other times I change the number, size and position of the ventilation slits in the entrance portal," the DLR scientist reports. It is elementary work, but with plenty of room for experimentation. "The level of realism achieved is of course much higher with actual tests than with purely numerical work. That is important to me," says the physicist from Celle.

At first, her work was directed towards studying the generation and propagation of pressure waves inside the tunnel. "I knew very little about pressure waves, so I had to 'get to know' them first," says Heine with a grin. Twenty small measurement probes installed in fixed positions in the tunnel record the pressure data during a test. Three pressure probes, an acceleration sensor and a light sensor are fitted on the train. Special software is used to record the measurements taken by the probes in the tunnel and a light-operated timing gate in front of the tunnel, and display them directly on a computer screen. "The data recorded in the train is stored on the train and then read out by the computer," Heine explains. She adds with a hint of pride: "This was specially constructed by Klaus Ehrenfried, my supervisor here at DLR."

The PhD student can use the recorded measurement data to determine the change in pressure and the pressure build-up caused by the compression wave – the wave generated by the train when it enters the tunnel. "I then compare my results with the theory and experiments described in the literature," says the researcher, describing the next stage in the process. The critical factor here is time: "How much time elapses between the formation of the pressure wave and it reaching peak amplitude? This is the quantity I want to work out." The longer it takes for the pressure wave to build up, the better – the passengers can adjust to it and the disruptive effects become less severe. "The wave must build up more slowly, so that in extreme cases the loud bang becomes a gentle pop - like opening a swingtop bottle," she says using a visual comparison. Of course, it would be much better if the acoustic shock disappeared altogether. "Not every tunnel journey involves an acoustic shock; it only happens in exceptional circumstances," the researcher clarifies.

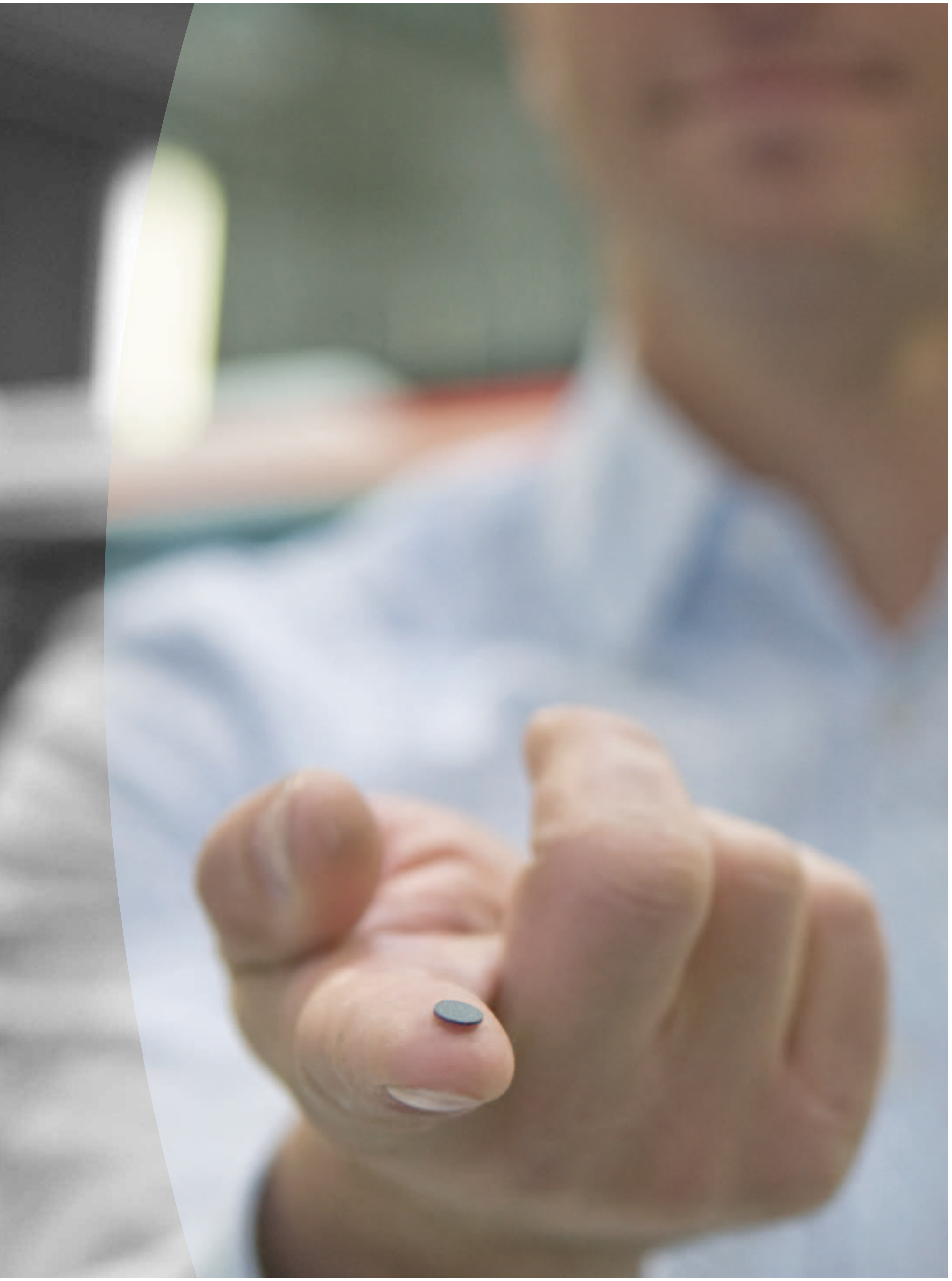
Time, speed and configuration

The pressure rise time and the configuration of the model train and the tunnel portal are important, but so is the speed at which Heine sends the train on its journey. In her tests to date, she has accelerated the model to a maximum 160 kilometres per hour on the 60-metre test track. "At some point, I want to reach 400 kilometres per hour, which is the highest speed that the catapult can accelerate a model train to," she explains. The current model train is too heavy for this, but there are plans for a lighter train. It will happen – Daniela Heine is just starting her research. ●

More information:
www.dlr.de/as/en/
http://s.DLR.de/6825
http://s.DLR.de/v3f0

The tunnel simulation facility at DLR Göttingen

An appropriate design is crucial for making trains faster and more cost-effective to operate. The tunnel simulation facility at the DLR site in Göttingen is the only one of its kind in the world, and is used for investigating the most aerodynamic shape for future trains. In the facility, scientists can research the running characteristics of model trains. When looking for an efficient method of accelerating model trains as quickly as possible, the DLR researchers took inspiration from the ancient Romans, who deployed torsion-powered arrow-shooting catapults. Model trains with scales of between 1:20 and 1:100 are catapulted to a speed of up to 400 kilometres per hour in the modern, 60-metre facility in a similar way. The latest measurement technology is used to investigate the aerodynamics of high-speed trains in a tunnel. The tunnel entrance is especially critical here – a train pushes its way into a tunnel like the piston in an air pump. This creates a pressure wave that can cause acoustic shocks. Preventing this is one of the goals of Daniela Heine's research.



Small bumps work wonders. Leading-Edge Vortex Generators (LEVoGs) – which do just what their name implies – weigh just 0.04 grams and help delay the onset of stalling.

Watching whales for better flight

For the first time in decades, DLR researchers have conducted a flight test to improve the aerodynamics of helicopters. Researchers at the DLR site in Göttingen believe they are on the verge of a significant breakthrough in increasing the manoeuvrability of helicopters. The inspiration for this aerodynamic innovation is a marine mammal – the humpback whale.

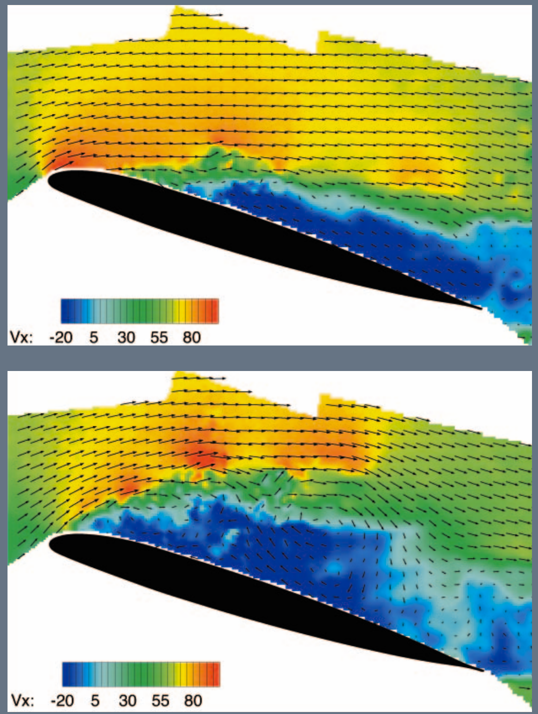
Making helicopters more agile

By Jens Wucherpfennig

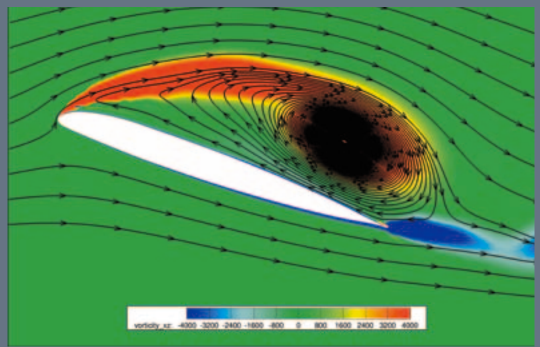
Humpback whales are notorious for their acrobatic skills – so much that they are referred to as the ocean's acrobats. The 30-ton leviathan's agility is there for all to see as it catapults its entire body out of the water. But what enables humpbacks to display this extraordinary dynamism? It has long been known that it has something to do with their large pectoral fins, but just recently researchers have established that details in the shape of the fins give these whales an advantage.

US scientists discovered that bumps along the leading edge of the whale's pectoral fins improved the flow characteristics. They ran comparisons between replicas of whale fins with and without bumps in a wind tunnel. The test showed that the bumps caused the flow over the fin to stall significantly later, resulting in higher swimming speeds and greater agility.

The US researchers did not think of applying this to aeronautics, but this idea immediately struck Holger Mai of the DLR Institute of Aeroelasticity in Göttingen when he read an article about this research on the Internet. Perhaps the 'whale bumps' could offer a solution to one of the greatest challenges facing helicopter aerodynamics – dynamic stall. This is the stalling of the airflow over the rotor blades that occurs on the retreating blades when the helicopter is flying at high speed. During the dynamic stall, large vortices are generated on the upper side of the rotor blade, causing loss of lift, an increase in drag and a very high pitching moment – which drives the leading edge of the blade to rotate downwards. In the 1930s, helicopter pioneer Henrich Focke conducted tests on a model rotor in the two-metre wind tunnel, then in use at the Aerodynamic Research Institute in Göttingen, to determine the threshold conditions at which flow separation occurs.



Wind tunnel tests show a much smaller region of flow separation with LEVoGs (blue area, upper image) than without (lower image).



Unwanted turbulence – this computer simulation shows the vortex formed above a rotor blade when flow separation occurs.

DLR SIMCOS project – predicting and controlling dynamic stall

The DLR project 'Advanced Simulation and Control of Dynamic Stall', SIMCOS, is part of the DLR-ONERA cooperation on helicopter technology. The aim of the project is to improve the prediction of dynamic stall and devise ways of controlling the flow phenomenon. Numerical methods are being further developed to optimise their implementation and bring simulation of the complexities of dynamic stall close to reality. SIMCOS is also refining the measurement techniques used in experimental testing and optimising their application. In addition, newly developed technologies in the field of dynamic stall control are being investigated. As well as the passive control technique described in this article, active techniques such as air jets are under investigation.

Read, experiment, patent

After reading the article, Holger Mai obtained a copy of the scientific publication describing the work carried out and set about testing the idea with colleagues during unused time at the wind tunnel. Could similar bumps have a positive effect on dynamic stalling, even with the complex aerodynamics of helicopters? The first improvised experiments were very promising. The researchers in Göttingen consequently patented bumps for stall control on helicopter rotor blades as Leading-Edge Vortex Generators, or LEVoGs. "Flow phenomena in water are similar to those in air, they just need to be scaled accordingly," says Mai. For this reason, the artificial bumps on the rotor blades are smaller than those on a humpback whale – they have a diameter of six millimetres and weigh just 0.04 grams.

Over the last few years, LEVoGs have been further investigated under the Advanced Simulation and Control of Dynamic Stall, SIMCOS, project, a cooperative venture between DLR and French aerospace laboratory ONERA. As part of this project, Benjamin Heine from the DLR Institute of Aerodynamics and Flow Technology has been carrying out basic research into the effects of the bumps, using numerical flow simulations and complex wind tunnel experiments. The investigations have clearly proven the effectiveness of LEVoGs. "They have had a significant effect," says SIMCOS project leader Kai Richter. "Stalling on the rotor blade occurs later and is significantly weaker. The negative influence of dynamic stall could be reduced by up to 40 percent."

Tests with the DLR Bo 105 research helicopter

The next step involved the first flight tests, carried out recently at the DLR Flight Facility at Braunschweig, and using the new bumps on DLR's Bo 105 research helicopter. For these tests, 186 rubber LEVoGs were glued to each of the four rotor blades. "The pilots have already noticed a difference in the behaviour of the rotor blades," says Richter. The main objective of this initial flight test was to demonstrate the safety of this new technique. "It was the first flight test at DLR involving helicopter aerodynamics in decades," he explains. Changes to the rotor are particularly safety-critical, and it was difficult to obtain the necessary approvals.

"Next, we will conduct a flight using a special measuring system to record the effects accurately. The helicopter industry is keeping a close eye on our development and, like us, is interested in seeing numerical evidence of its effectiveness," says Richter. If the idea proves successful, the DLR researcher hopes that existing helicopters could be retrofitted at little expense. For new helicopters, contours could be milled into the titanium leading edges of the rotor blades during the manufacturing process. ●

More information:
www.dlr.de/AE/en/
http://s.DLR.de/25bu
http://s.DLR.de/96cl

Kai Richter (left) and Holger Mai from DLR Göttingen glued 186 small rubber bumps onto each of the Bo 105's rotor blades. The research helicopter flight-tested them at DLR Braunschweig.

Cold cylinder for hot plasma

Chemical propulsion has been the traditional option for spacecraft, but electric propulsion systems are becoming an increasingly popular alternative. Between 1998 and 2001, NASA's Deep Space 1 spacecraft visited the asteroid Braille and Comet Borrelly powered by an ion engine. When the communications satellite Artemis, launched in 2001 by the European Space Agency, failed to reach its planned orbit, ion engines were used to raise it to the correct altitude. In July 2011, the US Dawn spacecraft reached the asteroid Vesta – powered across more than 320 million kilometres by the constant thrust of its ion engine. Electric propulsion systems have served these missions well, but they present a considerable problem for ground testing; in order to function, an ion engine needs to operate outside Earth's atmosphere. In a new simulation facility at DLR Göttingen, researchers will be able to create vacuum conditions replicating those encountered in space.

New simulation facility in Göttingen tests ion engines for spaceflight

By Manuela Braun

Even unfinished, the giant cylindrical structure at DLR's Institute of Aerodynamics and Flow Technology is imposing. "That is where we will install ion engines for testing." Andreas Neumann, in charge of the new simulation facility, points to an, as yet, imaginary location where electric propulsion units will be powered up. His voice echoes within the mirror-like metal cylinder. With its 12.2 metres in length, five metres in diameter and a volume of 236 cubic metres, this new vacuum chamber is the largest of its kind in Germany. This giant facility is a real heavyweight; the empty chamber alone weighs 25 tons, while the colossal cover that will seal the chamber during test runs weighs in at no less than 4.5 tons. But it is not just the vacuum of space that is simulated in the chamber. "In space, there is nothing in the region around a spacecraft and its propulsion system, something we seek to emulate by incorporating the largest possible distance between the walls of the test facility and the engine." The large internal volume of the facility enables researchers to minimise the impact of external factors on the propulsion unit being tested.

Despite its large dimensions, this test facility must be capable of performing sensitive measurements. Electric propulsion systems deliver thrust by ejecting plasma. Unlike chemically fuelled rocket motors, in which fuel and oxidiser react together to produce massive thrust for a short period of time, the thrust delivered by an electric drive is very low – tens of millinewtons, comparable to the weight of a one euro cent coin – but can be sustained for an extremely long time. To measure such small forces, the thrust scales need to be sensitive enough to register the weight of individual down feathers. Such measuring instruments require an environment as free from disrupting influences as possible in order to achieve the precision required. For the researchers at DLR, this represents a challenging and difficult task. "We have built in a lot of little tricks," explains Neumann, and the pride he feels is clear in his tone of voice.

