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Anniversary in the land of the penguins

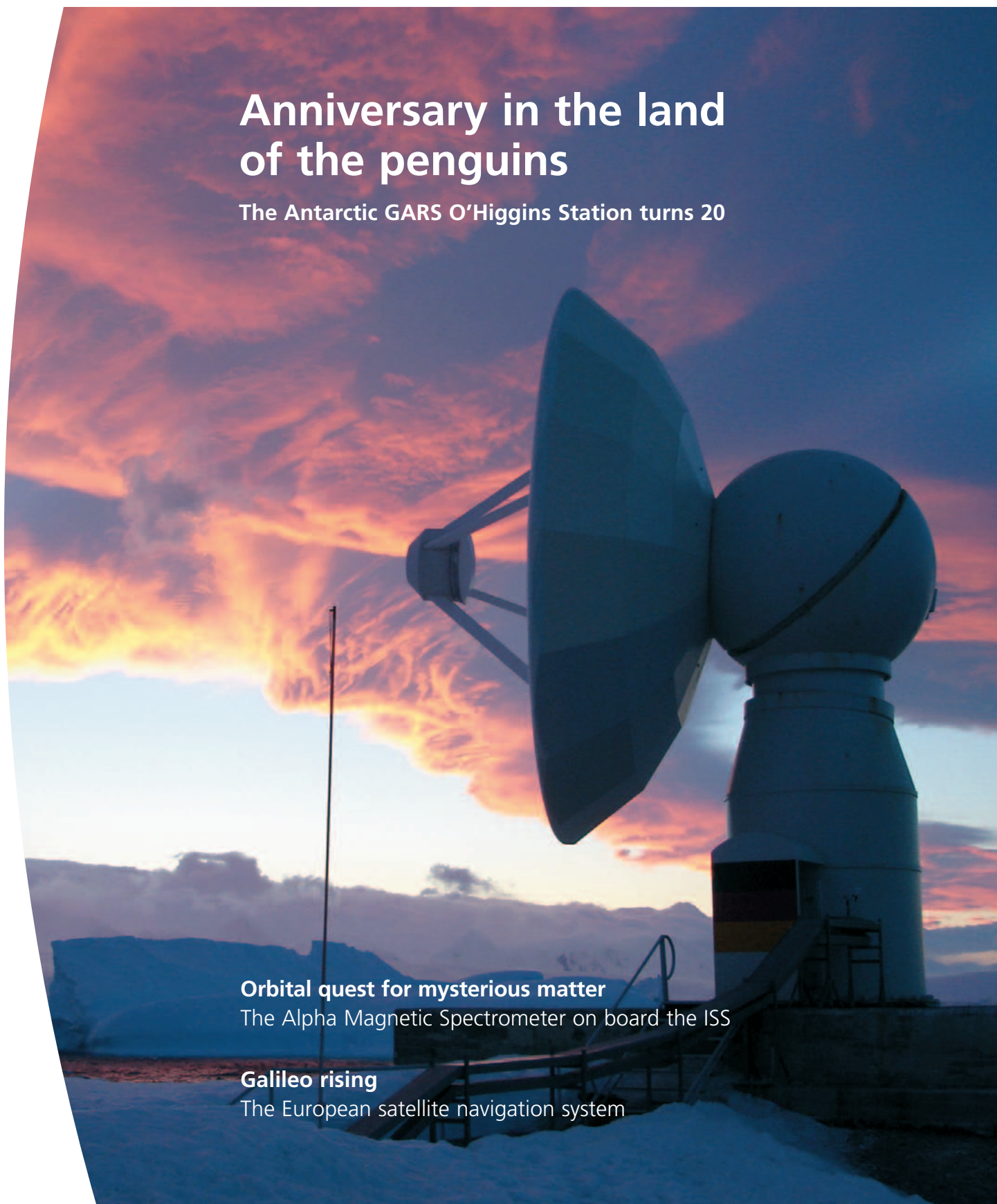
The Antarctic GARS O'Higgins Station turns 20

Orbital quest for mysterious matter

The Alpha Magnetic Spectrometer on board the ISS

Galileo rising

The European satellite navigation system



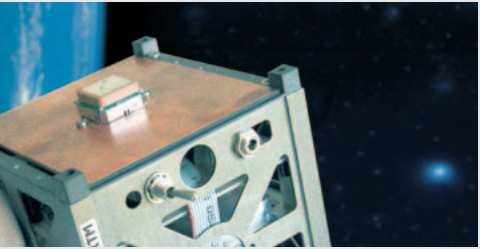
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The groundbreaking AMS project

Often overused, the attribute ‘groundbreaking’ is on safe ground here with the 6.7-ton Alpha Magnetic Spectrometer, AMS. This superb research tool has been orbiting Earth on board the International Space Station since May this year. It is not only one of the largest devices on the Space Station – it is also unique. When discussing the particle detector, German project leader Stefan Schael says: “If we do not detect any antimatter, we will be able to assume there is a high probability that it does not exist anywhere in the Universe.” Will the theory holding that matter and antimatter were produced in equal amounts during the Big Bang be proven correct? This interview clarifies how the ‘dark matter camera’ works and why the International Space Station is the ideal place for it.

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Dear readers,

2011 has proven to be an eventful and fast-paced year for DLR. The launch of the first two Galileo In-Orbit-Validation satellites occupies a prominent place at the top of our agenda, as does the recently-concluded Mars500 experiment. It is a busy programme, to say the least. In this edition, you can read about the amazing search for antimatter using the Alpha Magnetic Spectrometer on the International Space Station, how the changes occurring in energy policy are giving fresh impetus to DLR's solar research, and how the fuel cell powered nose wheel is opening up new possibilities for aircraft on the move on the ground. Meanwhile, the recent natural disaster in Japan and our associated work assisting with the relief efforts have demonstrated once again just how valuable the view of Earth from space can be. German Aerospace Day was, once again, proof of the tremendous public interest in DLR. Needless to say, this is only a partial list of activities – a full guide to DLR's work would have to be much longer than the issue you hold in your hands. But all these topics have something in common – the teamwork that brings DLR's outstanding results in research and science into the realm of the possible.

One of our smallest teams is probably the one at DLR's O'Higgins station in Antarctica. At temperatures as low as minus 20 degrees Celsius, two employees of the German Remote Data Sensing Center – a part of DLR – are responsible for operating this satellite ground station, which runs 24 hours a day, 365 days a year. Here, teamwork has a decisive role to play; indeed, it is crucial. And even when conditions are a lot less extreme, at DLR, the word TEAM is still written in capital letters. Without persevering scientists and a reliable operations team, it would not be possible to operate the two radar satellites TerraSAR-X and Tandem-X.

Whether written in capitals or lower case, much of our scientific work is only possible through interdisciplinary collaboration; teams drawn from our various institutes, disciplines, organisational units and scientific staff, all working towards a common objective. The possibilities for cooperation, the broad spectrum of disciplines and the working environment inherent at DLR are priceless assets and it is our duty to nurture and continue to extend them outwards.

After all, this also impacts our future activities. What new challenges will have to be met over the next few years? What type of competition will we have to contend with in the future? How can the standard of excellence achieved by DLR be maintained over the longer term? These are all questions to which there are no easy or clear answers. Many of the external influences from the worlds of politics and economics are out of our control, but what we can do is prepare ourselves as a team to encounter whatever the future may hold.

What makes us so optimistic? It is our fascination for research, the enthusiasm of being part of the process of change and, at the end of the day, of being part of a team that is helping to shape the future, acquiring ‘Knowledge for Tomorrow’. It is this that gives me such a feeling of anticipation as we embark on a new year.

Sabine Göge
Head of DLR Corporate Communications

Perspective

Mars – an artist's palette

The return of the Sun to Mars' south polar region after six long months of winter brings a growing glow to the volcanic plains of Promethei Planum, with its bright, earthen hues. The sight is surreal, resembling a mix of different oil paints on an artist's palette. The image actually shows coarse frost and ice deposits formed from carbon dioxide and water. Once summer arrives, this icy layer will almost completely evaporate and the typically Martian ochre of oxidised iron-bearing minerals will once again dominate the landscape.

The High Resolution Stereo Camera (HRSC), operated by DLR on board ESA's Mars Express spacecraft, recorded this scene. On 4 November 2011, the orbiter circled the Red Planet for the ten-thousandth time.



On 1 November 2010, Rolf Henke became the member of the DLR Executive Board responsible for aeronautics research. Henke was born in Lüdenscheid in 1956 and studied Aerospace Technology at the Technische Universität Berlin and at the Cranfield Institute of Technology (now Cranfield University) in the United Kingdom. At the start of his career, Henke worked at MBB (Messerschmitt-Bölkow-Blohm GmbH, now Airbus Operations GmbH). In 2006, Henke relocated his Aerospace Technology professorship to the Technical University of Rhineland Westphalia (RWTH) in Aachen and became head of its Institute of Aerospace Technology.