Ion propulsion

There are several ways of developing electric spacecraft engines; their underlying operating principles are similar. A propellant gas (for example, xenon) is ionised – that is, the electrons are separated from the atoms. These electrically-charged atoms are then accelerated using electric or magnetic fields. In the simplest case, a grid carrying a negative charge is placed across the exit of the propulsion unit. This charge causes the positive ions to accelerate towards and through the grid and exit the engine at high speed, creating thrust.

Tricks to prevent unwanted vibrations

One of those tricks is that the building in which the simulation facility is located has its foundations one storey below street level to prevent the vibrations caused by vehicles on the road passing the face of the building from affecting the test facility and its instruments. To avoid deformations in the vacuum chamber itself – such as those caused by changing pressure – affecting the measurements, the body of the test facility is mounted on special bearings on concrete blocks that allow for some degree of movement. The mounting to which the propulsion unit is secured is also fixed to a concrete block that is mechanically isolated from the rest of the vacuum chamber body – this ensures that any vibrations that affect the chamber are not transmitted to the propulsion unit, or to the thrust scale attached to it. Every component of this cavernous vacuum chamber needs to be able to operate free of external influences while tests are being conducted.

"We want to measure something precisely – how much thrust is the ion engine delivering?" A special measuring device works in much the same way as a laboratory scale, and is capable of registering even minute amounts of thrust. 'Thrust scales' such as those in the Göttingen test facility are sufficiently sensitive to register an earthquake occurring many kilometres away. Even the cables that need to be fastened to the scale can induce errors unless the researchers exercise great care and attention to detail while installing them. All activities need to be planned here, right down to the last detail. Another crucial factor is the direction in which the thrust is being exerted. "This is no trivial matter with electric engines," states Neumann emphatically. During tests, the thrust vector measurement provides information on how the propulsion unit will perform when in service – when operating in space. Two ring-shaped sensor systems in the chamber rotate around the electric engine while it is in operation and analyse the plasma beam.

The new facility should also enable researchers to examine whether or not the electrically charged propulsion exhaust has any adverse impact on the rest of the spacecraft. "What exactly does this plume of exhaust gas look like? To what extent does it propagate? Might the emissions from the propulsion unit have an effect on the solar panels?" These are just a few of the questions asked by the DLR researchers, all of which are to be answered by the tests conducted in this new facility. If a solar panel were to be damaged by the engine plume, the entire mission could be endangered. But if potential hazards like this can be identified by testing here on Earth, it will be possible to remedy them before flight. The measuring techniques capable of delivering such precise analyses are currently being developed to work accurately with the simulation facility.

An electric engine will be run in the facility for a year, or perhaps longer, to deliver the data needed by the researchers. This will closely approximate the actual service life of these propulsion units when in space: an ion drive is likely to operate for up to 15,000 hours during a mission. "Our team is going to be hard at work throughout this time, running and monitoring the test facility, as well as collecting and processing the data." The DLR facility operators and researchers can apply the experience gained with the adjacent simulation facility for chemical propulsion, which has been in operation at the Göttingen site for the last 30 years. The test facility for electric thrusters has many factors in common with its predecessor, such as vacuum technology, model calculations or even the operation of such a large system: "We still need to gain a truly precise understanding of the features unique to electric propulsion."

Refrigerated wall to capture particles

A complex pumping system maintains the chamber vacuum during test runs; liquid helium pumps extract the tiniest remnants of gas. "As soon as the propulsion unit starts to operate, and therefore to produce gas exhaust, these pumps really need to work flat out to maintain the vacuum within the chamber," explains Neumann. 'Pull-ups' are how the facility manager describes the work that the pumping system is called upon to perform. In addition, sections of the vacuum chamber are cooled down to minus 260 degrees Celsius. The particles in the background gas and expelled plasma freeze when they come into contact with the back wall of the simulation facility - this prevents them from ricocheting off the wall and back to the propulsion unit and its surrounding environment. A specially-shaped, graphite-coated replaceable cover protects the back wall of the chamber, on the opposite side of the ion engine. "The ions in the beam travel at very high speeds, so they ablate material from objects that they hit," says Andreas Neumann, explaining this precautionary measure.

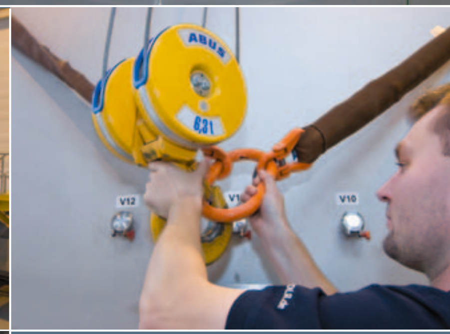
Although similar test facilities already exist in Europe and the United States, "our test facility achieves a uniquely high vacuum and, therefore, very closely simulates the conditions encountered in space," states Klaus Hannemann, manager of the Spacecraft Department at DLR Göttingen. With their existing simulation facility for chemical propulsion systems and their newly built facility for ion engines, the researchers in Göttingen are now able to cover a broad spectrum of satellite propulsion systems. The new facility has been built to address specific current needs, but has also been tailored to meet future requirements. "We asked the space industry to explain what issues had not been covered in previous tests on ion drives, so that we could address them," recounts Hannemann. "Also, the chamber has been designed in such a way that a wide range of different electric engines can be tested with it – including types that are currently only at the development stage."

Under way with plasma power

The next missions to fly with electric propulsion systems are already under construction. For example, the European Space Agency intends to use ion engines on a small geostationary communications satellite known as 'Small GEO'. The Euro-Japanese BepiColombo spacecraft will employ various propulsion options, including an electric system, on its journey to Mercury. "While it is true to say that ion drives only deliver a tiny amount of thrust, they use their fuel very efficiently and, when used over an extended period, they are able to accelerate spacecraft to very high speeds," says Hannemann. "This is why they are so eminently suited to interplanetary missions. Another core area of their application is satellites in geostationary orbits. Corrective manoeuvres need to be carried out continuously to compensate for deviations from orbit caused by the Sun and the Moon – and this is where ion drives, by virtue of their high efficiency, can substantially extend a satellite's service life." He is sure of his ground. It is already apparent that the demand for ion propulsion units is bound to increase. "It is not a question of whether electric drives are going to replace chemical ones. Instead, it has much more to do with how their respective strengths can be utilised to best effect, in combination, on a satellite. This development has real potential for the future."

The first run scheduled for the vacuum chamber in the new simulation facility involves a prototype engine. In years to come, following completion of their tests, propulsion units of this type will be used in space – having first encountered space conditions in Göttingen. ●

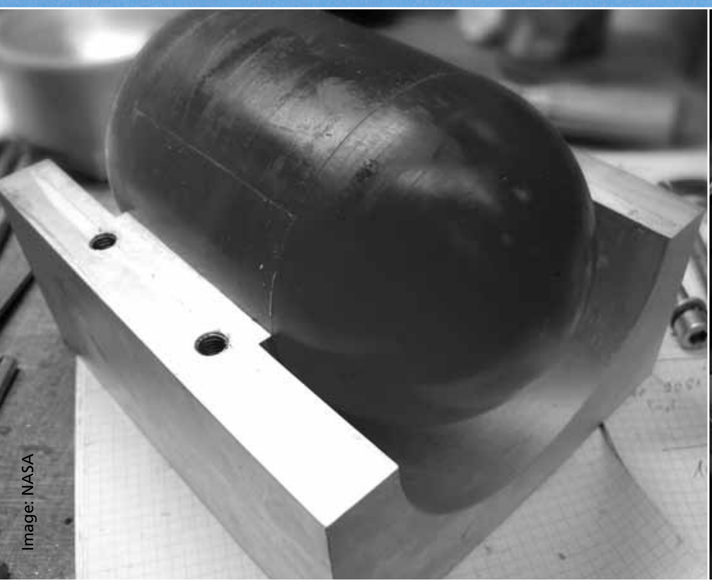
More information:
www.DLR.de/as/en



Before researchers create a vacuum nearly as good as the one in space, the chamber must be sealed and prepared for use.

Andreas Neumann is responsible for the new electric propulsion systems simulation facility in Göttingen; his team is planning the first test runs with ion engines.

External stores on the lower side of HALO's fuselage, shown in the top image, must be resistant to bird strike. A gelatin body is used to simulate the bird (bottom left). For these experiments, DLR uses a high-velocity gas gun at its Stuttgart facility (bottom right).



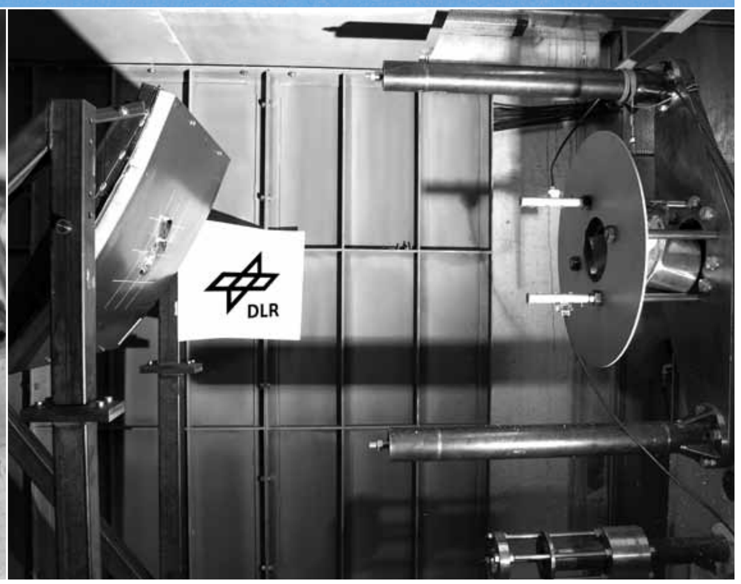


Image: NASA

Certified bird-proof

The High Altitude and LOng Range Research Aircraft, HALO, is one of the German Research Foundation's flagship projects. Its modular concept enables fast exchange of the numerous experiments carried on board. Some of the experiments involve installing instruments in specially designed containers on the fuselage and wings. To be certified for flight operation, these containers must be able to withstand bird strike – a challenge for the DLR engineers, which was addressed using new design approaches and manufacturing techniques for composite materials.

Special additions to the HALO research aircraft protect instruments against bird strike

By Dominik Schwinn and Jan-Henning Niediek

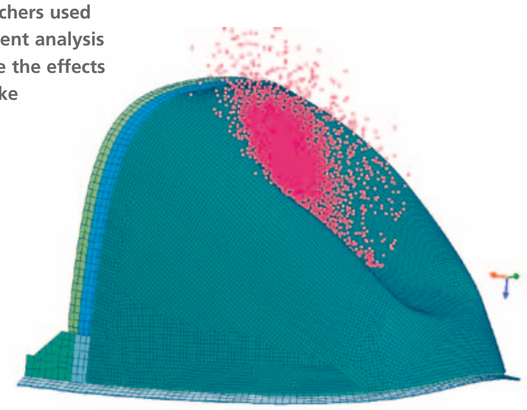
HALO was converted from a large business jet to an atmospheric research aircraft under the aegis of DLR. It needs to be able to carry out multiple experiments simultaneously, and for that reason it needs space. Depending on its configuration, the interior offers a generous 20 to 30 square metres for the instrument systems and scientists. The alterations inside the aircraft, which is used by a large number of German research institutes for their experiments, have been complemented by a number of modifications to the fuselage and wings. The Gulfstream G550 aircraft has been fitted with external stores under the wings (wing pods and sensor mountings) and under the fuselage (belly pod). To compensate for the aerodynamic influence of the belly pod, a second attachment, known as a ventral fin, was added to the rear of the fuselage on the belly of the aircraft.

Such extensive changes entail a complex certification process because the aerodynamic characteristics of the aircraft are altered by these add-ons – and the safety of the passengers and crew is always the highest priority. The structural integrity of the hull is also tested. Prior to approval, manufacturers must intensively test newly developed aircraft under extreme loads – as can occur in certain locations as a result of bird strike. If the aircraft is subsequently altered, the new parts must pass the same tests.

The additions to HALO, which were developed through collaboration between various DLR institutes, had to be manufactured using very special materials. Two different approaches have been undertaken to absorb the high energy from bird strike; tapered components are designed to split up the impacting object in order to keep the energy transfer during the collision to a minimum, thus reducing the shock loads on the component. An innovative shell for the round shape of the belly pod was also developed; two layers of fibreglass mesh and self-reinforcing polypropylene are combined using a technique especially optimised for this particular type of application. In the case of a bird strike, the energy is transferred into the structure, which deforms and therefore decelerates the impacting object, which is then deflected.

While a development like this is being formulated, a number of numerical models are simulated using finite element methods and then validated against experimental tests. To achieve realistic results, the engineers generate high-velocity impacts of gelatin having the mass of a 'standard' bird on the component under test. Following the agreement between the calculated deformations and those measured in the tests, one element – the ventral fin – was granted approval based solely on these results. This 'virtual' certification represents a milestone on the route to fully computer-based analysis and certification in aircraft manufacture. ●

DLR researchers used finite element analysis to calculate the effects of bird strike



About the authors:
Dominik Schwinn is an aerospace research engineer at the DLR Institute of Structures and Design; he led the design process of the HALO external stores that required bird strike simulations. Jan-Henning Niediek is a prospective technology journalist, and completed a student internship at the DLR Corporate Communications Department.

Unveiling the ‘invisible’

In spite of their size – sufficiently small to be imperceptible to the human eye – nanoparticles are making a big impact. Be it in medicine, civil engineering, chemistry or – as at DLR – in the aircraft and vehicle construction sectors, little ‘nanos’ are on their way to becoming the next big thing. Researchers are imbuing these tiny particles with desirable properties, thus creating significant benefits.

Nanoparticles – microscopic all-rounders whose potential DLR researchers in Braunschweig are unlocking in a ‘virtual institute’

By Jasmin Begli

Christine Arlt and Wibke Exner, excited about the ‘invisible’. The DLR Institute of Composite Structures and Adaptive Systems is exploring the capabilities of nanoparticles.

Nanoparticles

‘Nanoparticle’ is a term used for particles that are less than 100 nanometres across. A nanometre corresponds to 10^{-9} (0.000000001) metres. Ceramic, carbon or gold – in theory any material can exist in the form of nanoparticles and be used accordingly.

Wibke Exner with the ‘protagonists’ of her current research: transparent, liquid synthetic resin and nanoparticle powder.

Researching the invisible

“A metre is to a nanometre as Earth is to a hazelnut,” says Christine Arlt, Deputy Director of the DLR Institute of Composite Structures and Adaptive Systems in Braunschweig. A nanometre is a millionth of a millimetre, or 10^{-9} metre, and a nanoparticle is made up of just a few thousand atoms. These tiny particles only become visible under an electron microscope.

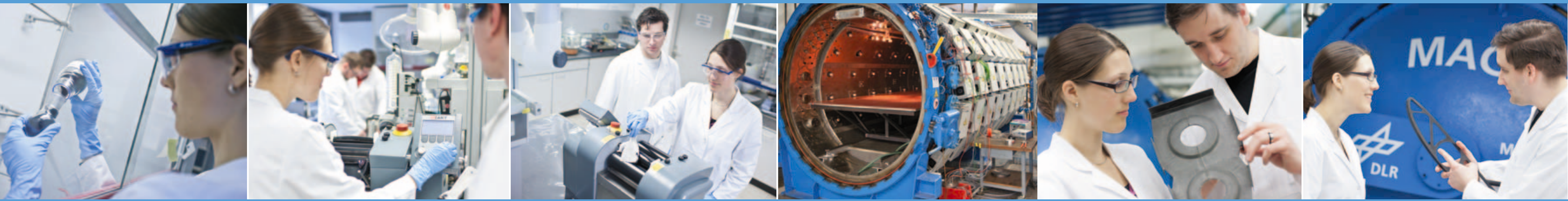
The DLR Institute of Composite Structures and Adaptive Systems has been studying the use of nanoparticles – primarily in aircraft construction – since the year 2000. The possibilities offered by these miniscule particles are also highly valued in the automotive industry. These primarily involve increasing the strength of materials and giving them other desirable characteristics.

Lighter composites with nanoparticles

DLR researchers are working on integrating nanoparticles into carbon-fibre reinforced composites – considered to be the material of the future for aircraft and vehicle manufacturing. Lighter and stiffer than aluminium, they are already used in some aircraft components. “Until now, composites have been used in fairly thick layers for aircraft construction, to ensure the highest levels of rigidity,” explains Christine Arlt. “The nanoparticles will strengthen the material even further, and the use of lightweight composites can be made more efficient as they will be able to be installed in thinner, even lighter layers. In addition, we can integrate selected properties into the particles.”

Shaken and stirred

Fibre-reinforced composite materials consist of fibres that are embedded in a polymer matrix. To improve this material using nanoparticles, DLR researchers must incorporate the nanoparticles into the liquid polymer resin in powder form before the resin is cured. But nanoparticles have a tendency to agglomerate into ‘clumps’; this is undesirable, as the particles only exhibit their capabilities when evenly dispersed in the resin. Therefore, the nanoparticle powder is stirred into the resin using special machines that not only produce large forces, but can sometimes use



The nanoparticle powder is stirred into the resin using special machines that use rollers. The carbon fibre is impregnated with the nanoparticle-containing resin and is molded in the shape of the desired component. The component is then hardened at high temperatures in an autoclave. Finally, the researchers examine the finished component.

The nanoparticles are homogeneously distributed in the plastic resin. In this case, the material is black because the nanoparticles are carbonaceous.

rollers or grinding beads to separate the nanoparticles from one another. When the mass is homogeneous and the nanoparticles are well distributed throughout the liquid resin, the researchers combine the resin and carbon fibre in the shape of the desired component. They saturate the fibres with resin and harden the component at high temperatures in an autoclave. Manufacturing of the basic composite component, reinforced with nanoparticles, is then complete.

Material matters

Different materials produce different results. Ceramic nanoparticles, for example, are particularly well suited for use in the area of material strength. When incorporated into the resin, the composite becomes stronger and more stiff; its fatigue properties and impact resistance are improved and components can be made thinner. Since this saves material and weight, it makes flying more environmentally friendly.

In the vehicle construction sector, the new, lightweight materials can be used for bodywork components. At present, fibre composites cannot be exploited optimally due to the indentations that form on their surface when the liquid resin is curing; post-processing of the components is made more complicated. "To get a smooth, even paintwork finish, the indentations must be smoothed out in an additional production process," says Wibke Exner, explaining the project. "Nanoparticles can save work here, because once stirred into the resin they can, under the right conditions, make the surface of composite bodywork components more uniform and, ideally, indentation-free." The team is investigating ways of optimising the materials for this purpose and is making progress on a daily basis.

Fire protection and damage visualisation

Nanoparticles have the ability to exhibit particular properties under specific conditions. One example from the research conducted at DLR is fire protection. When the nanoparticles used for this research are subjected to high temperatures, they decompose and water is released. If nanoparticle powder with this property is incorporated into liquid resin and then made into a composite component, the heat from a fire destroys the component. However, the release of water cools it, delaying the spread of the fire and restricting the generation of heat, gaining time – valuable time in which lives could be saved.

Damage to composite materials can also be detected early using nanoparticles with special properties. Colour particles are embedded in nanocapsules that are activated when the material is damaged. Cracks in the skin of an aircraft, for example, could be recognised immediately using this technique. But the DLR researchers want more – they do not just want to release coloured particles in the event of damage, they also want the nanoparticles to be able to 'heal' damage to a composite component. For this, the nanoparticles would contain substances that effect repairs in the event of their exposure as a result of a crack. Though there is still work to be done in this field, it is possible with the help of nanoparticles. "This is fascinating," says Exner enthusiastically. "We can give the nanoparticles even more amazing properties with a range of uses, even though they are virtually invisible."

Force measurement

Nanoparticle research at DLR is also carried out in the field of sensor technology. This involves measuring the forces acting on or in a composite component. This is important for load tests, for example. The researchers are working with tiny piezoelectric crystals for measuring force. We encounter piezoelectric elements every day – in lighters, for example, where they create the sparks that ignite the flame. By mechanically deforming a piezoelectric crystal, its polarisation can be changed. This generates a voltage at the surface of the crystal, which can be measured. This also means that mechanical loads in composite components containing piezoelectric crystals can be converted into an electrical signal. The researchers measure this signal to obtain information about the magnitude of the forces being exerted. The force transducer is integrated into the material, so there is no need to employ sensors that are applied after manufacture and that, in many cases, are disruptive.

Teamwork engenders success

At present, 25 people work at the multifunctional materials department of the DLR Institute of Composite Structures and Adaptive Systems in Braunschweig. Five of these are researching ways to improve and continue developing nanoparticles. They come from mechanical engineering, materials research and chemistry backgrounds. "We work in an interdisciplinary environment here," says Wibke Exner, who studied chemistry. "The materials researcher cannot manage without the chemist, and neither of them can do without the mechanical engineer, and vice versa. Also, we must work outside our own specialist area. There is plenty of variety."

The work varies between theoretical work at the computer and practical work in the laboratory, but because the object of their research is 'invisible', discrepancies sometimes occur. "Nanoparticles are always good for surprises," says Wibke Exner. "When stirring in the nanoparticle powder, the effect is not visible immediately because the nanoparticles are too small to see." The material can also suddenly harden during the stirring process, or perhaps will not cure when it is supposed to. "This is sometimes difficult, because you cannot always see the problem straight away. But of course this is also part of the fascination of nanoparticles. And when in doubt, your colleagues can give you the critical clue," says the researcher.

A 'virtual institute'

The DLR experts do not just have regular exchanges of information amongst themselves. The DLR Institute of Composite Structures and Adaptive Systems collaborates with other renowned nanoparticle researchers in a 'virtual institute' as part of the Helmholtz Association of German Research Centres. The Helmholtz Association regularly solicits proposals for 'virtual institutes', in which the sharing and pooling of knowledge is sponsored for periods of three to five years. The 'Virtual Institute' of Nanotechnology in Polymer Composites was created in 2008 under the auspices of DLR. "We have been working with our partners from research and industry, holding discussions and conferences and much more for over three years," says Christine Arlt. In addition to her activities at DLR, she is the current spokesperson for the 'Virtual Institute', which will remain in existence after the Helmholtz sponsorship ends. "Without the intense, mutual exchanges, where each partner is a specialist in a different area, we would never have made so much progress in nanoparticle research," Arlt says. The concept of the virtual institute has worked perfectly here; much more has been achieved than would have been the case had everyone been working independently.

Looking to the future

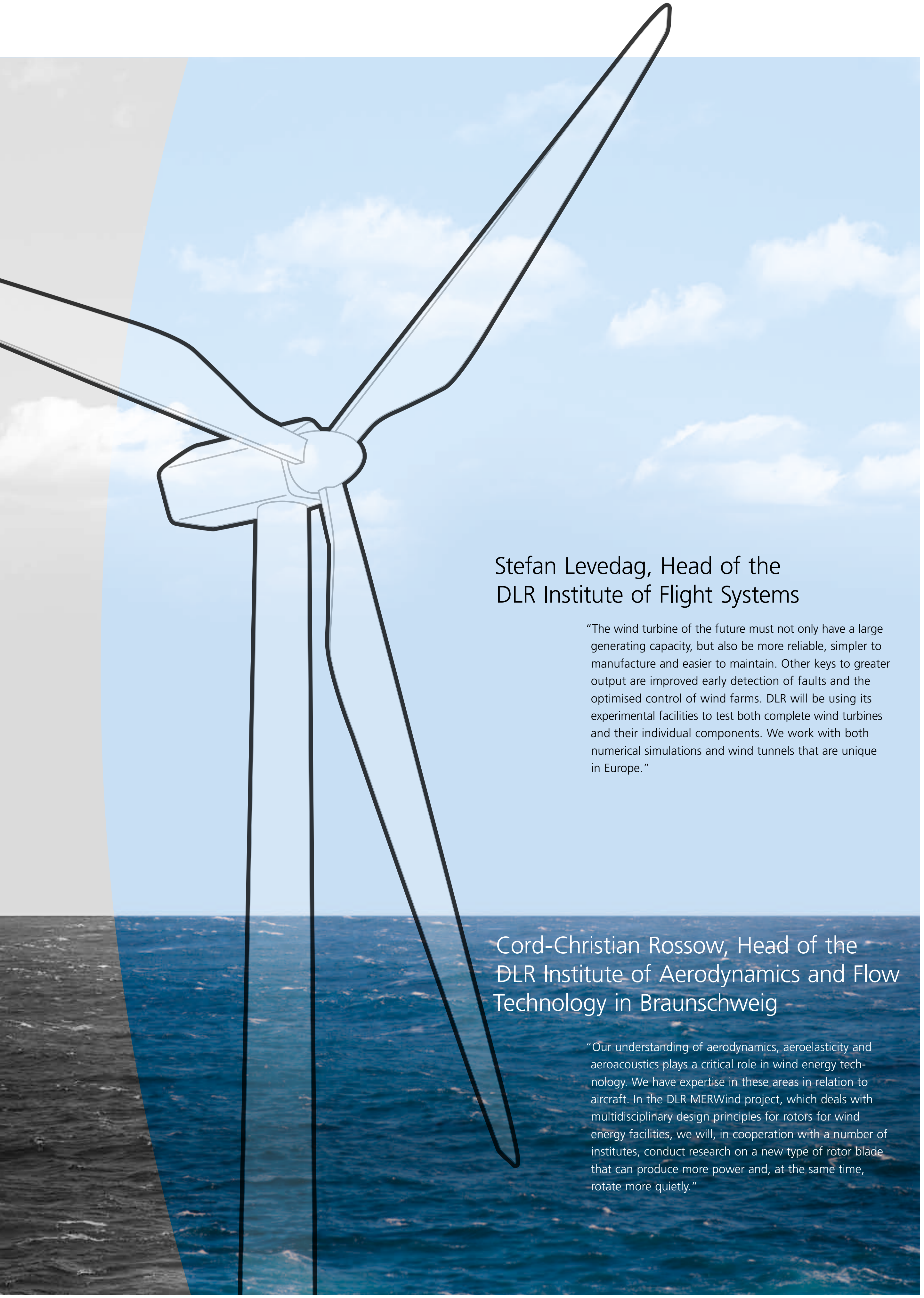
Prospects for the future and ideas for improvement have arisen at the 'Virtual Institute'. "We could do worse than study nature for ideas for further nanoparticle research," says Arlt, looking to the future. "A spider's web is elastic and stable because it contains a very specific arrangement of nanoparticles. We need to work on applying and positioning the particles in a targeted manner so we can consciously influence the way they are arranged and thus their particular capabilities," she says.

Back to work at the DLR institute in Braunschweig, it does not trouble the nanoparticle researcher that the results of her research will not actually take to the air for another 10 or 20 years. "This is normal in aviation," explains Exner. "The safety requirements are so high that innovations are only allowed to fly once they have undergone extensive, time-consuming tests. Its application to the automotive sector will happen more quickly." Until then, the team will continue researching the tiny particles that are so hard to see and yet are so effective, and will consider what useful properties can yet be given to the nanoparticles – always with the goal of making air travel safer and more environmentally friendly. ●

Virtual Institute

The 'Virtual Institute' of Nanotechnology in Polymer Composites was established in 2008 under the auspices of the DLR Institute of Composite Structures and Adaptive Systems. Other partners include the Technische Universität Braunschweig, the Technische Universität Clausthal, the Leibniz Universität Hannover and Aerospace & Advanced Composites GmbH of Seibersdorf, near Vienna. The project has been a great success and will be continued after the Helmholtz Association funding expires.

More information:
www.dlr.de/fa/en



Stefan Levedag, Head of the DLR Institute of Flight Systems

"The wind turbine of the future must not only have a large generating capacity, but also be more reliable, simpler to manufacture and easier to maintain. Other keys to greater output are improved early detection of faults and the optimised control of wind farms. DLR will be using its experimental facilities to test both complete wind turbines and their individual components. We work with both numerical simulations and wind tunnels that are unique in Europe."

Cord-Christian Rossow, Head of the DLR Institute of Aerodynamics and Flow Technology in Braunschweig

"Our understanding of aerodynamics, aeroelasticity and aeroacoustics plays a critical role in wind energy technology. We have expertise in these areas in relation to aircraft. In the DLR MERWind project, which deals with multidisciplinary design principles for rotors for wind energy facilities, we will, in cooperation with a number of institutes, conduct research on a new type of rotor blade that can produce more power and, at the same time, rotate more quietly."

Power for tomorrow

Aircraft are driven forward by the reaction to airflow generated by their turbines and fans; researchers at DLR understand this process well. The laws that apply here are also valid during the reverse of this process, when an existing airflow drives a wind turbine to generate power. DLR researchers will be making greater use of their expertise to design more efficient, quieter and lighter wind turbines. This will involve close collaboration between the areas of aeronautics, energy and materials research.

DLR researchers have an excellent understanding of turbines; now they are working on the wind turbine of the future

By Dorothee Bürkle

Wind energy is considered one of the most important technologies for sustainable energy supply. Whether on land or at sea, wind energy contributed the largest amount of power generated from renewable energies in Germany in 2011 – 7.6 percent. By 2030, wind power is expected to supply more than 30 percent of power demand. Achieving this goal requires not just expanding wind parks and building them offshore, but also significantly improving the performance of wind farms. At the same time, the turbines need to rotate more quietly and the manufacturing and maintenance costs must be reduced. Companies in this sector, which have to contend with increasingly tough competition in international markets, are extremely interested in new developments. With its expertise, DLR can respond to many of these challenges.

Lighter and larger

Experts estimate that, in the future, individual wind turbines will have a capacity of up to 20 megawatts. If turbine plant manufacturers were to increase the output of one of today's wind turbines to this extent, each individual rotor blade would be 100 metres long and weigh more than 100 tons. Companies in this sector know that this performance cannot be achieved with current designs; the materials employed and the fabrication methods must both be adapted. For example, the glass-fibre reinforced composite materials used for rotor blades thus far are not suitable. Such a rotor blade is not only too heavy, but also insufficiently rigid to maintain the blades at the necessary minimum distance from the tower as they bend under wind load. Researchers at the DLR Institute of Composite Structures and Adaptive Systems are developing rotor blades with a high carbon fibre content, which will be five times stronger and stiffer than those available now. They also want to use intelligent materials and special sensors to control the rotor blades so that they do not need to be feathered even when exposed to very strong gusts. The DLR Institute of Flight Systems will also use its research results to contribute to this topic.

How does the wind flow around a turbine?

Expertise in wind energy at DLR also comes from remote sensing technology. At the Institute of Atmospheric Physics, researchers are working with satellite data to produce more precise predictions of wind speeds at the locations of individual turbines or wind farms. Operators can use these predictions to optimise control of their turbines and, above all, precisely predict the power input to the grid. Using optical scanning systems – lidar systems – researchers can also record the wind flows and their interactions within an entire wind farm, making it possible to improve the design of future wind parks. ●

Participating DLR institutes:

Institute of Propulsion Technology

Institute of Composite Structures and Adaptive Systems

Institute of Aerodynamics and Flow Technology

Institute for Aeroelasticity

Institute of Atmospheric Physics

Institute of Structures and Design

'Rumble in the jungle'

A nine-hour flight from Paris and surrounded by tropical rainforest and the coast of the Atlantic Ocean lies French Guiana. This is where Europe's spacefaring nations launch their rockets and where the Galileo satellites that Europe is using to develop its own global navigation system depart from.

Guiana Space Centre – Europe's gateway to space

By Elisabeth Mittelbach

It is 32 degrees Celsius in the shade and the relative humidity is 85 percent. Thick jungle and mango swamps are all around, as are mosquitoes. Eleven kilometres from the mainland lie three small islands, used as a penal colony by the French from 1852 to 1951. In the middle of all this are several hundred Europeans, the majority working at the Centre Spatial Guyanais, CSG, Europe's spaceport 500 kilometres north of the equator.

French Guiana is almost the size of Austria and, though it borders on Surinam, Brazil and the Atlantic it is actually part of Europe. In this overseas department of France, 7000 kilometres from Paris, French is being spoken, the currency is the Euro and one can find baguettes, croissants and French cuisine.

Launchers and their payloads travel several kilometres on railway tracks to reach the launch pads

Its proximity to the equator makes the site, near the small town of Kourou, an ideal place for rocket launches. From here, the launch vehicles are further accelerated by the rotation of the Earth and they can lift heavier payloads into orbit using the same quantity of fuel than is possible from other launch sites further from the equator, such as Cape Canaveral or Baikonur. The rockets are launched east or north over uninhabited territory, directly towards the open ocean. Satellites can reach the most important orbits – geostationary transfer orbit and Sun-synchronous polar orbit.