Flying to 2050

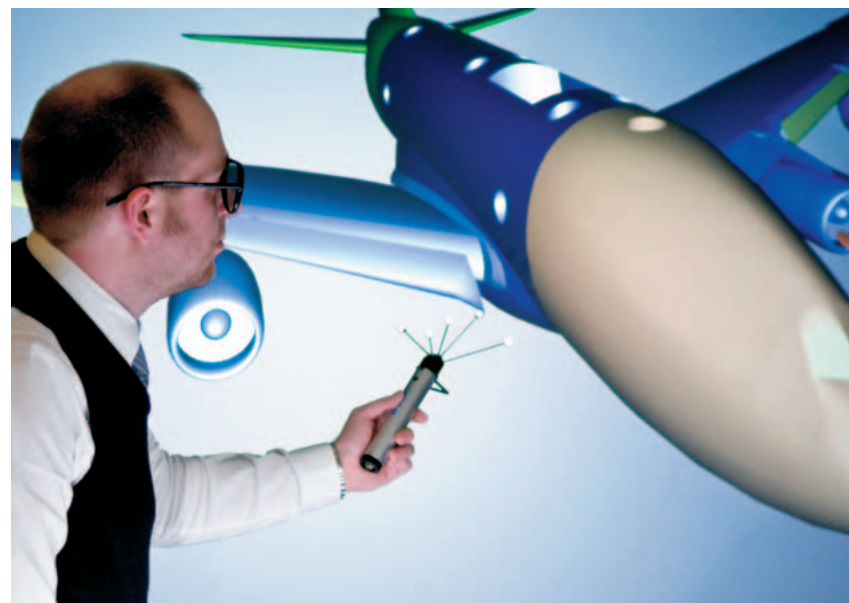
Imagination and intent – our keys to an environment-friendly and economically efficient transport system

By Rolf Henke

What will air travel be like in 2050? Matter-of-fact passenger numbers and revenue figures are not really a satisfactory answer to this question. Instead, people expect to hear of scenarios involving airborne taxis, shiny hypersonic jet aircraft and giant air freighters. Films such as 'Star Wars' or 'The Fifth Element' would provide a good answer – if DLR were the German Centre for Aviation Novels. I freely admit to enjoying intelligent science fiction – such as the narratives by Philip K. Dick, Frederik Pohl, Stanisław Lem or Robert Silverberg – but as the member of the Executive Board responsible for aeronautics research at Germany's national research centre, I have to, as it were, 'keep my feet firmly on the ground'.

The matter of the future of aviation cannot be considered separately from global developments such as the economy, education and wealth. All of these factors will have some impact on aviation. How will wealth be distributed 40 years from now? Will there be fewer holiday flights and an increase in the number of business jets? What conflicts might the world be engaged in by 2050? Will manned cargo aircraft still exist, or will Unmanned Aerial Vehicles (UAVs) have replaced them? What further developments can we expect from the electronics sector?

I can confidently predict that, just as sunbeds cannot replace beach holidays, video conferencing will not replace face-to-face meetings. There will continue to be goods that lose value rapidly, and must therefore be transported quickly. For this reason, passenger and cargo aircraft will continue to exist in 2050 – and, since we seem stuck in our archaic ways, so will airborne military equipment. But to prevent any technology enthusiasts reading this article from becoming disillusioned and turning the page to the next article, I now present a more detailed prediction of what the future might hold.



The components of future aircraft take virtual shape for the first time. Thanks to DLR's 'Powerwall', designers can now view products at close quarters, even if they only currently exist in the computer – and from all perspectives, as well. Here, Marc Tegeler looks at a 3D model of an A380. The projectors for the mural are located inside the Powerwall.

In terms of individual technologies, assistance systems will become more important, we will have a greater understanding of aerodynamics as well as improved knowledge about the properties of materials under load, and we will ensure the use of the most suitable materials for wings, fuselage and tails – always assuming, of course, that these still exist as separate components by then. The efficiency and operational availability of aircraft will continue to improve.

Regarding major components, we will continue to see aircraft engines – and indeed present-day aircraft types – in 2050, although alternative propulsion systems and fuels will penetrate the market to an ever greater extent. The differentiated design principle underpinning modern aircraft (wing, fuselage, engines, tail) has many advantages, as does the – closely related – distinction made between lift and thrust. Nature, however, teaches us about the efficiency of integrated construction methods. It is probably going to take more than 20 years to develop the materials, systems and construction techniques to meet aviation standards and adapt our philosophy accordingly. This means that major components like those that we know today are going to be around for a long time to come.

With regard to types of aircraft, there is going to be a small market for supersonic planes. Feeder aircraft capable of short take-offs and landings will help to relieve congestion at major airports, cargo aircraft will increasingly become unmanned (for example, goods will be transported by UAV), and we may even witness the advent of super-freighters in the form of a flying wing. UAVs are most certainly going to make their way into air transport, and in the foreseeable future they will also be used to monitor traffic, check pipelines and deliver materials to inaccessible locations, for example.

Procedures on the ground are also going to change. Security check areas will greatly increase in size, thereby speeding up airport operations. Through the application of total system analyses and syntheses, including the integration of multiple modes of transport, it will become possible to minimise the impact of events such as volcanic eruptions on our fragile transport systems. All of this will make aviation more reliable.

These developments will be requirement-driven, not only with respect to the external impact of aircraft and aviation (noise, emissions, ground procedures, consumption of energy and raw materials) but also in terms of 'internal' characteristics (comfort, use of human resources and costs). Both of these factors have been, and remain, drivers for new technologies and developments. One example of this requirement-driven approach is the new vision of aviation formulated by the European Commission in its 'Flightpath 2050' document, to which DLR contributed as the only European research centre involved. With new requirements driving change, I confess that the prospect of more numerous and increasingly challenging demands being made on the aviation sector would be pleasing to me personally. In all likelihood, this would give rise to more exciting research projects and also bring about fundamental changes.

Aeronautics research at DLR is already very well prepared for whatever the future may hold. The three core techniques involved are experimentation, simulation and data manipulation, and our collective task is to bring together the full range of disciplines in order to better understand the air transport system as a whole – from aerodynamics to life cycle analysis to interactive simulation of complete systems. We are prepared to tackle this task and to help create an aviation sector that is convenient for its users while being both environment-friendly and economically efficient.

DLR's performance capability is rooted in its institutes. To be brought to fruition, any aeronautics research programme must involve the collaboration of several institutes, and those at DLR extend their cooperation across all such programmes. The various areas of research at DLR come together at some exciting interfaces. Aviation and transport come together at airports, for example, while interdisciplinary solutions also emerge from different teams putting their heads together; aviation and energy in the generation of thrust and production of secondary energy; aviation and spaceflight in relation to satellite-based communication and navigation – the list goes on. We will be successful if we are able to 'keep our eye on the ball' across the spectrum – the requirements of the future, the experience from the past, the visible development paths – and, through all that, have the courage to follow uncharted routes. The more we succeed through our combined efforts, the better aviation will prove to be in 2050. ●

In brief



The Spanish twin-engine CASA 212 on the tarmac

Using data obtained from 1000 to 2000 metres above the ground once per day as well as once per night, the researchers can monitor how urban heat islands vary with time by analysing the cooling behaviour of all types of materials. The data collection flights were funded by the European Commission as part of the EUFAR project, with results due to be published at the start of 2012.

www.eufar.net
www.inta.es

A cool look at urban heat islands

Where do urban heat islands appear and what are their consequences? To find out, flights were conducted over districts of Bochum and regions of Munich and Regensburg as part of DLR's UR-TIR project (urban mapping with airborne thermal-infrared imagery).

The mission – conducted by DLR in cooperation with the Geography Department of Ruhr-Universität Bochum – relies on data acquired with an Airborne Hyperspectral Scanner (AHS). Both this sensor and the carrier aircraft – a twin-engine CASA212 – were provided by the Spanish Instituto Nacional de Técnica Aeroespacial (INTA).

The researchers want to classify urban land cover and its corresponding surface materials, as well as measuring the thermal radiation emitted by the terrestrial surface. Achieving this should enable them to measure the effects of urban heat islands in relation to different urban structures and their surroundings. The findings will give city planners information about construction methods that have a positive effect on the climate.

DLR Braunschweig launches city-wide traffic research project



The DLR test vehicle FASCar receives information from the next set of traffic lights about how long its current red phase will last

With support from the German Federal State of Lower Saxony, the city of Braunschweig and other partners, DLR can use AIM to create Germany's one-of-a-kind large-scale research facility. AIM covers the entire spectrum of traffic research from data collection, simulation and laboratory experimentation to field-testing in real traffic conditions. This enables the scientists to work intensively on the most diverse issues of transport research, be it the development and testing of driver assistance functions, modern traffic management or sociological transport analyses.

<http://s.dlr.de/xz96>

The city of Braunschweig has been turned into an intelligent mobility traffic research laboratory. This region is a perfect fit for the Application Platform for Intelligent Mobility (AIM) long-term research project. This is not due just to its size, but also its combination of road, rail, urban and rural transport connections and proximity to motorways. It is therefore an ideal place to analyse new traffic and automotive technologies under near-real conditions.

With the development of three communication units, AIM has now taken its first step into real-life city traffic. The traffic lights employ a wireless network to inform the DLR test vehicle FASCar about their switching between green and red. Based on these values and accurate position information, the appropriate speed is determined and the system displays it on the vehicle's speedometer. The drivers that adhere to these recommendations should be able to enjoy a green wave through city traffic.



The design of the new DLR lab building in Bremen allows visitors to observe the work being conducted on future satellites

A new space for satellites at DLR Bremen

A new laboratory for the development of complex space travel systems is now available at DLR Bremen. Scientists and engineers now have an area of 3300 square metres in which to assemble and test research satellites. They are also developing control systems for spacecraft.

The DLR Institute of Space Systems, founded in 2007 on the Bremen University campus, currently employs 160 people, who can now work together much more efficiently under one roof. Members of the public can access a number of viewing galleries in the building if they wish to know more about the Institute's current research.

Damping vibrations – DLR tests new Eurocopter system

An innovative system for suppressing vibration, developed by the EADS subsidiary Eurocopter at DLR Göttingen has been put to the test. The system dampens vibrations at their very source – on the helicopter rotor blades. This new technology prevents the rapid wear of components in the helicopter airframe and also means increased comfort for passengers.

The DLR Institute for Aeroelasticity is a European leader in vibration research. To test the new Eurocopter system, the rotor blade vibrations of an EC135 were electro-dynamically simulated on the test bench. In the tests, researchers determined how effectively the new system works against the artificial vibration forces. These vibration dampers are already in use on a larger scale to stabilise buildings subjected to strong winds and earthquakes.



Mid-air rotor blade vibrations are simulated on an EC135 helicopter, with the test assembly affixed to the rotor head.