Along the Route de l'Espace, spread over 50 kilometres, are the three enormous launch complexes of Europe's spaceport; one for the European heavy-lift launcher, Ariane 5, one for the Russian Soyuz rocket and one for the new European Vega rocket used for smaller payloads. It is principally satellites that begin the journey here, from beside the 50-metre high launch towers, but so does the European Automated Transfer Vehicle, ATV, used for carrying freight and fuel to the International Space Station. Assembly halls and satellite integration buildings are positioned a safe distance away from the launch pads. Within them, specialists check and assemble the individual components of various rocket systems, before the payload is integrated and the rockets are rolled out to their launch pads on rails. Most of the fuel and solid-propellant boosters used to generate additional thrust for the launches are manufactured directly on site.

Views of Europe's Spaceport in French Guiana (from left): Erection of the first Soyuz launcher in its launch complex, aerial photograph of the Soyuz launch vehicle that carried the first two Galileo satellites into orbit on 21 October 2011, and an Ariane 5 (far right) during launch.

In total, the site is roughly the size of New York City. Twelve kilometres from the Ariane 5 launch pad lies the entrance to the spaceport. The European Space Agency has an outpost here – including a spaceflight museum for quiet contemplation and the Jupiter control room. Every Ariane launch is tracked and controlled from here. Are the weather conditions suitable for launch? Are the launcher and its payload functioning correctly? Have the range safety requirements been met? Are all the control lights green and can the launch go ahead? The rocket is monitored until its payload has been safely delivered into orbit, and the relevant control centre takes over.

Shiny white models of the Ariane 5, Soyuz and Vega are showcased in front of the window separating the observation area from the actual control room. They convey an impression of their relative sizes. Ariane 5 transports heavy loads. For example, an ATV flight might need up to 20 tons lifting to an altitude of 400 kilometres to reach the ISS. With satellite launches, Ariane is configured in such a way that it can place payloads of up to 10 tons in geostationary transfer orbits. From here, a satellite can reach its intended position at an altitude of 36,000 kilometres.

First Ariane flight in 1979

Outside, the Sun is beating down; the tropical heat smothers one like a blanket. It is easier to think clearly in the air-conditioned halls and office buildings. This is where I meet Thomas Ruwwe; he normally works in the DLR Space Administration's Launchers department in Bonn, but is in Kourou on business, and he knows the spaceport well. "Ariane 5 is the biggest rocket launched from Kourou. The latest version consists of over 160 major components and subsystems, manufactured by over 350 companies in Europe," the engineer says enthusiastically. He effortlessly translates every acronym, of which there are many at CSG: ELA, MIK, BIL, BIF and BAP – these are the abbreviations for the various assembly buildings, integration halls and launch pads.

Since its inaugural flight on 24 December 1979, Ariane has established itself as Europe's most reliable 'taxi' into space. "Ariane 4 launched 119 times between 1988 and 2003; 116 of those were successful. Ariane 5 has been in use since 1996 and has launched 60 times so far," says Ruwwe. There are currently seven Ariane launches, three Soyuz launches and one Vega launch planned for 2012. "By launching near to the equator, the Soyuz rocket can carry heavier payloads into space," explains the expert. Commercial customers can be offered an alternative to Ariane 5 for medium-weight payloads.

Thomas Ruwwe regularly travels to Kourou to learn about the developments and missions at the spaceport and to talk to employees of companies based here, as well as ESA and the French space agency CNES. "Germany contributes 18.5 percent of the fixed costs of CSG and bears 22 percent of the Ariane development costs," he says. "So it's important to consolidate the role of the German Prime Contractor team in the development of the new upper stage, to set the work packages for German industry and to keep an eye on the budget."

Tight control of the ecosystem at the rocket launch site

His contacts also include the employees of Arianespace, the Ariane operating company. One of them is Hans Zeller. The aerospace engineer from Germany has led over 30 Ariane launches and today is Representative for ESA Programme

Centre Spatial Guyanais

1964: French space centre founded in Kourou, launch of the Véronique altitude research rocket

5 November 1971: Single launch of a Europa-2 rocket from the ELE (l'Ensemble de Lancement Europa) launch pad

1975: European Space Agency (ESA) founded

1975-1978: Conversion of the ELE launch pad for the inaugural launch of an Ariane 1 on 24 December 1979

1979-1989: A total of 28 Ariane rockets of types 1 to 3 launch from the ELA-1 (l'Ensemble de Lancement Ariane) launch pad, of which three are failures; afterwards the ELA-1 launch pad is decommissioned

1988- 2003: Construction of the new ELA-2 launch pad and launch of 119 Ariane 4 rockets, including three failures; ELA-2 launch pad subsequently decommissioned

Since 2004 the redeveloped Ariane 5 has been launching from the new ELA-3 launch pad

January 2005: Start of construction work for the Soyuz launch pad (ELS, l'Ensemble de Lancement Soyouz); inaugural launch of a Soyuz rocket on 21 October 2011

End of 2004: Start of work to convert the decommissioned ELA-1 launch pad into a launch pad for the Vega carrier rocket for light payloads

A different French Guiana: the Îles du Salut with the ruins of the former penal colony. The photograph shows the remains of the cemetery on the Île Saint Joseph.

About Kourou

Genoese seafarer Christopher Columbus discovered the coast of Guiana in 1498. About 100 years later, European immigrants started to settle there - first the Dutch, followed by the French and English as of 1604. As compensation for Portugal's defeat in the Orange War, the region was conceded to France in 1801.

In 1946 French Guiana became an overseas department with limited autonomy. It was known for Devil's Island, a penal colony lying 15 kilometres off the coast (the Îles du Salut). Up to 70,000 people were incarcerated there between 1852 and 1951. Many prisoners did not survive the exile.

		Mission	Height	Payload weight	Launch weight
Ariane 5	Ariane 5ES	ATV / ISS for heavy payloads of up to 20 tons into ISS orbit (400 kilometres)	50.5 metres	up to 20 tons	777 tons
	Ariane 5 ECA	Double launches of commercial satellites for distant geostationary orbit (36,000 kilometres)	50.5 metres	ca. 9.7 tons (single)	780 tons
Soyuz		ESA programme for the use of Soyuz in European missions with a medium payload as an addition to Ariane 5	47 metres	2.7 – 3 tons	311 tons
Vega		European carrier rocket for light payloads in low Earth orbit (200 to 1200 kilometres)	29.9 metres	1.5 tons	136 tons

Relations and Governmental Affairs at Arianespace. "My first day at Arianespace was 1 October 1989 – 10 days later I was in French Guiana," Zeller remembers with a laugh. Then he gets serious again: "A rocket launch is highly complex. The preparations here in Kourou are carried out by highly qualified teams and take many weeks – my longest launch campaign lasted over two and a half months. I arrived in October and got back to my family in Paris two days before Christmas," says the Bavarian.

ESA started developing the French space centre into its spaceport in 1975. It pays around two thirds of the annual operating costs and controls the European space missions in Kourou. However the 'landlord' since the foundation of the Centre Spatial Guyanais in 1964 is still CNES. It watches over the entire infrastructure and maintains close contact with the population. The spaceport is part of everyday life for people in and around Kourou. The occasional powerful rumble when a rocket launches is no longer unusual to them.

Specialists such as CNES environmental engineer Ann-Margret Amui-Vedel scrutinise every launch: "We investigate the air and water quality, as well as vibrations and noise, and observe and document the development of flora and fauna at the spaceport," she explains as she trudges through the savannah on the CSG site with a group of visitors. "All our studies have shown an impact on the environment, but that is true of all industrial usage. However, the effects are normally restricted to one kilometre around the launch zone." The variety of species and the ecosystem at CSG remain intact: "We have some 500 different species of birds here, as well as several hundred species of tree and 20 to 30 species of fish," comments Amui-Vedel. The birds in this area try to build hanging nests in the vicinity of the lightning protection systems. They have grown accustomed to this atypical environment; they fly away as the rockets make their way to space and "they return about an hour after a launch," the environmental engineer says. ●

More Informationen :
www.esa.int
www.cnes-csg.fr
www.arianespace.com
www.guyane.pref.gouv.fr (French)
http://mairie.kourou.info/web (French)

The European Spaceport is located on French soil. The fire brigade comes from Paris.

The launch facility covers an area the size of New York City; jungle also forms part of the scene.

Volker Schmid is responsible for the ATV space transporter in the DLR Space Administration team

En route to the Space Station with a heavy payload

The third and, to date, largest and heaviest space transporter, named after the Italian physicist Edoardo Amaldi, lifted off from Kourou to the International Space Station, ISS, on 23 March 2012 atop an Ariane 5ES launcher. Volker Schmid, Manager of the ISS division at DLR Space Administration, gives some details of this mission in a brief interview.

Mr Schmid, what is 'Edoardo Amaldi's' mission?

Like all ATVs, part of the mission of 'Edoardo Amaldi' is to supply the astronauts on board the ISS with food, drinking water and air, while also taking fuel, spare parts and experiments up to the Space Station. But the freight on board ATV-3 is somewhat different to that of its predecessor, the 'Johannes Kepler'. One of the key components of the ATV-2 mission was to raise the orbit altitude of the ISS by 50 kilometres. On the other hand, ATV-3 Edoardo Amaldi is delivering more dry freight, such as food and clothing. The spacecraft will be transporting a total of approximately 6.6 tons of freight to the ISS, including 100 kilograms of air and about 285 kilograms of drinking water.

How long will ATV-3 remain docked with the ISS?

Docking took place on 28 March 2012. After five months at the ISS, 'Edoardo Amaldi' will undock. Re-entry into Earth's atmosphere, where the third of a total of five European space transporters will burn up and disintegrate, is scheduled for early September 2012.

What is Germany's role in the ATV programme?

ATV is a joint European project run by the European Space Agency. The DLR site in Lampoldshausen is where tests needed for ATV missions were conducted on the re-ignitable upper stage engines on the Ariane 5. DLR Oberpfaffenhofen is the communication hub for all the control centres involved in ATV operations, which are located in Toulouse, Moscow, Houston and Redu, in Belgium. In overall terms, about 40 companies from 10 European countries, Russia and the United States supplied parts and components. German companies were responsible for about 48 percent of the manufacturing. DLR Space Administration is responsible for programme control and for representing German interests in ESA's ISS programme.

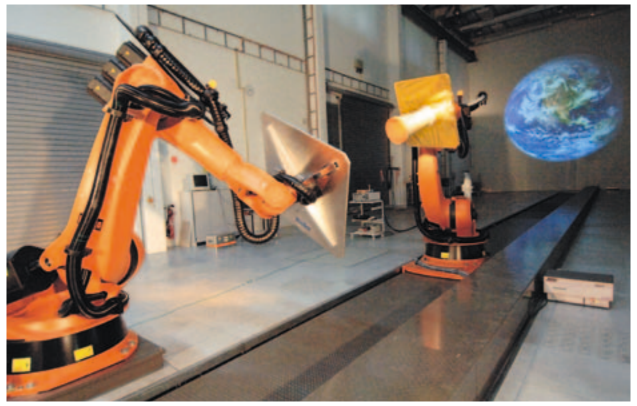
Salvage in space

As the robotic chase craft carefully approaches its irregularly spinning target, both objects gleam in the intense sunlight against the blue Earth and a black space backdrop.

DLR's Institute of Robotics and Mechatronics is planning a mission to demonstrate a robotic rendezvous in orbit

By Sean Blair

Drawing near, the advancing vehicle extends its jointed robotic arm, skilfully matching the target's spin before closing its 'fingers' onto the selected grapple point. Within a few moments, the secured target's spin has been slowed to a stop. The arm then manoeuvres the target to line up the berthing mechanisms and latch the two securely together; full docking of the target with the chaser is achieved, and the lights come up…



The European Proximity Operations Simulator, EPOS, test facility in Oberpfaffenhofen, which will enable satellites whose power has run down to be captured, powered up and controlled.

This rendezvous and docking has taken place, not in space – at least, not for now – but on the ground, within the European Proximity Operations Simulator, EPOS, at DLR's German Space Operations Center, GSOC, in Oberpfaffenhofen, near Munich. Twin industrial robots affixed to a 25-metre long track hold space hardware. Cameras and sensors follow their motion precisely and the test proceeds in lighting conditions matching those in Earth orbit.

The EPOS facility has a long history; it was originally developed by DLR and the European Space Agency in the late 1980s to test rendezvous and docking manoeuvres for spacecraft, including Europe's Automated Transfer Vehicle and Japan's H-II Transfer Vehicle – both in regular use today, delivering payloads to the International Space Station, ISS. In 2009 GSOC and DLR's Institute of Robotics and Mechatronics came together to completely redesign EPOS around a new focus – 'In-Orbit Servicing', developing and testing robotic systems to repair, refuel or otherwise extend the life of satellites in orbit.

Many millions of Euros and great skill and knowledge are invested in each and every satellite, but their working life remains strictly limited. Eventually, the propellant used for orbit and attitude control runs low, or gyroscopes or batteries begin to fail. The payload might still be working in exemplary fashion, but once its platform is no longer able to maintain its position in space, the satellite becomes nothing more than space junk.

Now, DLR's Institute of Robotics and Mechatronics aims to change the accepted rules of the game by applying advanced robotics to this problem. The aim is to extend the life span of high-value satellites and service a new market that could be worth billions of Euros.

Close-up image of ROKVISS, Germany's first space robotics experiment, on the International Space Station. This image was obtained during a space walk on 12 March 2007.

ROTEX – catching a ball in orbit

DLR has accumulated many years of experience operating robots in space, beginning with the Robot Technology Experiment (ROTEX) robot arm on board the Spacelab Mission-D2 Space Shuttle flight in 1993. Placed within a safety cage within Spacelab, the arm could be operated either from the module or from the ground. ROTEX proved sufficiently agile to catch a free-floating ball.

"For this first space experiment we faced a long communications delay," Landzettel recalls. "Type in a command from the ground and it would happen six to seven seconds later." To overcome this potential source of disorientation the DLR team used predictive graphics, so the operator would see what was going to happen and give the next command accordingly. "To acquire the necessary bandwidth, NASA gave us access to a high-rate data line to the Shuttle called the graphics and fax line – normal communications would not have sufficed."

ROGER – netting a satellite

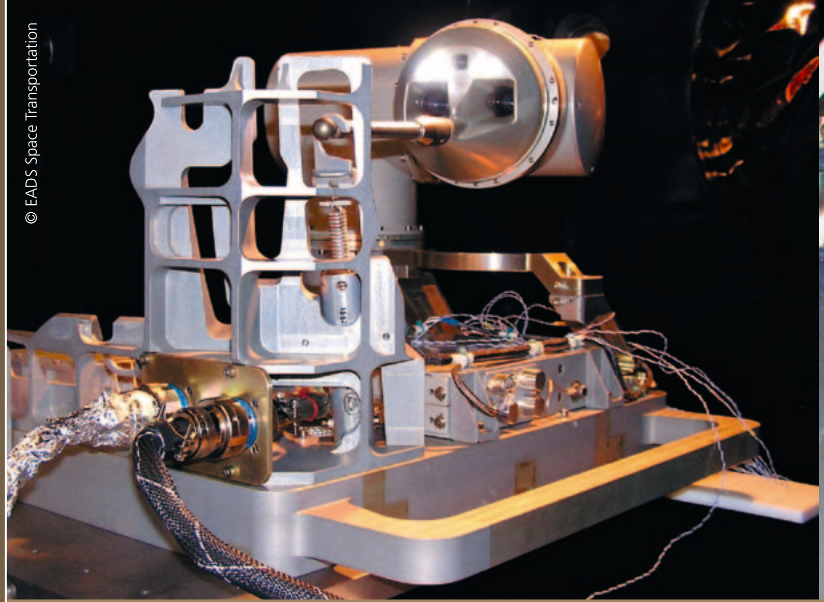
Geostationary slots are some of the most valuable space 'real estate'. The 2002 Institute's RObotic GEostationary orbit Restorer (ROGER) study, carried out for ESA, considered how to capture an uncooperative geostationary satellite and move it to a graveyard orbit. ROGER was based on a satellite deploying a tether equipped either with a gripper or a full-sized net. "Casting a net over the satellite might sound straightforward but nets operate quite counter-intuitively in space," says Landzettel. "The net would actually need a minimum of four actuators to unfold around its target – using a single gripper is much simpler."

ROKVISS – long haul in orbit

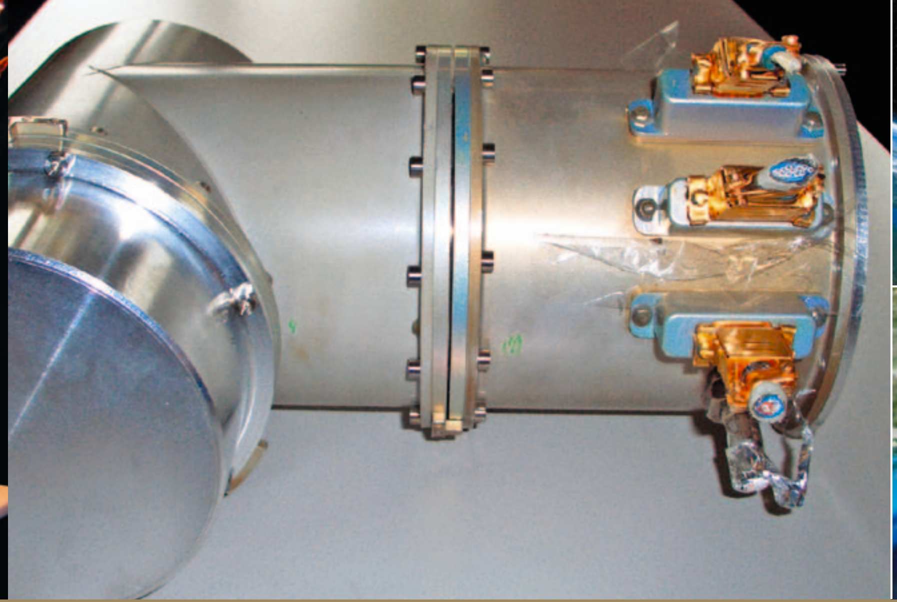
The Robotics Component Verification on ISS (ROKVISS) robotic arm spent six years attached to the exterior of Russia's Zvezda ISS Service Module, put in place on 26 January 2005. "With ROKVISS, we got to operate our hardware out in the space environment," says Landzettel. "This involves all kinds of challenges, such as lubrication and thermal control – the exterior switched from day to night 16 times a day for six years."

"ROKVISS was a multi-jointed, two-degree-of-freedom robot with each joint possessing two computers and a powered motor. This waste heat had to move to the outer surface of course, otherwise you'd burn out your system." Controlled via force-feedback telepresence from the ground, the robot performed the same exercise every month to build up a performance database. Unlike ROTEX, the travel time per command was a virtually imperceptible 12 - 31 milliseconds, depending on the ISS's position in the sky related to the nearby Weilheim ground station. This took clever engineering, emphasises Landzettel: 'ROKVISS had its own S-band receiver, while our system was linked directly to the main dish with a dedicated 34 megabit line sending data on to Oberpfaffenhofen, avoiding the standard DLR network. At times I operated ROKVISS directly from home via a DSL line, actually having the robot look down on Earth."

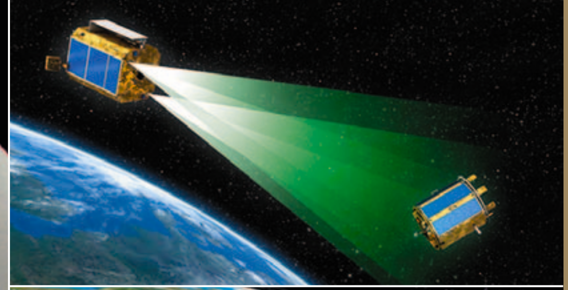
In November 2010 the arm was retrieved by spacewalkers, and then disassembled for its return to Earth the following June. It returned to the Institute last September where researchers commenced a full post-mission analysis.

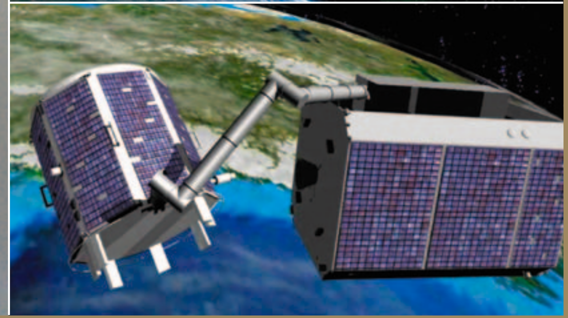


The intelligent lightweight hinged robot units from the ROKVISS experiment



Back from space – DLR's ROKVISS robotic arm shows no signs of external damage. The results of tests now being conducted confirm that the technologies developed by the DLR Institute of Robotics and Mechatronics are well suited for use in space.





Artist's impressions of DEOS as it covers a defective satellite with its double sensor (top) and a servicer as it turns the client for a docking manoeuvre.

"DLR has gained a lot of experience in close formation flying through missions like CHAMP, GRACE and now TanDEM-X," comments Klaus Landzettel, Coordinator of Space Robotics at the Institute. "And our institute has been operating robotics in space for long periods of time. We are currently in the process of putting both sets of skills together for automated rendezvous, docking and servicing."

The focus has been on two different types of in-orbit servicing missions. The first is intended for telecommunications satellites in geostationary orbit, whose lifetimes are typically limited to between 10 and 15 years due to availability of propellant. The second type is aimed at satellites in lower orbits and potentially a much less stable condition.

In 2007, a preliminary mission definition study was carried out in a consortium with ESA and Dutch Space to investigate a mission concept referred to as Orbital Life Extension Vehicle, OLEV, a small space tug with an ion thruster, which would dock with a telecommunications satellite nearing the end of its propellant supply and perform station keeping for it. To image its target at close range, OLEV would use a stereo camera comparing what is being observed to a computer model of the satellite in question. If the satellite appeared to be 10 centimetres in diameter, for instance, the system would be able to calculate that it is 50 metres away. This might be complemented with either a lidar or laser system to overcome solar glare or the darkness during eclipse periods.

"We considered using the satellite's apogee boost motor as a docking point because it is a standardised fitment available on the majority of today's telecommunications satellites." The OLEV spacecraft would be designed to have a 12-year lifespan, so it might be able to serve several different satellites for four to five years at a time. Unfortunately, the OLEV project was not carried forward due to a lack of finance, but one result of the research is ongoing negotiations with the US company ATK to supply capture devices for their ViviSat consortium, which plans to offer similar services to those envisaged for OLEV.

"For the second type of in-orbit servicing, we are targeting satellites stranded in wrong orbits and out of control, so they might be spinning in various uncontrolled ways," explains Landzettel. "And there are other limitations as well." Geostationary orbits allow for continuous line-of-sight communications with a single ground station. Therefore, direct telepresence is always an option, with operators wearing a data glove and experiencing force feedback, as though manipulating something right in front of them. What is more, the lighting conditions are generally stable, and the type of satellite assets OLEV was aimed at would have functional attitude control.

But none of this holds true in lower orbits. Since the satellite is orbiting faster than the Earth rotates, there will be a mere 8–10 minutes of contact per ground station. In addition, there are constant shifts between solar illumination and eclipse. "You have to thoroughly pre-plan your mission, and not all things can be anticipated, or teleoperated from the ground. Sometimes we might need the capture to proceed automatically."

"So our institute is at the stage of wanting to demonstrate that the technology is mature enough – this task can only be done in practice. This is the job of our Deutsche Orbitale Servicing Mission, DEOS, which is currently in its study phase."

DEOS will be a two-spacecraft mission, with a robotic-arm-equipped chaser and a separate target satellite, capable of simulating all kinds of differing initial conditions, such as fast spins, slow tumbles and so on. The aim is to gradually demonstrate an entire suite of in-orbit servicing capabilities, building up from distant rendezvous to close approach, formation flying to fly-around inspection, capture to stabilisation, servicing (represented by the transfer of a camera from capturer to target, with a fuelling experiment also under consideration), combined flight controlled both actively from the ground and autonomously, and finally, controlled de-orbiting of the combined satellites.

"We could have targeted an existing satellite instead of flying our own, but we would not acquire the varied capabilities we seek," Landzettel explains. "In this way, it will be like rendezvousing with a different satellite every time."

The DEOS capture vehicle will have a robot arm following the same design lineage as previously flown DLR hardware such as ROKVISS and ROTEX. In teleoperated mode, the arm will be quite compliant to its human operator, moving effortlessly and fast enough to capture an uncooperative satellite in the same way a person's hand instinctively grabs hold of a flying object. Alternatively, in automated mode, the system makes its own software model of the target satellite and its dynamic parameters, going on to select a suitable berthing point from its model.

An operational issue that DEOS will face was first and best articulated by Isaac Newton: "For every action there is an equal and opposite reaction." In weightlessness, each movement of the robotic arm will in turn move the spacecraft. "There are two ways of getting around this," says Landzettel. "One is just to compensate for these effects, but in practice, our compensation subsystem simply is not agile enough. The other – the one that we are pursuing – is to calculate all the force and torque effects on the platform in a dynamic model and factor them into the planning to get into the path of the other object."

It might sound difficult, but it has already been demonstrated in practice, with the DLR-contributed robot arm on the Japanese ETS-VII satellite, launched in 1997. "The Japanese let us try and it worked; by the end of the mission we were able to predict these effects to a tenth of a degree."

ETS-VII also carried out small-scale rendezvous and docking tests with a mini-satellite, establishing the field's feasibility. In 2007, the US Defence Advanced Research Projects Agency's double-satellite Orbital Express performed full-scale autonomous docking and also refuelling, and, since then, interest in on-orbit servicing has increased steadily. Commercial satellite servicing ventures are focusing on the easier territory of geostationary orbit for now, however, leaving the realms beneath to DEOS – although China is thought to be planning a comparable mission.

"Some people have thought DEOS might be useful for tackling orbital debris," Landzettel says. "In practice, sending up a new satellite each time you need to de-orbit an old one wouldn't be very cost-effective. Though perhaps de-orbit modules could be attached to several targets by a single spacecraft?"

In the past, in-orbit servicing has been both rare and costly – it would have been less costly to launch brand new Hubble Space Telescopes instead of the various Shuttle-based Hubble servicing missions. But if DEOS and parallel efforts succeed, the old rules of the game will change completely. •

About the author:
Sean Blair is a journalist for EJR-Quartz, based in Leiden (the Netherlands); he writes mainly for the European Space Agency and is a member of the DLR Magazine editorial board.

More information:
www.dlr.de/fa/en

A few weeks after Dawn's arrival, DLR researchers derived a complete digital elevation model of Vesta from stereo image data; the model makes the extreme topography of the asteroid visible in this false-colour image. From the lowest, blue-tinted regions in the interior of the large crater at the south pole to the highest elevations, shown in red and light grey, there is a 38-kilometre difference in altitude.

Portrait of a new, old world

The profession of planetary researcher is not suitable for the faint of heart. This fact became evident in the early summer of this year, as NASA's Dawn spacecraft reached its first destination, the asteroid Vesta. During lengthy meetings and international teleconferences held at the DLR Institute of Planetary Research in Berlin-Adlershof, tense curiosity was clearly etched on the faces of the researchers involved in this mission. What would this 500-kilometre-diameter witness to the early days of the Solar System turn out to look like? What would be revealed in the first images sent back to Earth by the spacecraft in May and June? And what would Dawn unveil once it began to orbit Vesta?

Dawn spacecraft reaches asteroid Vesta

By Ulrich Köhler and Ralf Jaumann

As the spacecraft approached Vesta, tension gave way to amazement, which soon shifted into extreme excitement. Even the images acquired from quite some distance exceeded the researchers' expectations and, as Dawn began transmitting more detailed images from orbit on 16 July 2011, their enthusiasm became boundless. The second largest body in the Main Asteroid Belt turned out to be full of surprises. The spacecraft revealed a system of furrows and ridges spanning the asteroid's equator whose origin so far remains unexplained. Vesta's south polar region is dominated by a large impact basin several hundred kilometres in diameter, attributed to a catastrophic collision with another large asteroid that might have come close to destroying this celestial body. The edges of this giant crater feature slopes that rise to several kilometres in elevation. In the centre of this circular depression stands a mountain with a peak around 15 kilometres high; its origin is still unclear. Another surprise was the black material visible in the vicinity of small impact craters. Whether Vesta's regolith – the uppermost layer of rock, now pulverised by innumerable impacts – could be concealing signs of early volcanic activity is something that remains to be determined.

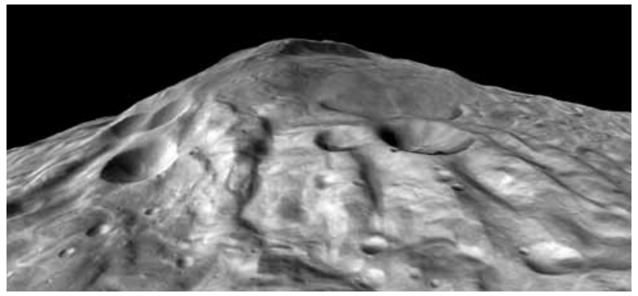
The spacecraft entered orbit around Vesta at an altitude of 2740 kilometres above its craggy surface. One key Dawn instrument is the 'Framing Camera', a German imaging system used to record surface features of the asteroid. In just a few weeks, using stereoscopic data obtained with the Framing Camera, DLR researchers were able to generate the first complete three-dimensional model of Vesta, determine the orientation of its rotational axis and compile an initial atlas of the asteroid, which is now serving as a reference guide for exploring Vesta further. The image resolution during the initial survey orbit was 260 metres per pixel. At the current, lower orbital altitude of about 680 kilometres, the resolution is 70 metres per pixel. In 2012, images will be acquired from a distance of roughly 180 kilometres, giving a resolution of about 15 metres per pixel.

In mid-2012, Dawn will use the thrust of one of its ion engines to depart Vesta, embarking on a journey to the dwarf planet Ceres, the largest body in the Main Asteroid Belt, which it will reach in February 2015. The mission researchers will have plenty to occupy them during Dawn's journey; they will be busy evaluating gigabytes of data to gain a better understanding of the early development of the Solar System, 4.5 billion years ago – the 'Dawn' era that gave the spacecraft its name. ●

More information:
www.DLR.de/en/dawn

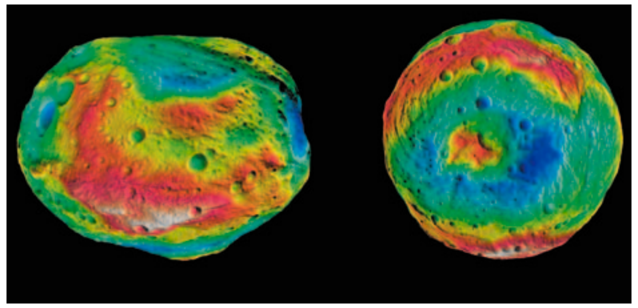
Dawn's 'eyes' – a German camera system

One of Dawn's suite of instruments is the 'Framing Camera', a German scientific imaging system funded by DLR Space Administration and developed and built under the leadership of the Max Planck Institute for Solar System Research in Katlenburg-Lindau, in cooperation with the DLR Institute of Planetary Research and the Institute of Computer and Network Engineering at the Technische Universität Braunschweig.



A 15-kilometre-high mountain stands in the centre of a large crater near Vesta's south pole

Vesta's equator is surrounded by hundreds of kilometres of long furrows and ridges, whose origin is still unclear.



Vesta is an almost spherical body with a dramatic topography. On the left, an image of its equatorial region – in the north polar region (top), seasonal conditions prevent modelling of the topography, as it is in shadow. On the right, an image of the south pole, which reveals a huge impact basin 460 kilometres in diameter.

Image of the Tango satellite acquired by its partner satellite, Mango, from a distance of 20 metres.

Around the Earth with Tango and Mango

A team at the German Space Operations Center, GSOC, took over operation of the Swedish satellites Tango and Mango for five months – an interesting yet very difficult mission, according to Mission Operations Director Ralf Faller. Interesting because the two satellites came within touching distance during the mission, and difficult because the original design for the Swedish mission did not include another team taking control of the satellites. During the time that GSOC was responsible for PRISMA, DLR engineers were able to successfully carry out experiments with Tango and Mango before handing control of the mission back to the Swedish operators.