DLR_School_Labs for Neustrelitz and Dresden

A new DLR school laboratory has been established in Neustrelitz. This DLR_School_Labs team has developed age-appropriate experiments, primarily aimed at bringing children and teenagers closer to research projects being carried out at the DLR site in Neustrelitz. The plan is to include tests involving data acquisition, electromagnetic waves and satellite navigation. In addition, there will be experiments concerning the impact of atmospheric pollution on sunlight.

While school groups are invited to use the DLR_School_Labs facilities for free, the same is true of their teachers, who are also welcome to participate in workshops to find out about the current status of research.

The opening of the DLR_School_Lab in Neustrelitz means that there are now nine DLR school laboratories across Germany. The tenth DLR_School_Lab will be set up in Dresden. There, students will be able to tackle questions concerning the key DLR subjects of energy and traffic from the end of 2012. The Dresden school laboratory is a joint project involving the Technical University (TU), the city and DLR. The DLR_School_Lab TU Dresden is located in the Technical Collections (Technische Sammlungen) in the centre of the state capital of Saxony. Matters, such as how fuel-cell-driven cars of the future will operate or how solar electricity will reach homes, will be demonstrated and considered in the experiments conducted.

www.DLR.de/schoollab/en



In the presence of numerous guests and a year 10 class from Neustrelitzer Carolinum school, Norwegian ambassador Sven Erik Svedman, Minister Henry Tesch and DLR Chairman Johann-Dietrich Wörner (left to right) officially inaugurated the DLR_School_Lab in Neustrelitz at the beginning of this term.

A new shape for aircraft fuselage and wings



This design of the fuselage and cabin was developed by DLR researchers using computer simulations

DLR scientists are taking another step towards the aircraft of the future; the fuselage and cabin design have been amalgamated in a computer model. The 'Blended Wing Body' combines better fuselage aerodynamics and more space for passengers in a single design.

The aircraft's fuselage blends smoothly with the wing, improving the lift. With this aerodynamic shape, the engines need to do less work and the aircraft can be lighter. This would give a 20 percent reduction in fuel consumption. Although the model is still in the development phase, DLR scientists can already use the computer model to test how the aircraft would perform under real conditions. Next, the researchers want to further optimise the aircraft and integrate essential systems, such as air-conditioning, hydraulics and flaps.

<http://s.dlr.de/z5qy>

Alexander Gerst to fly to the ISS

German ESA astronaut Alexander Gerst is due to head to the International Space Station (ISS) in May 2014. He will stay there until November 2014 on a long-duration mission. In an interview on the DLR website, in which he also answered questions regarding his application and selection, the trained geophysicist and enthusiastic volcanologist reported that his Russian is progressing well.

After Thomas Reiter, Alexander Gerst will be the second German ESA astronaut to live and work on the ISS for a number of months. In September 2009 he underwent basic training at the European Astronaut Centre (EAC) in Cologne and was officially appointed an astronaut at the end of 2010. In 2014 he will supervise ISS Expeditions 40 and 41 on board a Russian Soyuz spacecraft as Flight Engineer. Gerst has already started his mission training at NASA's Johnson Space Center in Houston (Texas).



Alexander Gerst was born in 1976, the year in which Sigmund Jahn became the first German to travel to space.

<http://s.dlr.de/l207>

At the cradle of aeronautics research

With over 7000 visitors at its open day on 18 September 2011, the DLR site in Göttingen experienced an unprecedented level of interest among aeronautics enthusiasts. The total number of visitors for the previous open day was 3900.

Researchers from Göttingen gave presentations on their research on aircraft, spacecraft and trains under the slogan 'At the cradle of aviation'. One of the highlights was the display of the Antares DLR-H2 motor glider, the first manned aircraft in the world capable of taking off using only power from a fuel cell. This propulsion system allows it to fly without generating carbon dioxide emissions.

Also unique are the tunnel simulation facility, a catapult for high-speed train models, and the High-Enthalpy Shock Tunnel for investigating spacecraft re-entry. Visitors were able to test their wind resistance in hurricane-strength airflows using the wind tunnel. There was also a programme on aircraft construction and space shuttle slides for children.



Georg Dettleff (in the background) tells visitors about the Göttingen Propulsion Beam Simulation Facility, where the behaviour of satellite propulsion systems under space conditions is investigated.

Safer helicopter flights

A helicopter with a bulky external load must remain stable and controllable while in the air. In future, this is likely to be controlled with a new pilot assistance system developed by DLR. The system positions and stabilises loads automatically, so the pilot no longer has to concentrate on controlling the load.

An external load can easily start to swing as a result of a gust of wind or a manoeuvring error. The pilot is unable to see the load and must rely on information from others to react accordingly. The HALAS (Hubschrauber Außenlast Assistenz System) project – which is being jointly developed by DLR and iMAR GmbH – is intended to address this problem. It will ensure that, if the load starts to swing, the helicopter will move so as to damp the motion.



During flight tests with DLR's research helicopter (FHS), its rescue hoist was examined, among other things.

Good framework for innovation

New ideas for products, services and processes are in greater demand than ever before. DLR is expanding its role as a technology provider and development partner for the economy, taking another step in this direction in 2011 – the DLR Executive Board adopted an innovation policy and a mandatory DLR framework for innovation.

The innovation system is the mechanism through which DLR's potential for innovation can be significantly enhanced; as a result, the benefits of research can be demonstrated to both government and society. It consists of guidelines for promoting the culture, goals, strategy and process of innovation as well as supporting methods and tools. It also promotes awareness of the active transfer of research results to the industrial supply chain, encouraging all members of staff to collaborate with industry and use their research results to develop new applications. DLR's Executive Board is providing the necessary framework conditions to achieve this.

The system also includes the analysis of important trends such as idea workshops, market research, support for newly-founded companies and a DLR-wide 'portal for innovative ideas' to collect, assess and develop ideas for innovation projects. To complete the loop, DLR is cooperating more closely with industrial companies that are incorporating DLR technologies, developing them to market maturity and successfully launching them on the market.



Working with IQ Wireless GmbH, DLR has developed the 'Fire-Watch' system, which employs technology derived from space-based optical sensor systems. FireWatch detects forest fires in their early stages by automatically recognising smoke, even at night. The image shows the FireWatch technology on the fire lookout tower at Zesch am See, about 45 kilometres south of Berlin.

Around the Universe in 80 Questions

Questions about the Universe, astronomy and spaceflight fascinate many people, but the answers are often complex and long. DLR has now published a book that answers the key questions about the cosmos in 80 short contributions. The book is titled: **Why does the size of the Moon change? Around the Universe in 80 Questions.** The colour-illustrated, pocket-sized 168-page book was published by KOSMOS, and is available in German for € 14.95.

Two pages are dedicated to each question, with an accompanying illustration. The texts are written in a natural and simple style, and anyone interested in the cosmos is sure to discover some exciting findings inside. The collection was inspired by an online campaign to celebrate the International Year of Astronomy in 2009. The 'Astronomy Questions of the Week' project was very popular, both among visitors to the DLR webpages and in magazine and newspaper websites.



Orbital quest for mysterious matter

The Alpha Magnetic Spectrometer (AMS), a seven-ton, four-metre-high particle detector installed on the International Space Station (ISS), is being used to help a team of researchers from all over the world come a step closer to solving riddles about our Universe and, by extension, our own existence. The experiment addresses questions concerning the existence of antimatter and dark matter, and could lead to ground-breaking discoveries. In this interview Stefan Schael, an experimental physicist and the German project lead for AMS, explains how the instrument is being used and the discoveries it could lead to, and shares the story of the long road leading to its launch and commissioning.

Can the existence of antimatter and dark matter be proven?
Is it necessary to go to the International Space Station to do so?

By Marco Trovatiello



Stefan Schael, German project leader for the Alpha Magnetic Spectrometer experiment.

Professor Schael, could you start by describing the operating principle of the Alpha Magnetic Spectrometer and the aim of the experiment in simple terms? People often speak of it as a 'dark matter camera', but it is not a camera in the normal sense, is it?