A look back at the Swedish PRISMA satellite mission

By Manuela Braun

The preparation time for a satellite mission is usually up to three years. Usually. The Swedish PRISMA satellite mission, on the other hand, was quite unusual in this respect. "A mere 14 months passed between the actual decision to undertake the mission and the mission itself," Ralf Faller recalls. "That is an extremely short period of time." But a financial shortfall at the Swedish Space Corporation left virtually no other option; although the Swedes could still just about manage to launch the satellites on their budget, the actual operation of the mission was another story. Without the support of GSOC, the mission and its experiments would have been at risk – so, in October 2009, the two partners began negotiating this international arrangement. Even then, the planning phase would be extremely short; at the time, everyone involved in the mission expected Tango and Mango to be launched in March 2010, just six months later.

Another unexpected problem arose: "Our first worries as to whether this would really be a straightforward cooperation came up at the first meeting in Stockholm," remembers Martin Wickler, responsible for Earth observation and technology missions at GSOC. Everyone had become aware of how difficult it would be for the Swedish team to place the mission in someone else's hands. DLR's Ralf Faller shrugs his shoulders sympathetically: "Well, I can understand; when you have planned and supervised a mission from the outset, you also put your heart and soul into it. It is no different with us and our missions." In addition to the preparations for handing over the mission, the matter of how the GSOC team would work with its Swedish colleagues also had to be considered.

Discussions about discussions

The two satellites were finally launched on 15 June 2010, entering Earth orbit in formation flight. In the meantime, discussions regarding how and where the cooperation should proceed continued on the ground. In May 2010, it had been agreed in principle that GSOC would be able to offer support, but the scope of the assistance had not been clarified precisely. The DLR Space Administration also became involved and offered financial support using funds from the German Federal Ministry for Economics and Technology – in the case that significant amount of the work would take place at the DLR site in Oberpfaffenhofen. "The mission was very attractive for us; the two satellites would fly in different formations and get very close to one another – this would be excellent training for future missions such as the Deutsche Orbitale Servicing Mission, where, for example, a rendezvous with a defective satellite might be made in order to effect repairs," says Faller of GSOC's interest in the success of the Swedish mission. Had it not gone ahead, these important DLR experiments could not have been carried out.

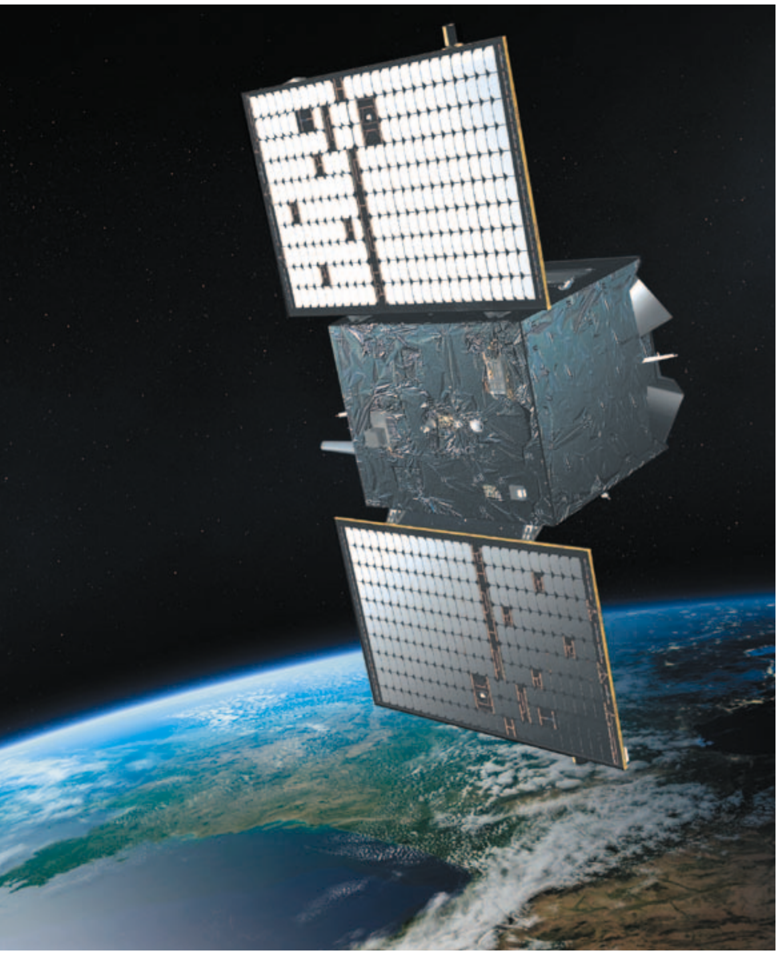
While negotiations continued, preparations were already underway for the German team. "With PRISMA, it was never the intention for another team take over control of the satellites," says Faller. The original plan for the mission with Tango and Mango was for the Swedish team that had built the satellites to operate them as well. Manuals? Full documentation of the satellites? Not available. "We had to create these ourselves, to an extent." In August 2010, DLR employees started shuttling between Oberpfaffenhofen and Solna, near Stockholm; they were trained by means of simulations before the satellites were launched, and worked in shifts with the Swedish team during the first months after the launch.

The devil is in the details

Before Tango and Mango were actually placed in the hands of GSOC for five months on 14 March 2011, several problems still needed resolving – and under intense pressure. "The devil is often lurking in the details," remembers project leader Ralf Faller. The Swedish telemetry and command system had to be integrated into the DLR control room. "This is nothing like loading new software onto a computer," Faller says, chuckling. "Our system at GSOC is strongly protected by firewalls." Furthermore, the Swedes had only made provision for one ground station, at Kiruna, to be used for the two satellites; this threatened delays in transferring data to the German control centre. Consequently, a separate communications link with a suitable bandwidth needed to be rented for this task. Eight additional consoles were installed for the flight operation engineers and scientists in Oberpfaffenhofen. "A number of existing elements from other missions was used, but everything needed to be retested – we had to ensure that everything would function correctly during the mission." Tests, acceptance procedures – the team did everything under great time pressure, yet with the required precision.

Finally, on the afternoon of 14 March 2011, the preparation work came to an end and the German operational phase of the PRISMA mission began in the DLR control room; the first commands were sent to Tango and Mango from Oberpfaffenhofen. Initial test commands had been sent to the satellites to ensure that everything was functioning flawlessly after the transfer. "When the Swedes sent the last commands we had a final look over our colleagues' shoulders and then carried on seamlessly at GSOC," recalls Faller, thinking of the moment when responsibility of the two satellites switched over to DLR after lengthy negotiations and a short preparation time. It was a tricky moment that needed to be planned precisely. Which data from the satellites did the control centre taking over need to know? Who should book the ground station for the last passage before the handover? Every responsibility needed to be carefully defined.

The experiments began just two days after the handover. In the initial weeks, this meant working at night for the PRISMA team at GSOC: "You just have to get on with operating the satellites when they are contactable." At first, connections to the two spacecraft could only take place via Kiruna. In April 2011, two additional ground stations were added to the network: the GSOC tracking station at Weilheim and the German Remote Sensing Data Center facility at Inuvik, in Canada. This took a lot of effort, but gave a crucial advantage: "It meant that contact with the satellites during the daytime was possible too." So the night shifts came to an end. Tango and Mango could now be sent commands and return telemetry data up to seven times a day during normal office hours.



The main satellite, Mango, was actively controlled and could observe its partner, Tango, using an on-board camera.

Camera view of Tango

The fact that the main satellite, Mango, had a camera on board enabled the flight operation engineers to carry out an especially exciting experiment; over a period of several days they allowed Mango to move in from a distance of over 55 kilometres to four kilometres from the second, smaller satellite, Tango – doing so using only information they got from the camera images. To the layman, the satellite flying with Earth in the background is simply a beautiful sight, but experts can use the images to calculate the position of the satellite. "Approaching a non-cooperative object," says Benjamin Schlepp, who was involved with planning and carrying out the experiments, "added another layer of difficulty, because Tango was not sending any GPS data for this experiment and could not be actively controlled either." To fly in the intended formation, the engineers acquired camera images every day, downloaded them, calculated the positions of the satellites and sent new manoeuvring commands. It was no easy task. "Sometimes you have to drift slowly, sometimes quickly, and always ensure a safe formation; we needed to be very careful during the approach," explains Schlepp. The procedure for doing this has not yet been fully developed. "If we wanted to fly a satellite close to another – faulty – satellite without GPS at some point, we had to use this opportunity to practise."

Experience gained from the TanDEM-X mission, in which two satellites flying in a sophisticated formation are surveying Earth from an altitude of 514 kilometres, was helpful with another DLR experiment. For 19 days, the researchers observed how the manoeuvres were being calculated on board the satellites to autonomously acquire a number of different formations at different distances. "We had simulated and tested this experiment frequently on the ground beforehand," says Schlepp. Now the engineers on the ground just had to keep a watchful eye on the satellites to prevent a possible collision. "Everything went very well; the satellites flew as expected, and we now know that flying autonomously while the data is being monitored in real time on the ground works."

A special kind of mission

The GSOC mission came to an end after five months, on 23 August 2011. What had happened during the handover in March was on the operations plan once again, in order to hand PRISMA back to the Swedish operators. Just a day later the first experiment commands were sent from Solna once again. A mission with numerous difficulties had been carried out successfully. "In fact, Tango, the target satellite, had been designed to operate for only one year," says Martin Wickler from GSOC. "However, we were able to hand two fully functional satellites back to the Swedes." It was a successful close to a mission where just about everything was a bit different. ●

More information
http://s.dlr.de/912x
http://s.dlr.de/p7k1
www.dlr.de/rb/en/

The DLR satellite ground station in Inuvik, Canada. DLR uses the station, which was commissioned in 2010, primarily to receive data from the German TanDEM-X radar satellite. The German-Swedish PRISMA mission used the station to communicate with the satellite pair Tango and Mango.

Even though the camera on board Mango was used to keep an eye on Tango, the view of the Earth below could not be overlooked.

Excellence in information security

ISO 27001 certification for the DLR Institute of Space Operations and Astronaut Training

Secure management of information is the backbone of any space mission. The requirements for this are specified in the international standard ISO / IEC 27001; only a few organisations are currently certified as being compliant with this standard. The DLR Institute of Space Operations and Astronaut Training acquired this accreditation in 2011. The German Space Operations Center covers multiple ground stations, the Mobile Rocket Base MORABA, the European Astronaut Centre and other facilities. With the certification, the Institute has become the only control centre organisation in the world to demonstrate a level of security that meets demanding international standards.

The ISO 27001 standard deals with the risk-based implementation and maintenance of an information security management system in a business environment, and is therefore a proven means of achieving comprehensive and efficient information security. In addition to the implementation of technical protection measures, it also addresses organisational and personnel arrangements in an integrated manner.

The subject of the certification is the information security management system of the DLR Institute for Space Operations and Astronaut Training concerning the operation of Earth observation satellites. This includes servers, networks, network components and workstations in the secure areas of the German Space Operations Center at Oberpfaffenhofen and Weilheim and all relevant support processes.

Felix Huber, Director of Space Operations and Astronaut Training at DLR, holding the ISO 27001 certification.

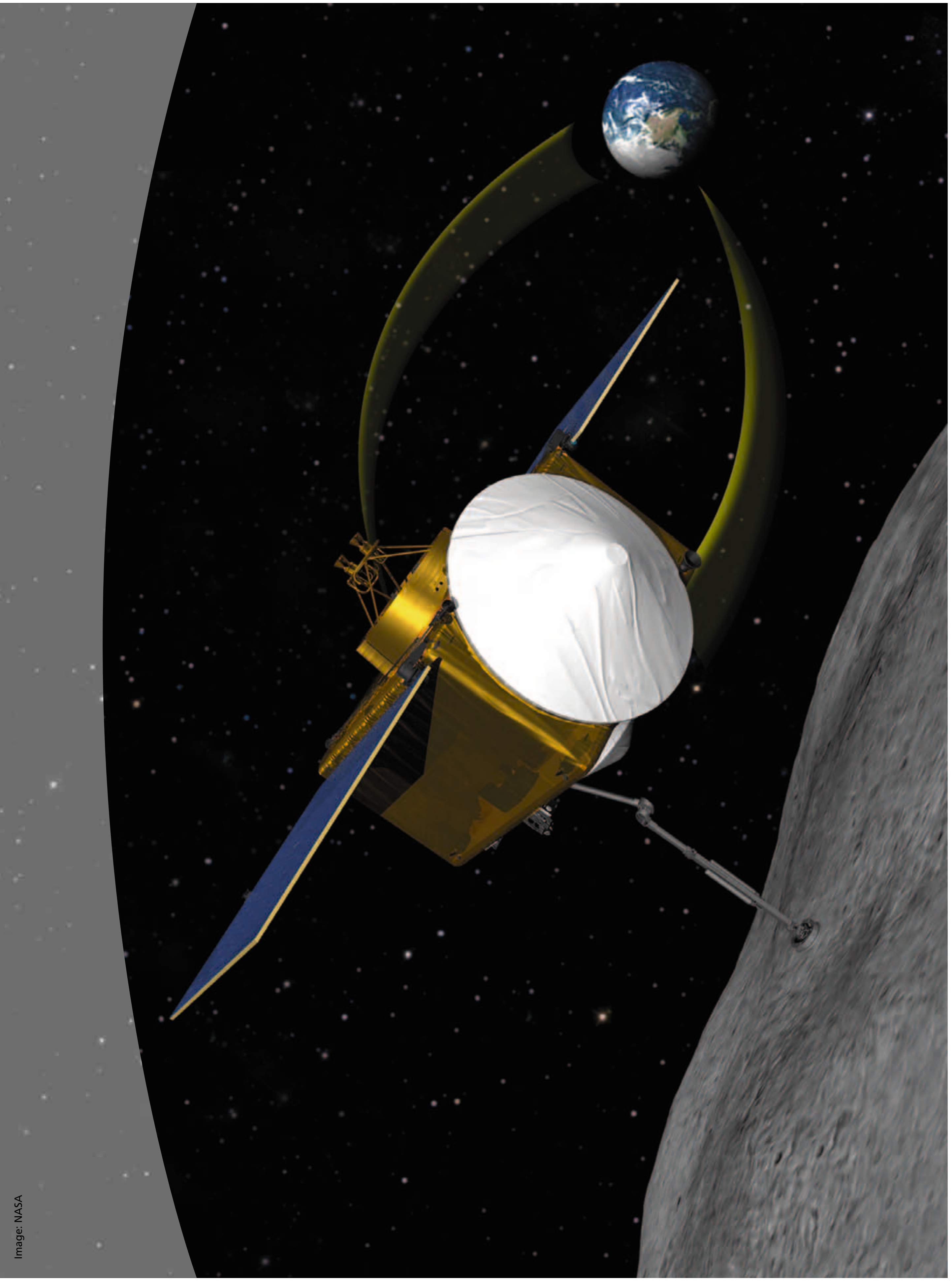


Image: NASA

Cosmic time capsule

DLR is participating in NASA's OSIRIS-REx mission, which will collect samples from a near-Earth asteroid in 2019 and return them to Earth.

By Ulrich Köhler and Harald Michaelis

Scientists and engineers can be cryptic when selecting names for their creations; the robot mechanic 'R2-D2' from the film series 'Star Wars' is an iconic example of this. Now a NASA spacecraft has been named OSIRIS-REx. To learn about the early history of the Solar System, NASA will launch the spacecraft in 2016 towards asteroid 1999 RQ_{36}, which was discovered in 1999. Shortly after its arrival in 2019, OSIRIS-REx will collect a small sample from the asteroid's surface, which will reach Earth in 2023.

Those at least 60 grams of pristine material might provide insights into the origin of life. 1999 RQ_{36} formed from the remnants of a rotating disk of gas, dust and organic molecules – at the centre of which, over four and a half billion years ago, the Sun was born and the planets formed. Asteroids and comets are the 'leftovers' of this process, so they contain concentrated 'star dust' from even older stellar remnants and the remains of galaxies that have ceased to exist.

With a mean diameter of 560 metres, 1999 RQ_{36} is an extremely dark coloured, relatively lightweight, but very carbon-rich member of the Apollo asteroid family – and it is an Earth-crossing asteroid. It orbits the Sun at a distance of 169 million kilometres on average, just 20 million kilometres more than Earth; their orbits intersect every six years. Based on current knowledge of the potential danger posed by this near Earth object, there is thought to be a very low probability of a collision with 1999 RQ_{36} in 2182.