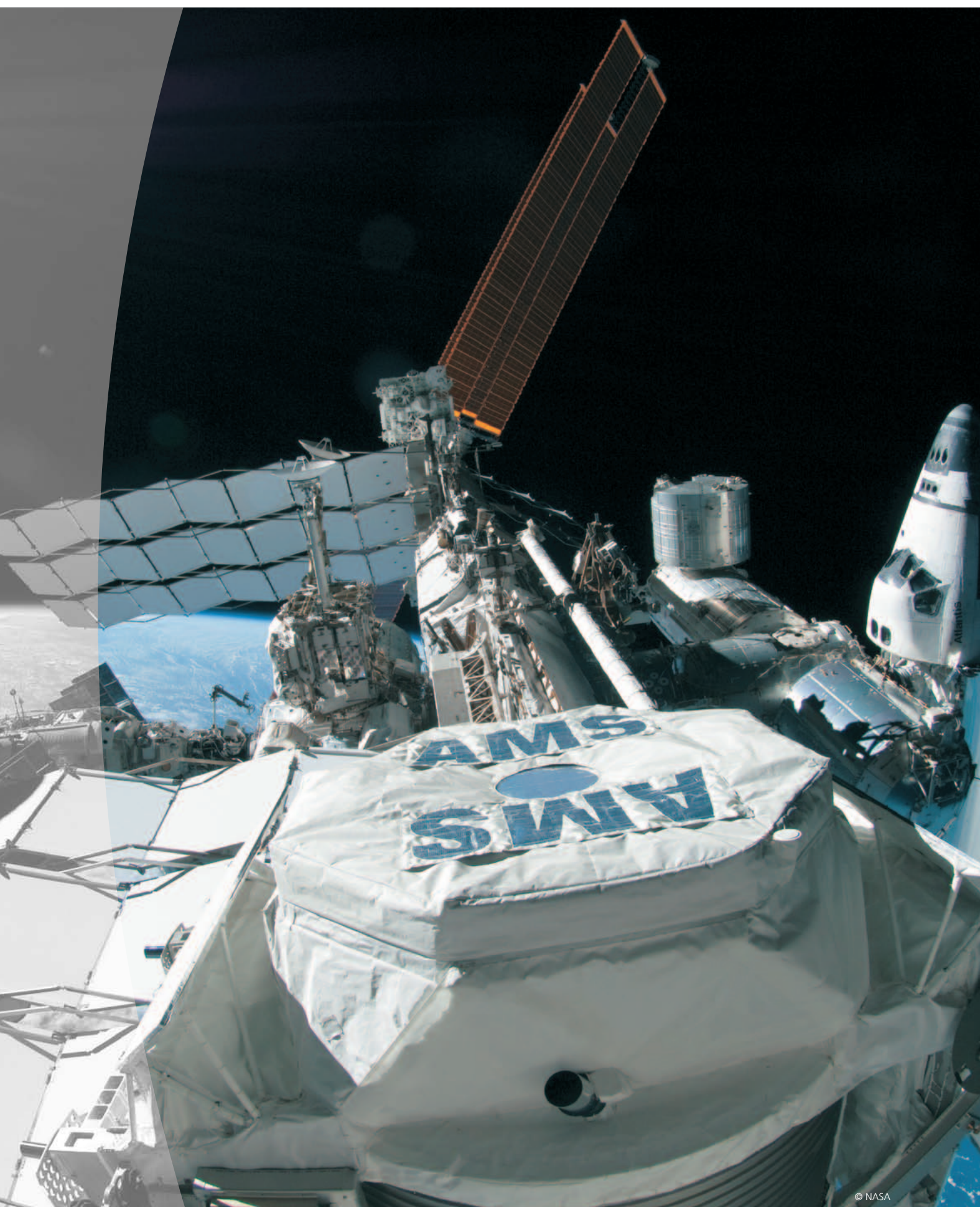
I could give a two-hour lecture on this question alone. I will begin with a few basic considerations that led to the AMS experiment. One of the problems in physics today is that a number of recent cosmological observations are not compatible with current theories. This means that there are phenomena in our natural environment, the Universe, which we do not fully understand. Some of the fundamental questions in physics include: Why do we exist? Why does it appear that equal amounts of matter and antimatter were not formed after the Big Bang? Why is the Universe not made of light alone?

When you say 'we', you mean matter?

Yes, that is correct. This has nothing to do with the question of why there are intelligent beings like us in the Universe. Of course, the fact is that matter is needed in order for us to be here, but we do not even understand why matter exists in the Universe!

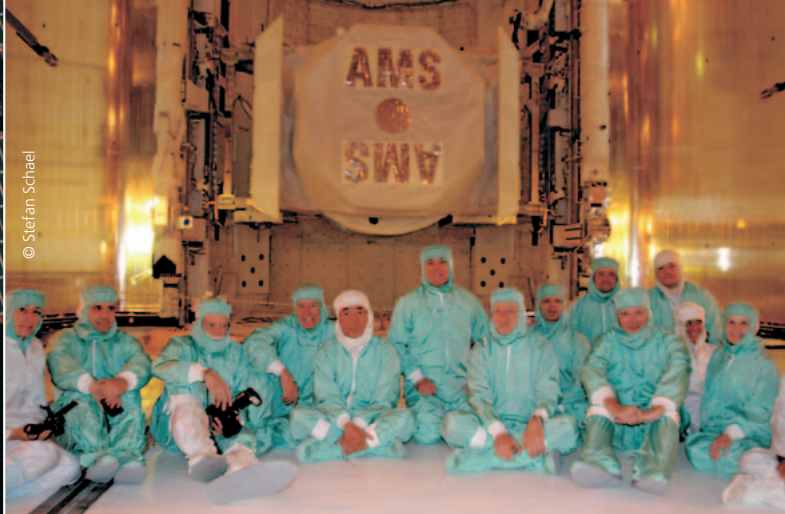
A second, more fundamental problem is that we observe our Sun, along with the planets in the Solar System, moving around the centre of the Milky Way in a stable orbit. We can even measure the speed at which the Solar System is orbiting the centre of our galaxy. But when we calculate whether the gravity of the Milky Way is sufficiently strong to keep the Solar System in its orbit, we come to the conclusion that the Sun should theoretically be flung out of the galaxy. If that happened, there would be no life on Earth. This leads us to the question: why do Earth and the other planets exist?

AMS after installation on the International Space Station's Starboard Truss. To the right is the docked Space Shuttle Endeavour, which carried AMS into Earth orbit.

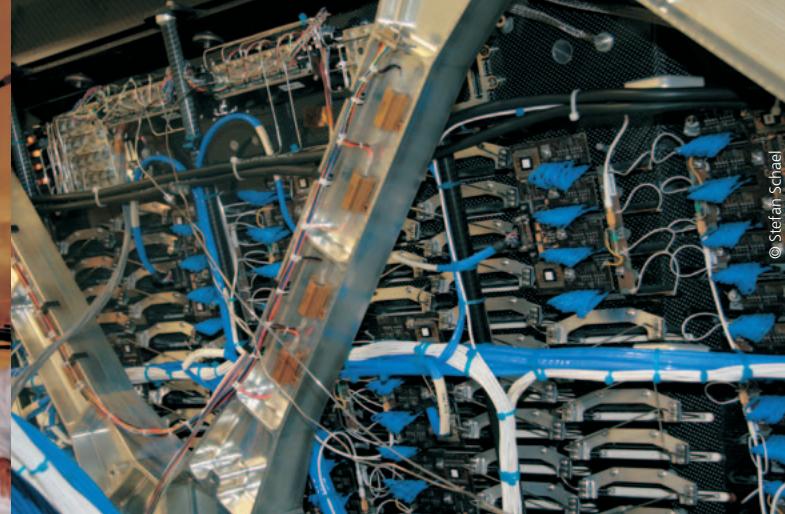




NASA astronauts and STS-134 mission specialists Greg Chamitoff (left) and Andrew Feustel (right) install AMS on the ISS exterior structure



Samuel Ting (middle), Stephan Schael (fifth from right) and the other members of the AMS team in the Payload Changeout Room, during preparations for the launch of AMS on board Space Shuttle Endeavour.



Detail of the German-built Transition Radiation Detector (TRD), which plays a key role in studying the existence and nature of dark matter.



Part of the German AMS team in the clean room of the I. Physics Institute RWTH Aachen. Visible in the background is the Transition Radiation Detector.

Are you hoping to use the AMS experiment to help answer these questions?

Exactly. We do have a physical model that might explain this phenomenon. What we refer to as dark matter plays an important role in this model. We presume that the answer must be a new type of elementary particle that we have not yet detected. If we were to find it, we might understand why the Sun does indeed orbit the centre of the galaxy in a stable path.

So AMS is intended to help us find dark matter?

Yes, that is right. But I would like to say a few words about antimatter and follow up on your opening question. One currently valid model assumes that antimatter was left over after the Big Bang. In this scenario, there could be galaxies made of antimatter, but they would look exactly the same as our Milky Way. The stars would shine in exactly the same way as in our own galaxy, and they would die off every so often in a huge, yet brief supernova explosion. In this way, antimatter particles would be accelerated to high energies and, since the Universe is a near-perfect vacuum, they would reach us, pass through our spectrometer and we could observe them. If we were able to detect such particles, we would know that the Universe consists of as much matter as antimatter and we would have solved this puzzle.

Why must the particles be detected in space or, more accurately, on the ISS, 350 kilometres above Earth? Have we not already been trying to track down antimatter for some time now, using particle accelerators like the one at CERN, the European Organization for Nuclear Research?

Yes. In fact, we have been investigating the asymmetry between matter and antimatter for 50 years, but the experiments we are carrying out on Earth have not revealed enough for our needs. In this regard, AMS is a pioneering experiment, as it will increase the measuring sensitivity by a factor of over a thousand. And that is only possible in space...

Why?

Here on Earth, we are only able to identify neutral particles such as photons because the atmosphere and magnetic field protect us from charged particles, which are one component of cosmic radiation and dangerous for all living things. If we were not shielded from them, there would be no life on Earth. This is why we have to go into space, to the ISS, to encounter such charged particles.

Let's come back to antimatter. Do you think you will be able to find evidence of its existence?

If we do not detect any antimatter, we will be able to assume there is a high probability that it does not exist anywhere in the Universe. Speaking personally, I would be surprised if we do find antimatter, but as a scientist one needs to be careful making such predictions; an experiment with this level of sensitivity has never been performed.

But one way or another, the conclusions drawn at the end of the AMS mission will be groundbreaking. If you don't find any antimatter, physics textbooks will need to be rewritten...

Not actually rewritten, but we have been trying to build on incomplete theories that lie at the heart of the standard model of particle physics for over 30 years. We still have not managed to use these theories to solve the mysteries of the Universe and answer the question about our existence. Nevertheless, it is very clear that we are not currently advancing our theoretical understanding. To do so, we need new experiments and new observations...

... and new data from experiments such as AMS?

Yes, we need new experimental data. This is precisely what we, as experimental physicists, are trying to do; develop and construct measuring instruments with much higher accuracy – and then hope that we can unravel the next mystery, or at least the clue to the next step that lies within the range of these experiments.

How is this highly sensitive spectrometer working thus far?

AMS is working superbly, as well as we had hoped it would. The measurements that we are getting are extremely precise, even better than expected. We have not been able to achieve this accuracy with particle accelerators on Earth yet. I find that fantastic. We are running at 100 percent – everything has worked as planned. It is a tremendous technical and engineering achievement. But we are also facing a dilemma. The data we are recording is so precise that it would not do it justice to publish it prematurely before its calibration is thoroughly tested. It would not be fair to the instrument. In effect, we need to understand our instrument better than originally expected. This means there is a great deal of detailed work ahead of us.

Have you found anything of significance yet?

Before creating any expectations, one must demonstrate that the measuring instrument – the basic physics – is working properly. We are already making good progress and anticipate a first publication as early as 2012 or 2013. I cannot say today whether we will have found dark matter or antimatter by then, or whether we will perhaps have found something else entirely, but I can tell you that we will have some excellent results. We will definitely meet the expectation of obtaining measurements 1000 to 10,000 times better than with previous experiments.

Currently, we are fully engaged in guaranteeing the operation and functioning of AMS. In this regard, we have already agreed a financing package for the next three years with the DLR Space Administration. At this point I must say that our DLR colleagues have done a great job here. AMS was and is not a simple project – some really difficult decisions have had to be made, and DLR's assessment has been correct. It is thanks to this that we have been able to develop such a wonderful instrument and are now in a position to carry out excellent research on an international scale.

Let's talk about the duration of the mission. Is it true that 11 years will be the optimal length of time, so that you are able to take measurements throughout a complete solar cycle?

This is a difficult question. Of course we have asked ourselves for how long AMS will keep taking measurements. The current forecast is about 20 years. The space agencies in the other countries involved have committed themselves to operating the ISS until at least 2020, and there is even a statement of intent that the ISS will continue to operate until 2028. Ideally, we would take measurements for more than 11 years, precisely because of the solar cycle. We are doing this work in a totally unknown environment in which we are unable to control the acceleration mechanisms responsible for the incoming particles. We are measuring everything there is in the Universe and there are a few rare results that might lead us to finding something completely new. For example, a supernova explosion in our galaxy cannot be predicted. If this type of event were to take place, it would be a shame if our unique measuring instrument were no longer there to witness it. My opinion is that we would do well to keep AMS operational for as long as possible - not least because operational costs are rather low in comparison to those related to development and construction. If everything goes to plan, after 10 or 12 years we will have data that achieves excellent levels of precision in terms of statistical averages.

Let's take another look at the technology. What was especially challenging about constructing the AMS instrument?

This was mainly a matter of the magnetic field required. AMS detects charged particles and has been designed to be used in space – these are the basic requirements. To determine whether particles are positively or negatively charged, a magnet is used to deflect these particles along a path whose direction depends on their charge. When such a magnet flies in low Earth orbit on a space shuttle or the ISS, its magnetic field interacts with Earth's magnetic field. Consequently, great caution must be taken when designing the magnet, otherwise the interaction between these forces might be so large that attitude control cannot be maintained and the ISS might begin to tumble. Naturally, the first thing that NASA and DLR said was 'show us that it works'. This is what we did with AMS-01, our precursor experiment that spent 10 days on board the Space Shuttle Discovery in 1998. We not only proved that we had built an instrument – incorporating a magnet – whose interaction with Earth's magnetic field did not affect the control of the Shuttle or the Space Station, but also that it was sufficiently robust and mechanically stable to survive a shuttle launch, installation on the ISS and take highly precise measurements.

Why is AMS also referred to as a dark matter camera?

This is because it has a semiconductor detector similar to those found in digital cameras. What we are doing is photographing the charged particles that enter the instrument.

So the comparison is not so far off the mark?

No, it is actually quite good. But we are acquiring up to 6000 images per second, and this just from cosmic radiation. We measure this with 300,000 separate channels.

Let's talk about the German contribution to AMS. At RWTH Aachen, you are concerned with, not just scientific research, but also with the development and construction of the new types of instruments required, such as AMS.

That is correct; it makes up a good 50 percent of my work as a Professor and Chair for Experimental Physics. We perform experimental physics. If you want to discover something new in this field, you need a new, even more precise measuring device. Designing and building one is the first task. Take the Hubble Space Telescope as an example. You build a telescope, launch it into space and acquire the most incredible data above Earth's

atmosphere. But nobody can build the new instrument that we need for our experiments, so we have to do it ourselves, according to our own specific requirements. It is not something you can buy off the shelf.

Which components of AMS were designed and built in Germany?

Development work took place at two locations in Germany, at RWTH Aachen and at the Karlsruhe Institute of Technology (KIT).

With AMS-01, we already had two important subsystems: the Laser Alignment System and the Anti-Coincidence Counter – both important components of the track detector, which analyses the incoming particles. With AMS-02, in addition to these components, we built the Transition Radiation Detector, which sits above AMS, so to speak, and weighs around 500 kilograms. We built the whole detector ourselves and KIT contributed the data acquisition system.

In summary, it can be said that here in Germany, with comparatively limited financial resources, we managed to produce an independent detector for this measuring instrument. This was a great achievement, for which the basics were set up by my predecessor, Klaus Lübelmeyer, and DLR. I think that we are now playing a leading role in this project. It turns out that our Transition Radiation Detector is the key instrument for research into the nature of dark matter. Even in science, such an effort is not fully predictable, but requires good fortune. Clearly, we are very lucky to have been in the right place at the right time with the right instrument.

Let’s talk about the history of AMS. Everything moved quite quickly following the launch on 16 May 2011. AMS was switched on for the first time after just two hours in the shuttle payload bay; it was installed on the ISS on 19 May, began recording data and, as you have already said, is functioning perfectly. But getting there was a long, drawn-out journey...

Correct. Samuel Ting, Nobel Prize winner and the ‘father’ of AMS, approached Daniel Goldin, NASA Administrator at the time, and made him aware of the need to carry out fundamental research on the ISS. Goldin understood immediately; the space agencies from other countries, including DLR, came on board, and today AMS is on the ISS. It is by far the biggest and most publicised fundamental research experiment on the ISS. From my perspective, it adds to the legitimacy of building a structure like that up there. Basic research, as another Nobel Prize winner, Steven Weinberg, said, involves discoveries that can change the world. AMS has the potential to change the world with its discoveries.

In Germany, Klaus Lübelmeyer set the project, which I have led since the year 2000, in motion. In 1996, DLR provided the funding for AMS-01 in its capacity as the Federal Government’s space agency. Two years later, AMS-01 spent 10 days on board the Space Shuttle Discovery as a technology demonstrator. In 1999 DLR committed to the funding for AMS-02, and a launch date of 2003 was planned. But things worked out differently as there were no shuttle launches for four years. In 2005, when the problems concerning the NASA Space Shuttle programme intensified, we were informed that there would no longer be a flight slot available for AMS...

And that was the low point of the project. You had invested years of work...

More than five years, and the instrument was ready. In addition to this, the space agencies of the other participating countries decided to reduce support for the project. Ultimately it was Samuel Ting and leading European politicians who persuaded the US government to reverse NASA’s decision; DLR also decided to go ahead on behalf of the German Federal Government and allowed us to carry on. Here, Peter Hintze, Parliamentary State Secretary in the German Federal Ministry of Economics and Technology, and Johann-Dietrich Wörner, Chairman of the DLR Executive Board, made strong personal commitments.

Did you ever consider using a European Ariane heavy lift rocket as a platform for getting AMS to space on board a satellite?

AMS has high power consumption and communications requirements, for example in terms of data down- and up-linking. This does not mean that an appropriately sophisticated platform could not have been built to operate AMS as a free flying satellite, but why would we do this when we already had the infrastructure for such a sophisticated platform in the form of the ISS? From my perspective, the ISS is the ideal platform for running experiments such as AMS in space.

Back to AMS’ long journey to space...

Well, it took until 2008 for the STS-134 mission to gain approval, taking AMS with it to the ISS.

And that only happened in May 2011. Why did it take so long?

Mainly because we needed to rebuild AMS after such a long interval. Originally, AMS was only supposed to operate on the Space Station for three years and then be brought back to Earth. Of course, with the discontinuation of the shuttle programme, that became unlikely, so we had to adapt the magnet and detector components for a longer mission, to optimise the scientific return.

The results of the AMS experiment will be made generally available. How exactly will that happen?

I believe that whenever we carry out research to understand how the Universe originated, many people want to know how we have reached our conclusions – not the technical details, but certainly the results and what implications these have for individuals.

What implications are these?

First of all, the insight is of value in itself, because it gives rise to intellectual freedom. One does not have to decide between belief system A, B or C, rather, in the ideal case, science will tell us how the Universe originated. This gives society freedom; it becomes more difficult to manipulate it. Just as it gave society freedom once it became understood that Earth orbits the Sun, not the other way around. We are not the pinnacle of creation; Earth is not the centre of the Universe. Results like these are the basis for an open and free society and, consequently, can change all our lives. In the medium term, the



AMS inside Space Shuttle Endeavour’s payload bay

© NASA

findings of fundamental research in physics tend to lead to new technologies. Think back 100 years to the development of quantum mechanics and then consider the semiconductors, lasers, solar cells, computers, the Internet and smartphones that are the result.

So communicating these results is as important as the results themselves?

Yes, if you like. Another part of my job is to communicate the knowledge we have acquired in the last decade and that which we can anticipate for the future. I do this in presentations and articles aimed at the general public. If we make exciting discoveries, I will ensure that the public is informed about the aspects that have wider significance, while the scientific community will learn the details in specialist publications. ●

About the interviewee:

Stefan Schael was born in 1961 in Leverkusen and is head of the I. Physics Institute B at RWTH Aachen (Rheinisch-Westfälische Technische Hochschule Aachen). He studied physics in Bonn and Heidelberg, obtained his PhD at the University of Karlsruhe and qualified as a professor at the Ludwig Maximilian University in Munich. Following a research period at CERN (the European Organization for Nuclear Research) and work as a scientific staff member at the Max Planck Institute of Physics in Munich, he moved to RWTH in early 2000. His research interests include particle and astroparticle physics. Besides the AMS experiment, he has worked on various different international research projects, such as CMS, a detector at the CERN Large Hadron Collider. Schael is married and has two children.

More information:
www.ams02.org
<http://s.DLR.de/c5w3> (video)

A handful of satellite

Small enough to fit in one hand and barely a kilogram in weight yet crammed with remarkable technology – these are ‘CubeSats’ with the names BEESAT-1, -2 and -3 (Berlin Experimental and Educational Satellite). Students at Technische Universität Berlin are building these tiny spacecraft; DLR is supporting these future aerospace engineers in accomplishing their goals.