In addition to returning a sample of the asteroid, the primary goal of the mission is a complete geological, mineralogical and physical characterisation of the asteroid's topmost layer of dust – the regolith – and the detection of resources for the potential exploration of asteroids by astronauts. The mission will measure the albedo properties of 1999 RQ_{36}; this is of interest because two effects of solar illumination can alter the orbit of an object. In their path around the Sun, asteroids absorb solar infrared radiation and, because of the thermal inertia of the regolith, reradiate it from their night side. The effect is a small force on the asteroid known as the 'Yarkovsky effect'. Radiation pressure can also influence the orbit in a manner that is dependent on variations in albedo. While small, these forces act over long periods of time to alter the orbit of an asteroid, but the effects vary depending on the asteroids' shape, rotation, wobble and surface composition. If researchers wish to refine their value for the probability of a collision with Earth, they must understand how radiation effects will change the asteroid's orbit.

Scientific management of the mission is the responsibility of the University of California, and it will be operated from NASA's Goddard Space Flight Center in Maryland. Remote exploration of the asteroid at distances of between five kilometres and just 700 metres will involve six experiments over the course of 505 days, during which the sample will also be acquired.

Five scientists from DLR's Institute of Planetary Research are involved as co-investigators in the OSIRIS-REx mission; parts of the sensor electronics and the focal plane of the three-part camera system are being developed and built there, and qualification tests and calibration of the sensors will be carried out at the Institute as well. DLR will be providing its expertise in stereo image data interpretation and planetary geodesy for analysing the images and data, generating maps and digital terrain models of the asteroid, determining its reflection properties (photometry) and investigating its mineralogy.

Then, after 2023, DLR will receive a very special delivery – part of the returned sample will be analysed there. The complex infrastructure for this will be developed at the Institute of Planetary Research during this decade. In the best tradition of Humboldt, Berlin's famous explorer, DLR researchers will be entering *terra incognita* when they begin inspecting this 'star dust'. ●

Osiris, a 'divine eye' for asteroid research

OSIRIS-REx is the third spacecraft in NASA's New Frontiers programme of medium class scientific missions. In Egyptian mythology, Osiris embodied the origin and passing of life; 'Rex' is the Latin word for 'king'. The first letters of the various mission goals have been formed into an acronym:
Origins,
Spectral **I**nterpretation,
Resource **I**dentification,
Security,
Regolith **Ex**plorer – **OSIRIS-REx**.

About the authors:
Harald Michaelis is Co-Investigator on OSIRIS-REx and Head of the Department of Planetary Sensor Systems at the DLR Institute of Planetary Research. Ulrich Köhler is a planetary geologist and is also responsible for science communication at the Institute.

More information:
www.DLR.de/PF/en

Legendary heroes and Roman priestesses

When a spacecraft orbits above distant celestial bodies, the on-board camera looks down onto *terra incognita,* unknown – and unnamed. It is then that planetary researchers begin not only to study them, but to decide which geological features are worthy of a name in the atlas – and what that name should be. After setting a general theme, the research begins, and with it, the lengthy effort of browsing through history books, archives and historical sources. For craters bearing the name Ali Baba on Saturn's moon Enceladus, or Floronia, the Vestal Virgin, on Vesta, DLR planetary researcher Thomas Roatsch bears some responsibility.

How cosmic craters, mountains and valleys get their names

By Manuela Braun

The Vestal Virgins, Roman priestesses devoted to the goddess Vesta, vowed to live in chastity in her temple for 30 years. But celibacy was not always easy – and some, such as Floronia and Marcia, were punished for losing their virginity by being buried alive. But today, they are honoured by having craters named after them on the asteroid Vesta.

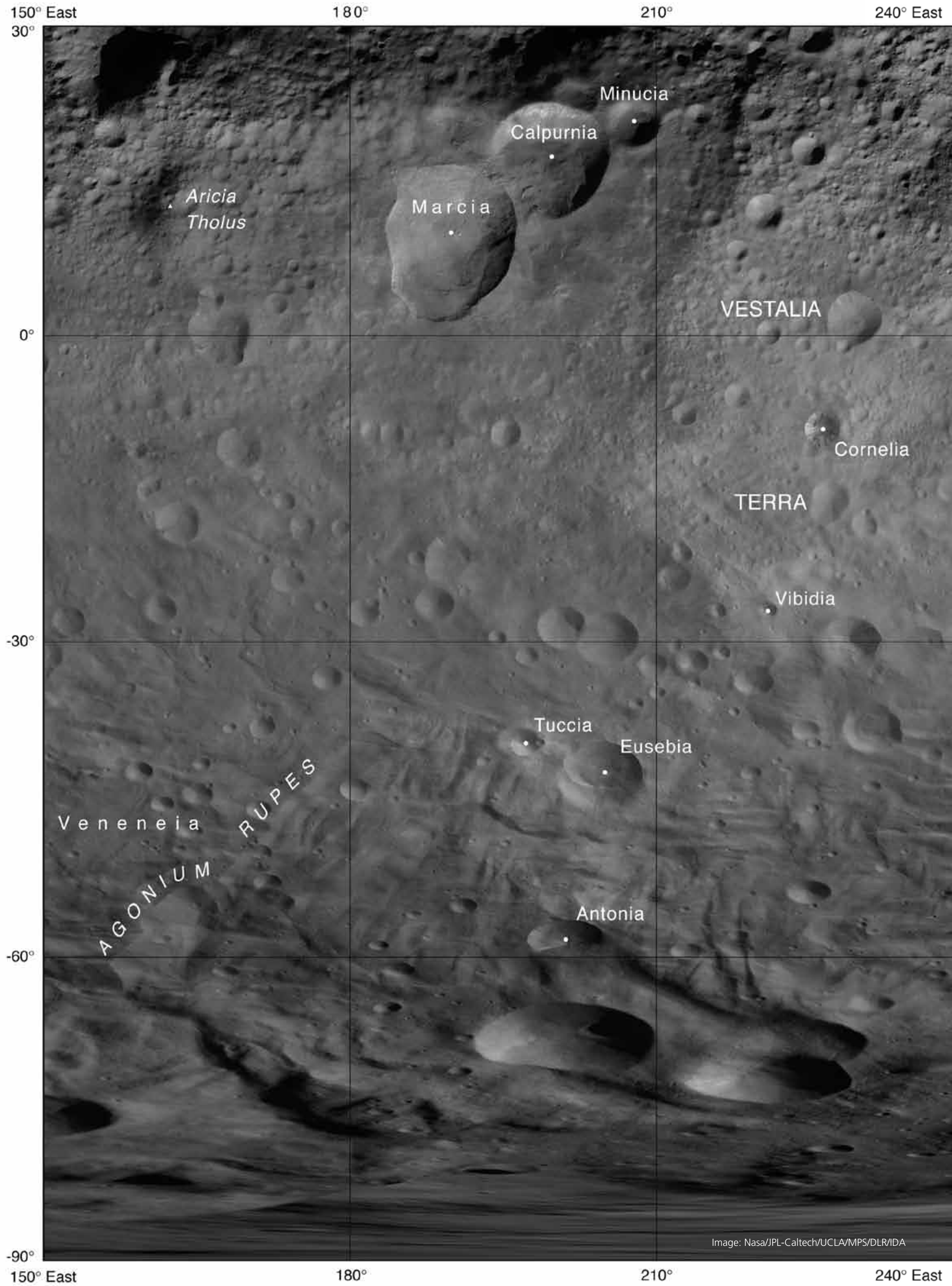
"The Vestal Virgins we found in the course of our research are almost all known for contravening the rules of their priesthood," Roatsch reveals. He leafed through books with help from Italian colleagues on the international Dawn mission. Which Vestal Virgins are documented in the sources? And the search for crater names goes on – inevitably. The requirements are high since the features of celestial bodies need to be named for the maps. "You learn a few things along the way."

Roatsch and his colleagues have been working through the classics for the atlases of Saturn's moons; 13 volumes of Richard Burton's translation of The *Arabian Nights* for Enceladus, Homer's *Odyssey* for Tethys, the legend of King Arthur for Mimas, and mastering Virgil's *Aeneid* in Latin was necessary for Dione. Roatsch must thank a colleague from the United States who prepared a list of name suggestions from the *Song of Roland*. "Hopefully, we will not have to do any more research on that." The large moon Rhea, on the other hand, caused a great deal of work due to its size – 80 name suggestions from different myths were needed at once. The result – names ranging from the Korean sky god Ananin to the Babylonian goddess Zicum.

Ali Baba, Sinbad, Roland, Claudia and Arthur will only find their way onto the official maps once the International Astronomical Union has accepted the suggested names. Craters are 'baptised' with personal names; on the other hand, features such as valleys or entire regions get names from other areas. For example, the list of names for Vesta includes cities where the cult of Vesta was followed. Duplicate names are unpopular, and when naming individual regions or features of a celestial body, alphabetical order is followed. Exceptions are rarely made, but Vesta's south pole is one of them, at least partially; the sizeable crater in the asteroid was named after the most well known Vestal Virgin, Rhea Silvia, mother of Romulus and Remus. The name Rhea had already been given to one of Saturn's moons, and Silvia had already been given to a small asteroid. However, for the most prominent landmark on the asteroid, the researchers joined the two parts of the name together: 'Rheasilvia'.

Thomas Roatsch and his team will have to think about the next names in February 2015, when the Dawn spacecraft reaches Ceres and directs its camera at more uncharted territory. Whoever surveys an asteroid has the privilege of selecting names for the maps. "But the theme for Ceres has not yet been fixed." No matter which story is used for this celestial body, the planetary researchers will not be spared – they will have to continue reading books and studying sources. But then, Roatsch will be sure of one thing – these craters, valleys and regions will have been 'baptised' at DLR. ●

More information:
http://planetarynames.wr.usgs.gov/



DLR scientists look to Greek and Roman mythology (and elsewhere) to find inspiration for naming newly discovered phenomena. The story surrounding the Vestal Virgins of ancient Rome is being used to name features of asteroid vesta, whose surface is shown in this map.

Image: NASA

Queen of trumps unplayed

Fifty years ago, everyone spoke about the legendary 'Mercury 7' – the first seven US astronauts, from Shepard to Slayton, to score points for the United States in the Space Race. But the Soviets had beaten them twice – they performed the first space walk and Valentina Tereshkova was the first woman in space. The United States and NASA could have been first to send a woman into space if… – … well, if not just the Mercury 7, but also the women of the Mercury 13 had got a look-in – sorry, a lift-off. Yet it did not happen.

Spaceflight as a male privilege – remembering the Mercury 13

By Rolf-Michael Simon

The Mercury 13 were the protagonists of a short but notable chapter in the story of spaceflight for which the end was never written – so today, hardly anyone remembers it. In retrospect, it is surprising that, analogous to the Mercury 7, 13 highly qualified American women had passed the same selection tests. At the dawn of the space age, consideration was given to the idea of sending women into space as well – women being generally smaller and lighter than men, but no less capable.

Image: NASA

The women of the Mercury 13 showed purposefulness, strength and courage during the Space Race. Their groundbreaking achievements smoothed the path for subsequent generations. The University is proud to honour such pioneering spirit. (From the citation at the awarding of honorary doctorates to the Mercury 13)

William Randolph Lovelace II, a physician and chairman of the committee at NASA supervising the biomedical tests for spaceflight candidate selection, wanted to put this into practice. He convinced Brigadier General Donald Flickinger and invited Geraldine 'Jerrie' Cobb to undergo the same tests as the Mercury 7. Jerrie was 28, had been a full-time professional pilot for over 10 years, and held multiple world records. She passed the tests with such distinction that she was asked to nominate more women for an, as-yet, unofficial training programme. Its name was WISE – 'Women in Space Education'. The number of 'First Lady Astronaut Trainees', FLAT, predominantly nominated by the renowned Association of Women Pilots – the 'Ninety-Nines' – was ultimately reduced to 13 – the Mercury 13.

These excellent pilots took the same physical fitness and endurance tests with Lovelace in Albuquerque, New Mexico, that had been developed for selecting the Mercury 7. Not satisfied with this, three of the women put themselves through a second round of additional tests, and Jerrie Cobb even underwent a third one.

The next stop for everyone was the Naval School of Aviation Medicine in Pensacola, Florida, and two of the women gave their jobs up to be able to attend. But a few days before they were due to set off, the tests were cancelled; without a formal request from NASA, the navy would not provide facilities for unofficial tests.

The women took their case to Washington, wrote to President Kennedy and spoke with his Vice-President, Lyndon B. Johnson. In July 1962 there was a two-day hearing before a committee of the House of Representatives on the subject of gender discrimination. Ironically, this was branded as illegal two years later in the Civil Rights Act, but by then this was no longer of any help to the Mercury 13. NASA insisted that astronauts should have a degree in engineering and be military test pilots – requirements that no women could meet in 1962. Two years later, Valentina Tereshkova flew into space. "We really should not have abandoned this first to the Soviets," the might-have-been US astronauts commented bitterly.

One small consolation was that, 45 years later, the women of Mercury 13 were awarded honorary doctorates by the University of Wisconsin. ●

About the author:
Rolf-Michael Simon is a journalist based in Essen.

Sparkling cocktail in Hangar-7

Even during the descent to Salzburg Airport, the matte lustre of a complex of buildings catches the eye as they shine in the sunlight. At first glance, it resembles a gigantic flat loaf of bread – that has been not particularly well sliced in half – surrounded by aircraft on a huge parking area. Coming closer, the building looks like the profile of an aircraft wing; on the ground, the spirit and purpose of this ensemble finally becomes clear. Standing opposite the Salzburg Airport terminal area, the visitor faces Hangar-7. Although the name might at first lead one to believe it is just an aircraft storage building, Hangar-7 is much more than that – upon close inspection, a multi-dimensional world of experiences is revealed.

Historic aircraft and more at Salzburg Airport

By Hans-Leo Richter

The Douglas DC 6B, a superbly restored former state airliner from Yugoslavia, is the flagship of the Flying Bulls. The elegant exterior matches the flawless technical level of this magnificent representative of the large piston engine era.

Opening times: daily 09:00 – 22:00

Contact: Red Bull Hangar-7 GmbH, Wilhelm-Spazier-Str. 7A, A-5020 Salzburg, www.hangar-7.com, www.facebook.com/hangar7, Tel: +43 662 2197, E-mail: office@hangar-7.com

Directions: Hangar-7 is located opposite the terminal area at Salzburg Airport. Leave the A1 autobahn at the airport exit and then turn onto the Innsbruck highway towards Salzburg. Beyond the underpass beneath the runway, turn right into Wilhelm-Spazier-Straße, which goes past the Red Bull complex. At the end you will find a large car park.

Folded-up powerhouse: the Chance Vought 'Corsair' from an unusual perspective. The 2100-horsepower radial engine can accelerate this fighter to around 700 kilometres per hour.

The owner and creative mind behind this unique world of experiences is Dietrich Mateschitz, an Austrian energy drink entrepreneur, whose company philosophy – '... gives you wings' – and private interests come together in a spectacular way. On entering the hangar, visitors predictably find a variety of highly interesting aircraft, but the sight of a Formula 1 racing car in the midst of these numerous historic aircraft might seem incongruous and something of a surprise. Visitors are in danger of becoming positively baffled when faced with numerous large-scale works of art, paintings, prints and statues. How does this all fit together?

Cuisine, art and gull wings

Hangar-7 at Salzburg Airport is more than a museum or exhibition platform for historic aircraft; it is a complete, multi-dimensional work of art – a home for high technology from the worlds of aviation and Formula 1, as well as art exhibitions that change on a regular basis. Boundary-transcending fascination is everywhere one looks, and it certainly makes visitors curious. But upon closer inspection, everything comes together harmoniously.

The wide range of aircraft and ultra-modern Formula 1 cars form the spectacular backdrop to the multi-dimensional world of adventure in Hangar-7. The architecture (lower left) is unmistakeably based on the profile of an aircraft wing.

The multi-functional ensemble is complemented by multiple rest and relaxation areas where exquisite top-level European culinary delights await guests, such as the 'Carpe Diem Lounge-Café' on the ground floor or the 'Mayday' bar on the second floor. The focal point of the gastronomic offerings is, without a doubt, the 'Retaurant Ikarus'; here, under the auspices of chef Eckart Witzigmann – renowned far beyond Austria – different guest chefs offer their works of appetising art each month. The most spectacular gastronomy facility is high up, just underneath the glass dome – the 'Threesixty' bar, from which visitors can enjoy a truly unique panoramic view.

The extraordinary architecture is a highlight in itself. The building, a steel and glass ellipsoid, is modelled on the profile of an aircraft wing. Equally impressive and artistic is the shell – a vast and delicate network of steel tubes supporting the glazed outer skin, with over 7000 square metres of glass. In addition, each of the 1754 differently-sized glass panels has a special transparent coating to prevent reflection of the Sun, stopping them from dazzling pilots on approach to the airport.