Students build and operate picosatellites

By Martin Fleischmann

Once the domain of superpowers and the largest corporations, the shared CubeSat standard has extended access to space to modestly budgeted university departments or the very smallest of companies. The only problem is, up until now, the actual abilities of these ‘pico-satellites’ have been limited. The Berlin students, under the leadership of their professor, Klaus Briess, are set to change this. For the first time, they have succeeded in installing three reaction wheels in a CubeSat, a prerequisite for precise stabilisation about all three axes. This is a critical step in the development of, for example, navigation satellites with significantly small dimensions. BEESAT-2 will therefore demonstrate the use of micro reaction wheels for attitude stabilisation.



The BEESAT team in the control centre at Technische Universität Berlin

Its predecessor, BEESAT-1, was launched on a Polar Satellite Launch Vehicle (PSLV) from the Satish Dhawan Space Centre at Sriharikota, north of Chennai in India, on 23 September 2009 and placed in a nearly polar orbit at an altitude of approximately 730 kilometres. Since then, it has already circled Earth 9000 times travelling at a speed of 25,000 kilometres per hour. Its siblings, BEESAT-2 and -3, will follow in 2012 although, on which launcher and from which space launch centre has yet to be decided. The picosatellites are certainly very flexible – Cyclone 4, Dnepr, PSLV, Rockot, Soyuz and Vega launchers can all be used to place them in orbit.

The university's Berlin Mission Control Centre is responsible for operating the satellites. From here, the picosatellites are controlled using either direct or timed commands. Direct point-to-point transfer is used to deliver all data from the satellites to the control centre, where it is then evaluated. The aim of the missions is to test the functionality of new, miniaturised technology as well as its suitability for use in space, and to apply this data and test results to develop new microsatellite technologies, ultimately enabling future missions to be equipped with high-performance, low-cost components. As picosatellites can be built relatively inexpensively, they are also ideally suited for educational purposes. Design, verification and operation of such satellites help students develop precisely the same working methods and team skills needed for larger-scale satellite missions; they receive optimal training for employment in the space sector.

BEESAT-3, the last in this series of picosatellites, is equipped with a payload data handling system, a ‘Highly Integrated S-Band Transmitter for Pico Satellites’ and an Earth observation camera. The S-band transmitter, designed to return images obtained with the Earth imager, is being flown for test purposes. BEESAT-3 is also equipped with novel solar sensors designed by Technische Universität Berlin that will determine the orientation of the satellite with respect to the Sun. Other subsystems such as onboard computers, a UHF radio communication system and various sensors incorporate redundancy, so that the entire system can continue to operate in the event of a partial malfunction – another unique feature for such a small satellite. ●

More information:
<http://is.gd/beesat>

Galileo rising

As soon as Europe's first navigation satellites were launched and deployed in orbit, responsibility for operating them was transferred to the DLR GfR Galileo Control Centre in Oberpfaffenhofen.

Europe's satellite navigation system starts to take shape

By Sean Blair

On 21 October 2011, the first two operational Galileo satellites were carried into orbit by a Soyuz ST-B launcher from the new launch site in French Guiana. The first elements of the Galileo constellation had been put in place. There is still a long way to go – another 28 spacecraft need to be launched by the end of this decade – but Galileo's deployment in orbit has finally begun.

The launch was followed attentively at DLR's facility in Oberpfaffenhofen, near Munich. This was due to more than just professional interest, because the launch meant that a long-awaited duty was about to begin. Once the satellites' systems were activated during the launch and early operations phase, control of the satellites was transferred to an elegant, glass-fronted building on the Oberpfaffenhofen site – the Galileo Control Centre, operated by a commercial subsidiary of DLR, the Gesellschaft für Raumfahrtanwendungen (DLR GfR).

"The control centre is at the heart of the Galileo ground segment," explains Walter Päßgen, Technical Director of DLR GfR. "Or, more accurately, it's part of a double heart, because we work alongside a second centre located at Fucino, in Italy. Oberpfaffenhofen is responsible for monitoring and controlling the satellites; Fucino oversees the processing of navigation functions and the preparation of navigation signals for rebroadcast from the satellites."

Having two control centres increases the robustness of the Galileo system; they work closely together and are operated by the same company. The European Commission funds Galileo, with the European Space Agency acting as its procurement agent. DLR GfR won the contract to operate Galileo, along with the Italian company Telespazio; the two firms formed a joint venture – SpaceOpal GmbH.

"Under the current contract, which runs until 2014, we follow a split-centre approach, where we manage the satellites and Fucino manages the navigation services," adds Päßgen. "Beyond then, the aim is that either centre will be able to take over the other's tasks in the event of an emergency, so the two teams are being cross trained. We want a system that runs as

stably as possible, so each control centre will carry out its primary tasks and have a small team capable of taking over the remaining activity at very short notice, supported later on by the team from the other centre. Ultimately, we should both be able to switch between the two roles seamlessly, as needed."

Oberpfaffenhofen is also home to the German Space Operations Center (GSOC), which has been managing spacecraft since the 1970s. Operating two satellites at once is nothing new, but the TanDEM-X mission has so far been the most challenging, with vertical and along-track distances of 200 to 400 metres. Galileo is uncritical in this respect, but it is demanding because of the large number of satellites in the constellation. Päßgen explains: "The performance of the satellites has to be checked every day, to ensure that important parameters remain within defined ranges." These include power availability and attitude control – ensuring the main antenna remains pointed to Earth.

"Operational planning can be less rigorous than for a scientific mission, but it gets complicated as we work up to the final 30-satellite constellation. This is new for Europe; we have had fleets of satellites before, but not this large, and not in medium Earth orbit. Even with a global network of ground stations – there will be five in the final configuration – we will only have contact with a few of the satellites at any given time and must use a planning system to select the best contact opportunities. Medium Earth orbit is quite a stable orbital environment, but it is envisaged that manoeuvres to correct drift may be needed from time to time."

The Oberpfaffenhofen control centre has a staff of around 60: "Our operations team first had to get to know the ground segment and then prepare an operational database of procedures for receiving telemetry, uplinking commands and so on. Once that database was populated, verification and validation had to be performed, which involved working with satellite simulators and – in advance of launch – the actual satellites on the ground, first at the manufacturing facility in Rome and then, as they awaited launch, in French Guiana."

21 October 2011 – a Soyuz launcher carries the first two Galileo In-Orbit Validation satellites into space





Galileo satellite number one during mechanical testing at Thales Alenia Space in Rome during May 2011

When the post-launch handover finally came, the control centre began overseeing a three-month campaign of in-orbit testing using a specially equipped ESA ground station located at Redu, Belgium. Similar test campaigns will be carried out for each group of Galileo satellites; the next pair is scheduled for launch in 2012.

"This is a very exciting time for us," says the head of the Galileo Control Centre. "My DLR colleagues and I were involved in the first studies with the European Space Agency and the European Commission more than 10 years ago, so it is a great feeling to finally have the first satellites in space and know that more are on the way."

Shaping the future of Galileo

Oberpfaffenhofen's three-year designation as DLR's Centre of Excellence for Satellite Navigation marks a recognition that multiple institutes are working on different aspects of the issue and so receive extra resources to support their interaction. DLR GfR and the DLR Institute of Communications and Navigation both have important functions in satellite navigation.

"As a research institute, our aim is to enable precise and reliable position determinations, as well as to maximise their availability," says Christoph Günther, the head of the Institute. "To do so, we must study and characterise all influences on the satellites, the propagation medium, the receivers and potential sources of interference. Our work can be applied to all satellite navigation systems: GPS, GLONASS, Compass and so on – as they have much in common. However, Galileo is the one system we can influence. Understanding the related phenomena is the basis for developing mitigation mechanisms, both at the receiver and system level."

"Although extremely stable, atomic clocks can exhibit small irregularities, such as phase or frequency jumps, roughly once a year. Timekeeping using several clocks – or the 'composite clock' technique – is a promising method for minimising the impact of these irregularities. This concept can be used on the satellites – for example, using as few as two clocks to increase signal availability. The composite clock can also be used at the system level, to complement the timing facilities in Oberpfaffenhofen and Fucino, and would include all satellite and ground clocks."

"Integrity is another area of central interest; for example, if you want to land an aircraft, you have to be sure to touch down on the runway." This is currently addressed by using local augmentation systems that provide corrections and statistics to the aircraft; the aircraft can then compute an improved position and error bounds. The standard for 'Category I' landings, guiding the pilot down to 60 metres above the runway for a final decision to land, has been settled recently. The Institute is currently working on 'Category III' procedures, for landings in zero visibility. Besides theoretical work, it has built a testbed in Braunschweig – the only one of its kind in Europe – and carried out the first flight tests in the world for the new standard. The situation is very similar in the maritime domain with the Institute's testbed in the harbour of Rostock-Warnemünde.

"Local augmentation provides the very high levels of integrity needed by the most demanding operations. In less critical cases, autonomous ways of determining integrity are developing into an attractive alternative. With the increasing number of satellites, consistency checks amongst the signals will often be sufficient to detect signal anomalies. Bounding position errors in such scenarios is another topic addressed at the Institute. It also involves developing monitors on the satellite to detect particular types of anomalies. We are starting this research now, in preparation for when the satellites need replacing."

The verification of the signal characteristics of existing satellite navigation systems is important as well. Since receivers only provide predictable results for signals that meet the specifications, this must be verified. The Institute uses the 30-metre antenna at DLR's Weilheim ground station for this purpose (see side bar).

The propagation of signals from the satellite to the receiver is a source of errors and uncertainties. The plasma in the ionosphere can cause extra delays equivalent to distances of several tens of metres that can vary with solar activity. Using dual frequencies is one way of eliminating much of this error, but this is not always possible. To address these delays, the Institute has developed simple regional and global models and also provides an ionospheric prediction service, including a first experimental one-hour forecast.

"Ionospheric scintillation can also induce a loss of signal, even in dual frequency receivers, or prevent the resolution of carrier phase ambiguity that is needed for precision applications, such as surveying." The Institute is working on an index that characterises the level of scintillation and on forecasting it. A broad range of users might then use this to plan their work, to ensure the necessary levels of accuracy, integrity or both.

Jamming is a threat to even the most vital navigation systems; the use of 'personal privacy devices' by trucks passing the ground-based augmentation system at Newark airport has increased awareness of this issue. Although satellite navigation provides positions of unmatched accuracy and reliability, the small power levels of the received signals – typically 0.1 femtowatt – make them susceptible to both intentional and unintentional interference. For this reason, in a programme running over several years, the Institute has developed measures against jamming, including the use of multi-antenna setups. The solutions developed are also effective against 'multipath', that is, the superposition of the desired signal with several reflections, and 'spoofing', which is an attempt to mislead the receiver and cause it to output an incorrect position. "In a different context, the levels of suppression reached today would allow you to listen to a whispering person while you are operating the loudest available pneumatic drill," remarks Günther. ●

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:

<http://s.dlr.de/39z0>

The European satellite navigation system

Galileo is Europe's independent satellite navigation system. The complete Galileo system will consist of 30 satellites in three medium Earth orbit planes, with a configuration chosen to provide global coverage.

Each satellite transmits precise timing information, used by receivers to calculate the journey time and, from that, the distance the signal has travelled to reach them.

Four satellites have to be visible for a navigation fix, which provides the three spatial coordinates as well as the offset between the receiver clock and system time.

Ultra-accurate time measurement is key to the system's success; the hydrogen maser clocks on the Galileo satellites keep time to better than one second in three million years, but still have to be kept synchronised accurately with one another. A timing error of one nanosecond equates to a 30-centimetre ranging error.

Sensor stations monitor satellite signals, which are the basis for checking clock performance and orbital positions; currently two (up to five in the future) telemetry, tracking and control stations connect to the satellites and are linked to the Oberpfaffenhofen control centre, while uplink stations transmit navigation corrections to the satellites. Updates are prepared at the Fucino control centre every 100 minutes.

GATE to Galileo

The Galileo Test and Development Environment (GATE) around Berchtesgaden has transmitters situated on nearby alpine peaks to create a 65-square-kilometre test range for Galileo researchers and product designers. GATE is available for commercial as well as academic research and is often used by the DLR Institute of Communications and Navigation. "Having requested permission from the authorities, we locally jammed the signal and analysed the performance of our multiple-antenna receiver. The tests in the real environment confirmed the substantial improvement compared to standard receivers, as we had expected," explains Christoph Günther.

The eight mountaintop stations transmit signals identical to those that will be sent by the Galileo satellites that will be in orbit from 2014. A key feature of GATE is its 'Virtual Satellite' mode. The stations transmit signals with frequencies and phases that simulate eight overflying satellites for an observer in the test area. Receivers and applications under test can use a signal that is no different to a 'real' Galileo satellite signal – apart from the direction of propagation.

The big dish

In collaboration with the DLR Institute of Communications and Navigation, GfR is using the German Space Operations Center's 30-metre dish antenna in Weilheim as the Galileo Signal Monitoring Facility, under a mandate from ESA. Celebrating its fortieth anniversary next year, the antenna was built to operate the US-German Helios I and II solar probes. "It remained unused for many years, but we realised it would be ideal for signal verification," says Christoph Günther. "It has been equipped with new instrumentation, and carefully calibrated. Its enormous gain will allow us to characterise the signal properties of the Galileo satellites with great accuracy."

"We have investigated the GPS satellite SVN49 in cooperation with its US operators and characterised its signal and antenna pattern. We also studied GLONASS, Compass, and even satellites from the regional Japanese Quasi-Zenith Satellite System. We can analyse any satellite that appears above the horizon in Weilheim."



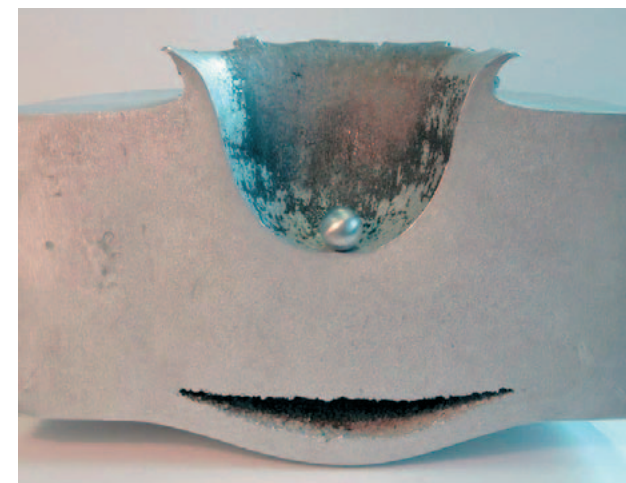
The Galileo Control Centre at DLR Oberpfaffenhofen, from where the satellites will be controlled and monitored.

Look out for space junk

It is getting crowded in low Earth orbit; in addition to Earth observation and communications satellites and the International Space Station (ISS), the amount of space debris is constantly growing. This increase constitutes a clear and present danger to both satellites and astronauts. DLR researchers from the Institute of Technical Physics and the Microwaves and Radar Institute are working on methods for detecting orbital debris and determining the corresponding orbits. The aim is to identify the threat of a collision in advance and prevent it through effective debris avoidance manoeuvres.

DLR researchers are working on ways of tracking orbital debris

By Wolfgang Riede und Uwe Völker



This massive aluminum plate shows clear signs of destruction after a small aluminum ball strikes it at seven kilometres per second

Debris in low Earth orbit moves at a speed of around eight kilometres per second. Because of this high speed and the associated kinetic energy, it must be assumed that an impact with an object more than one centimetre across will cause a satellite to cease functioning. Impacts involving objects more than 10 centimetres across are regarded as catastrophic, since complete disintegration of the impacting objects is to be expected. Such an event occurred on 10 February 2009, when the active US communications satellite Iridium 33 collided with the defunct Russian Cosmos 2251 satellite. The total mass of space debris increased by about 1.6 tons and the number of catalogued objects rose by 20 percent within a matter of seconds.

Currently available orbit information for space debris is insufficient. The Space Surveillance Network, operated by the US Department of Defense, monitors around 1000 active satellites and determines collision threats for roughly 22,000 catalogued objects. However, this represents only about three percent of the estimated number of objects measuring more than one centimetre across.

As the crew of the ISS has repeatedly experienced, a comprehensive catalogue of the orbits of space debris objects is crucially important for protecting space infrastructure. For example, at the end of June 2011, the ISS astronauts had to take shelter in a Soyuz capsule because an item of space debris was approaching and the advance warning came too late to

Artist's impression of the distribution of space debris objects in low Earth orbit

perform an avoidance manoeuvre. This debris missed the ISS by just 250 metres. There is a particularly high risk for astronauts performing spacewalks on the ISS.

Detection using lasers

Detecting objects larger than one centimetre in Earth orbit is therefore essential. Optical methods offer the possibility of detecting space debris with excellent accuracy and within shorter time intervals. The data required to determine an orbit can only be acquired when the corresponding object is in the field of view, meaning that there are only a few minutes available for this task. For this reason, the DLR Institute of Technical Physics has developed a concept to build up a comprehensive space debris catalogue that can be kept up-to-date using passive optical methods to detect 'new' objects. If a telescope is operated in such a way that the rotation of the Earth is compensated for, natural celestial bodies such as stars or planets will appear as points on the resulting image, while sunlight reflecting off space debris will be revealed as a light trail.

As a first step, the azimuth and elevation of the object are roughly determined using the angular data of the observation telescope. To acquire additional information on the position of the object, it is then illuminated with a laser pulse. The reflected photons are captured with a telescope and used for both fine tracking and distance measurement. The desired accuracy is of the order of metres in every direction for objects 1000 kilometres away. In principle, this technique can even be used in the daytime.

The laser systems must meet stringent requirements for beam quality and pulse energy stability and are currently being developed at the DLR Institute of Technical Physics. In parallel with this activity, a technology demonstrator that will determine the orbits of space debris by tracking and ranging is being planned.

Radar-based detection

Along with optical methods, radar can also be used for detecting and determining the orbit of space debris objects at altitudes of up to 1000 kilometres. The advantage of radar is that it can be operated regardless of time of day and almost independently of weather conditions. It involves transmitting

microwave signals and measuring the echoes reflected from orbiting objects, using a frequency range that is only minimally affected by clouds and precipitation. Initial ideas on using a radar system for operational space monitoring are currently under consideration at the DLR Microwaves and Radar Institute. In particular, the intention is to enable the location of smaller-scale objects, with the goal being the detection of targets one to five centimetres across. In addition, DLR researchers aim to increase the accuracy of orbit determination and significantly expand the area of the celestial sphere under observation.

Researchers plan to install an innovative multi-channel radar system with digital beam forming to accomplish this. They are also developing operational methods such as the simultaneous use of multiple antennas to be operated in a bi- or multi-static mode. The end result should be a way of mitigating the now generally recognised threat from space debris.

Subsequently, laser-based optical methods and radar-based systems could be combined in an operational network to enable the compilation of a new catalogue of orbital data for space debris objects, 10 to 100 times more accurate than any that has come before. ●

About the authors:

Wolfgang Riede heads the Active Optical Systems Department at the DLR Institute of Technical Physics in Stuttgart. Uwe Völker is developing the appropriate concepts for laser-based detection of space debris and generation of hazard analyses.

More information:

www.DLR.de/TP/en
www.DLR.de/HR/en



30-metre radar antenna
at the DLR site in Weilheim



© ESO

Very Large Telescope (VLT)
laser system for astronomical
observation

"In the lifetime of the International Space Station, up to 2020, there's a 1-in-12 chance we will lose an astronaut on an extravehicular activity because of micrometeoroids or space junk."