Opposite Hangar-7 is Hangar-8; these buildings are the 'home base' of the Flying Bulls, the Red Bull owner's fleet of historic aircraft. An Austrian airline pilot with a North American T 28B Trojan, a single-engine high performance training aircraft, laid the foundation for this remarkable collection in the 1980s. In the following years other aviation rarities were added, and the connection with energy drink manufacturer Dietrich Mateschitz finally gave the colourful group a name – the Flying Bulls.

State aircraft or sleek lightweight

Today, the collection comprises 25 different aircraft and helicopters, in which civilian models have a place, as do former military aircraft. An undeniable showpiece is the legendary Douglas DC 6B, a four-engine medium- and long-haul passenger plane from the 1950s; it has, of course, been painted in the standard Red Bull colours, but is obviously not just any retired airliner. In its day, this DC 6B was the official plane of Yugoslav statesman Josip Broz Tito. The exterior of the Douglas DC 6B is highly attractive, but its elegant interior décor, with the finest wood panelling finished with a leather trim, clearly fulfils any expectation you would have of a (albeit former) state aircraft. A glance into the cockpit reveals sophisticated GPS-based avionics. The flight guidance systems are state-of-the-art, so the ageing DC 6B is anything but a mere fair weather flyer.

Another eye-catcher is the North American B 25J 'Mitchell', a twin-engine bomber dating back to 1945. This old timer's reflective, polished aluminium skin continues to attract looks from visitors at air shows and aviation events. The 'greenhouse' compartment in the nose – today fitted with a comfortable leather seat instead of the original, rather less luxurious accommodation for the bomb aimer – makes this aircraft a visually, and literally, outstanding showpiece. Lovers of powerful radial engines get their money's worth with the Chance Vought F4U-4 'Corsair'. The power unit, an 18 cylinder, 2100-horsepower double-row radial engine, can accelerate the fighter to over 700 kilometres per hour. A notable feature of this early carrier aircraft is its folding gull wings, which give it the look of a somewhat menacing spider when they are stowed. Though fully aerobatic in its earlier days, this rare model moves through the air somewhat more sedately these days.

Visitors can also marvel at a Cessna 'Caravan' equipped with floats, several Alpha Jet basic trainers, a Boeing 'Stearman' – a marvellous biplane with a powerful radial engine – as well as various helicopters. One of the smallest aircraft is always the star of the show; the single-seat BD 5J 'Microjet' is a miniature aircraft powered by a jet engine capable of accelerating the small 'bird' to around 450 kilometres per hour, a good speed for a such a minimalist aircraft. This sleek, low-wing monoplane appeared in the James Bond film 'Octopussy'; naturally, Roger Moore evaded his villainous pursuers once again in the Microjet…

When the air show is on, it is time to take off

Particularly appealing is the fact that all the aircraft and helicopters on display are still flightworthy. In Hangar-8, just across from the exhibition and not accessible to visitors, they are maintained in accordance with all manufacturer and aviation regulatory authority requirements and carefully prepared for appearances at numerous aviation events, flying days and air shows. In addition to routine maintenance work, a Bristol 'Sycamore' helicopter from the 1950s is being restored and prepared for display. This model was the first helicopter to be fully developed and manufactured in Great Britain. It was used mainly for rescue purposes, and, in its day, 50 were used by the German Army.

Owner Dietrich Mateschitz doesn't just indulge a passion for aviation. His energy drink group has also become known across the world as the main sponsor of two Formula 1 teams. Red Bull Racing has been at the pinnacle of motorsport for two years now, and the Toro Rosso team – the Italian version of the name – acts as a talent pool for 'Young Bulls' from the company's junior teams.

Among the Formula 1 cars on display in Hangar-7, a 2008 Toro Rosso STR 3 is especially attention grabbing. This is the car in which Sebastian Vettel, then just a promising youngster, won his first Grand Prix victory, at Monza – to the surprise of the entire motor racing world, in pouring rain and against stiff competition. This win was the beginning of a successful Formula 1 career that continues to this day. David Coulthard's Red Bull RB 3, used for the 2007 British Grand Prix at Silverstone, is of even greater visual interest. This car is covered with around 20,000 portraits of people from all over the world. For 10 pounds, those interested could 'immortalise' themselves by placing their picture on Coulthard and Webber's Red Bull cars. The resulting revenue of around one million dollars went to the Red Bull 'Wings for Life' Spinal Cord Research Foundation. Coulthard only came eleventh at Silverstone – presumably he drove the 'artwork on wheels' somewhat cautiously during the race.

And on the website, the Corsair roars

Ultimately, the Hangar-7 exhibition concept embodies a simple, almost visionary concept by combining numerous dimensions of experience and subjects, cleverly complemented by a comprehensive presence on the Internet. Lovers of aviation history will find www.flyingbulls.at especially interesting. Atmospheric videos will put you in the mood to see the numerous aircraft in the collection, and visitors can bring a range of piston engines and turbojet engines to life. Under 'Aircraft/Specifications/Sound sample', superb machines such as the Wright 'Cyclone' 14 cylinder double-row radial engine (1700 horsepower) that powers the B 25 'Mitchell' or the Pratt & Witney R 2800 two-row radial engine (18 cylinders and 2500 horsepower!) and, finally the 2100-horsepower 'Corsair' all come to life. Hearing all the cylinders in the two-row radial engines kick into life and let their sonorous rumble ring out is truly a pleasure. So turn the volume up, close your eyes, take a deep breath and enjoy. The only thing missing is the smell of burnt oil. ●

Changing exhibitions in Hangar-7 permanently emphasise the interdependent relationship and closeness of fine arts and dazzling hi-tech monuments

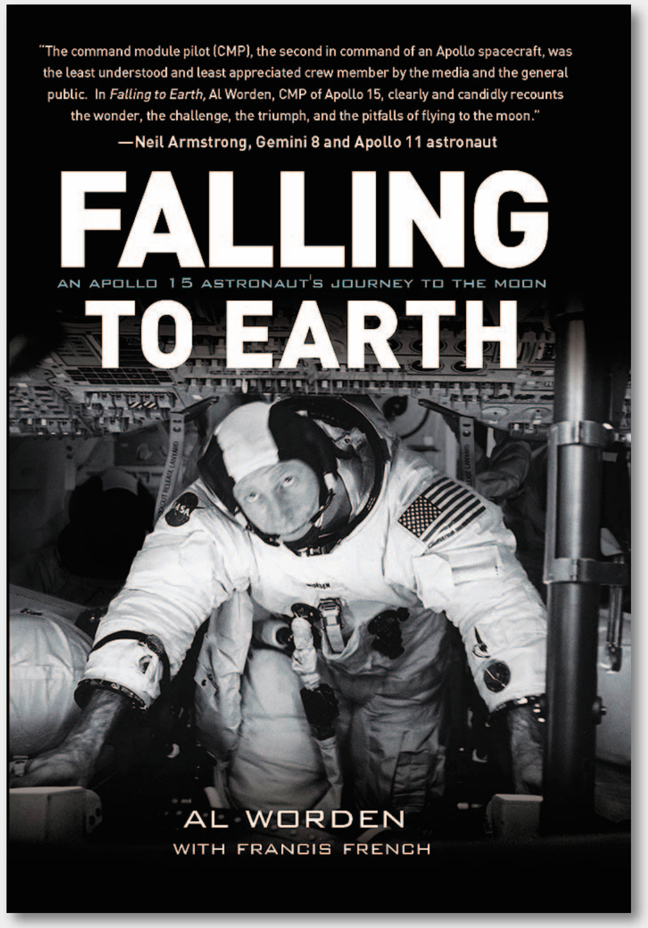
Art, chat and sport

Many artists who are well known in their own countries but have not yet established themselves internationally, have found an extraordinary, atmospheric, temporary platform in Hangar-7. Each exhibition cycle introduces the art scene of a different country, be it China, South Africa, Iceland or, in Europe, Italy, Great Britain, Poland and the Czech Republic, the most recent country to make a guest appearance.

TV chat shows on current topics in politics, culture and science are also broadcast from here. ServusTV broadcasts a chat show every Thursday evening. High calibre hosts welcome interesting personalities – unconventional thinkers and opinion makers of our time. Claus Peymann, Ursula Plassnik, Wolfgang Rihm, Dani Levy and Neil Armstrong have all been guests on the show in the futuristic Hangar-7 at Salzburg Airport.

The ServusTV sports coverage, in German, also has a new set time. At 21:05 on Mondays there is a live chat and sports show from Hangar-7 at Salzburg Airport. Current subjects in football, motor sport, winter sports and extreme sports are discussed by the moderators with celebrities and experts from the world of sport.

Reviews



Falling to Earth

Al Worden is one of the 24 humans to have ventured to the Moon. As command module pilot for the Apollo 15 mission in 1971, he spent six days in lunar orbit; three of these in solitude as his colleagues explored the lunar surface. In **Falling to Earth: An Apollo 15 Astronaut's Journey to the Moon**, the former astronaut describes various facets of his life, from farmer to soldier, and aviator to astronaut. Worden's recollections of his space activities are truly mesmerising. His deep space extra vehicular activity, about 80,000 kilometres from the Moon, made him the first human ever to see the entire Earth and Moon simultaneously simply by a turn of the head.

Worden participated in some of the most challenging missions ever to be undertaken by mankind. From his involvement in Apollo 15 to his work on the pioneering Apollo 9 and Apollo 12 missions, as well as the dangerous Apollo 13, his career was truly on the rise. Surprisingly, a mere nine months after returning from the Moon, he was dismissed from his position at NASA, with one week to remove all of his belongings.

What sparked this sudden 180-degree turn in the former astronaut's life? Worden had never disclosed the events that caused such upheaval at NASA, and which brought an end to his career. This book is an honest narration of the life of an Apollo astronaut - a man first publicly honoured, then shunned by his former colleagues, who was later able to regain his self-esteem. This book is a see-it-all journey to the Moon and back, a 'live' recollection of amazing sights, feelings and experiences. Definitely worth a read or two.

Karin Ranero Celius

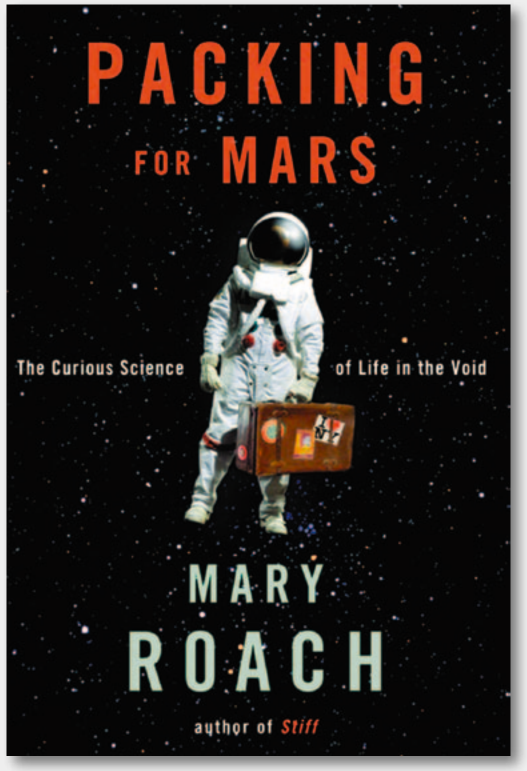
Fourth rock from the Sun

Mankind has put humans on the Moon and constructed the International Space Station. The next logical step might be a manned mission to Mars. But, are we ready for such a mission? And would humans actually endure the journey? These are two of the many questions that US journalist and popular science writer Mary Roach asked herself.

The result of her two-year quest for answers is her book **Packing for Mars: The curious science or a life in the void**. Using information gathered at various space agencies, such as JAXA, Roach describes the efforts made to send humans into space and how future astronauts are selected. She has truly done her research, keeping up-to-date with the latest achievements, such as being present at the opening of the hatch marking a succesful end to the short simulation conducted in preparation for the Mars 500 experiment. Her many interviews with various cosmonauts, such as Aleksandr Laveykin and his colleague Yuri Romanenko give the reader an account of the difficulties of living with two or more people, often from different cultures, in a small and confined space. This very descriptive narrative is peppered with often hilarious anecdotes about topics like hygiene and toilets, or the mysterious 'Three Dolphin Club'.

Throughout this engaging story, the author makes a passionate call for a trip tp Mars. At present, however, space agencies have no short term plans for manned missions to the Red Planet. And although it is already possible to visit Mars without leaving Earth, we could firmly say that there are many issues to resolve and questions to answer before we can actually start packing for Mars.

Dirma van Eck



Mega-monumental Mars film

John Carter. This could be the answer to the next-to-last question on 'Who Wants to be a Millionaire?' But there is a popular story attached to this everyday name. This John Carter is currently struggling through a wild, reckless, breathtaking hunt on the big screen, fighting for good and against evil, which exists in Barsoom too - Barsoom being Mars! We can finally see life there, even if only on the big screen - something for planetary researchers to enjoy for over two hours in the film **John Carter** (directed by Andrew Stanton [Finding Nemo]).

John Carter, the first space hero, was conceived 100 years ago by Edgar Rice Burroughs, who later brought Tarzan to life as well. He is a Confederate cavalry officer who, unexpectedly, finds himself on Mars, where he will live many epic adventures. In this Disney production, he even falls in love with a Martian princess with earthly good looks. It is a fantasy world with no rockets, computers or light sabres; instead we are presented with grandiose images of a world of cliffs and deserts, where advanced civilisations live, such as four-armed, semi-good Tharks (which are green) and calots (Martian hunting dogs), good Heliumites and evil Therns and Zodangans. It is a monumental 3D epic à la 'Cleopatra' or 'Alexander the Great' from Pixar Studios, an homage to Steve Jobs, with armies of digital and real extras. Well worth seeing! How does it end? Well...

Ulrich Köhler

Here comes the Sun

2012 has been proclaimed the 'Year of Sustainable Energy for All' by the United Nations. This is the perfect occasion to take a look at one of these sources of energy: the Sun. In 2008, Rob Van Hattum presented **Here comes the Sun,** a 50-minute documentary showcasing the developments in this emerging industry. It centres around an interview with Hermann Scheer, socialist politician and author of two books on solar energy, who was personally responsible for steering major legislative initiatives through the German parliament in the 1980s. His feed-in tariff law and separate subsidy programme for 100,000 solar panel roofs made investments in solar energy lucrative, turning it into the fastest growing industrial sector of Germany.

Solar energy was originally embraced mostly for idealistic reasons, but technological innovations and the introduction of mass-production have since made solar energy feasible. Many countries have followed Germany's example, and are introducing legislation to support the technological development and exploitation of solar energy. This documentary emphasises the current Energy Technology revolution taking place, with the energy sector increasingly being taken over by technological companies, and affordable renewable energy being made available to households everywhere.

Four years have passed since this documentary was made, yet the predictions made hold true. From parabolic mirrors, to concentrated solar power with the benefit of seawater desalination as well as direct evaporation; all of these are a focus of current research at DLR.Through projects such as DESERTEC, offshore solar islands and the development of energy storage technologies, DLR and Germany will continue to lead this Energy Technology revolution for many years to come.

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, transport and energy is integrated into national and international cooperative ventures. As Germany's Space Agency, the German Federal Government has given DLR the responsibility for the planning and implementation of the German space programme, as well as the international representation of Germany's interests in this field.

Approximately 7000 people work for DLR at 16 locations in Germany: Cologne (Headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Göttingen, Hamburg, Jülich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Stade, Stuttgart, Trauen and Weilheim. DLR also has offices in Brussels, Paris, Singapore and Washington D.C.

Imprint

DLR Magazine – the magazine of the German Aerospace Center

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

Editorial staff: Sabine Göge (Legally responsible for editorial content), Cordula Tegen, Marco Trovatello (Editorial management), Karin Ranero Celius, Peter Clissold, Sean Blair (English-language Editors, EJR-Quartz BV)
In this edition, contributions from: Jasmin Begli, Manuela Braun, Dorothee Bürkle, Dirma van Eck, Merel Groentjes, Ralf Jaumann, Elisabeth Mittelbach, Hans-Leo Richter and Jens Wucherpfennig

DLR Corporate Communications
Linder Höhe, D 51147 Cologne
Telephone: +49 (0) 2203 601 2116
Fax: +49 (0) 2203 601 3249
Email: kommunikation@dlr.de
Web: 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 2190-0108

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

DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center