Bill Cooke, lead scientist of the Meteoroid Environment Office at NASA's Marshall Space Flight Center, at the 2011 International Space Development Conference in Huntsville, Alabama. <http://s.dlr.de/5ot5>

Star gazers – first class

Astronomers observing in the infrared region of the electromagnetic spectrum have a unique window through which to study space. It offers them views of star formation deep inside dense clouds of dust, and the spectral ‘fingerprints’ of the molecules and atoms provide information on the temperature, gas density and velocity of celestial bodies and nebulae. Observations in the mid and far infrared cannot be performed from Earth’s surface however, because the radiation is absorbed by water vapour in the atmosphere. The Stratospheric Observatory for Infrared Astronomy, SOFIA, flies at an altitude of up to 13.5 kilometres, leaving most of the atmospheric water vapour beneath it; this enables it to observe under conditions similar to those in space, for a tiny fraction of the cost of a satellite-based observatory. In April this year SOFIA completed its first flight with the German Receiver for Astronomy at Terahertz Frequencies, GREAT.

The German GREAT instrument’s first flight aboard SOFIA

By Thomas Bührke

The SOFIA airborne observatory is the only one of its kind in the world, and gleams impressively in the sunlight. At 35 years of age, SOFIA is no longer a youngster, but her paintwork is new, the engines have been replaced and the name ‘Clipper Lindbergh’ decorates her side in neat cursive letters, a 2007 tribute to a previous flying pioneer on the eightieth anniversary of the first transatlantic flight.

SOFIA has had an eventful life; no other commercial aircraft has undergone such a major conversion. The story began in 1995. Until then, NASA had been operating the Kuiper Airborne Observatory, a modified Lockheed C-141A transport aircraft equipped with a 90-centimetre telescope. Astronomers wanted a larger telescope, however. At first, the engineers thought that the Kuiper observatory concept could simply be scaled up by a factor of three; they were mistaken.

In the mid 1990s, NASA acquired a Boeing 747SP; SP stands for Special Performance version. This variant is about 15 metres shorter than a normal jumbo jet and only 45 were built. Its lighter weight, combined with an unchanged fuel capacity, increases its range, meeting the astronomers’ requirement for the greatest possible observation flight duration. NASA’s German partners were responsible for building the largest telescope that could be accommodated within its airframe.

Problems arose when it came to cutting a four by six metre hole in the aircraft’s fuselage. If you open a car window while travelling at high speed, it causes severe rhythmic buffeting; the car acts like a large organ pipe. When the same scenario is applied to an airliner flying at 900 kilometres per hour, the violent, acoustically generated forces could seriously damage or even destroy the aircraft structure within minutes.

Numerous wind tunnel tests and computer simulations were performed. Costs increased enormously and ultimately exceeded the budget, estimated in 1997 at approximately one billion dollars, by a factor of three. “The project was nearly cancelled in 2002 as a result of the technical and financial problems,” recalls DLR’s Dietmar Lilienthal. He has been working on the SOFIA project for 15 years and was actively involved in the installation of the telescope in the 747SP, which took place in the United States.

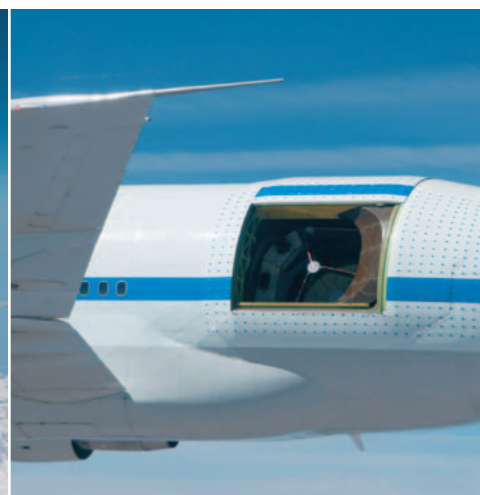
SOFIA and the GREAT instrument	
Flight altitude:	11 to 13.5 kilometres
Operating team:	3 flight crew, 10 to 15 operators plus scientists and guests
Future observing flights:	1000 hours per year (more than 100 nights)
Telescope weight:	17 tons
Spectral range:	0.3 to 1600 microns
Telescope slewing range:	6 degrees horizontally 50 degrees vertically
Operational lifetime:	20 years



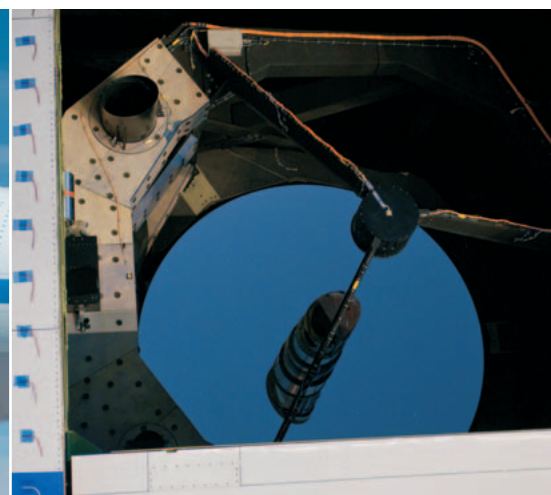
© All images: NASA / Tom Tschida



SOFIA on a test flight in December 2009. The Boeing 747SP, which has a shorter fuselage than a standard 747, spent years undergoing modifications.



The stratospheric observatory's telescope door opens for the first time. SOFIA will capture infrared radiation from space during almost 100 night-time flights per year.



The primary mirror is at the heart of the telescope. With a diameter of 2.7 metres, it will receive signals from space unimpeded by Earth's atmosphere.

From the German perspective, cancelling the ambitious project was never an option because the companies contracted to manufacture the telescope, MAN and Kayser-Threde, had already delivered it as agreed. When the funding for the development of the scientific instruments provided by the German Research Foundation ran out at the end of 2007, DLR provided additional finance.

Virtuoso instrument in the form of a dumbbell

Several strategies had to be adopted to solve the aircraft's flow problems. Firstly, aerodynamically shaped reinforcements were added to the outer skin forward and aft of the door. These 'spoilers' guide the airflow around the opening in such a way that they avoid problematic turbulence. In addition, the two-part sliding door is only opened as far as is necessary for the telescope to carry out its work.

The telescope itself is a masterpiece of German engineering. Lilienthal compares it to a dumbbell. At one end is the 2.7-metre diameter primary mirror; the collected light is then reflected consecutively by two smaller mirrors parallel to the longitudinal axis of the aircraft into a camera or spectrograph, which forms the other end of the dumbbell. The centre of the dumbbell passes through a 50-centimetre-thick pressure bulkhead that separates the front part of the assembly from the rear, exposed telescope area. The scientific apparatus is located in the passenger cabin and is thus accessible to the astronomers during flight, a major advantage if the researchers need to make any adjustments or repairs.

The telescope mount is separated from the bulkhead using 12 air-filled shock absorbers to prevent minor disturbances in the aircraft's flight path or vibrations from the engines from being transferred to the telescope. Since the telescope weighs roughly 17 tons, several steel plates have been bolted to the floor of the front section of the aircraft to counterbalance its weight.

More than two dozen test flights before 'first light'

SOFIA had to complete around 25 test flights, during which over 1000 sensors monitored the behaviour of the aircraft and telescope. The high point came on 30 November 2010 when SOFIA took off for its maiden scientific flight, the first of a series of three. On board was a team of US astronomers, who tested an infrared camera. The astronomers were excited by the time all three flights had been completed. Alois Himmes, DLR's SOFIA Programme Manager, who was also on board, was truly impressed as well – even though, during the flight "my feet slowly became cold and my ears were buzzing despite, or maybe because of, the headset, and the water and sandwiches tasted no better than those you get in economy class."

The first German research team boarded the airborne observatory in April this year; Rolf Güsten from the Max Planck Institute for Radio Astronomy, Jürgen Stutzki from the University of Cologne and other team members prepared the 500 kilogram GREAT instrument they had developed for its 'first light'. A total of 12 people were onboard SOFIA for this flight, including the astronomers, a three-man flight crew, aircraft and telescope engineers and a science journalist.

First night with GREAT

On the evening of 12 April 2011 at 20:00 local time, SOFIA took off from its home airport, the Dryden Aircraft Operations Facility in Palmdale, California. The sliding door in the rear was closed during take off. Surprisingly, when it was opened at an altitude of 5000 metres, no effect could be felt. Even the pilot was only made aware that the door had been opened by a display in the cockpit. SOFIA flew on as if there were no large hole in its side. Observations began when the aircraft reached an altitude of 11.7 kilometres. The astronomers' first target was one of the brightest objects in the sky – Saturn.

SOFIA airborne observatory

The Stratospheric Observatory for Infrared Astronomy, SOFIA, is a joint US-German project for which DLR bears 20 percent of the costs. It is expected to have a service life of 20 years. In September 2011 SOFIA flew non-stop from its home base in California to Europe, where it was on show during German Aerospace Day at DLR's headquarters in Cologne-Porz with the GREAT instrument installed. The airborne observatory also visited Stuttgart, home of the German SOFIA Institute.





Concentration during one of the first observation flights. Precisely positioning the telescope, which looks out of the port side of the aircraft, to observe the chosen area of sky involves following an elaborate script.

The GREAT instrument that is used to analyse the radiation was developed by the Max Planck Institute for Radio Astronomy and the University of Cologne, under the leadership of Rolf Güsten (on the far left in this image). The Max Planck Institute for Solar System Research and DLR's Institute of Planetary Research (Heinz-Wilhelm Hübers) were also involved.

An international, interdisciplinary operating team of up to 15 people flies through the night to capture and decipher stellar radiation.



Planning an observation flight is a complex logistical process. Since the telescope can only observe out of the port side of the aircraft, SOFIA must fly a precise course so that the chosen celestial body remains in its field of view. The telescope can only be moved six degrees horizontally and about 50 degrees vertically. Finally, after approximately 10 hours, SOFIA had to land back at Palmdale.

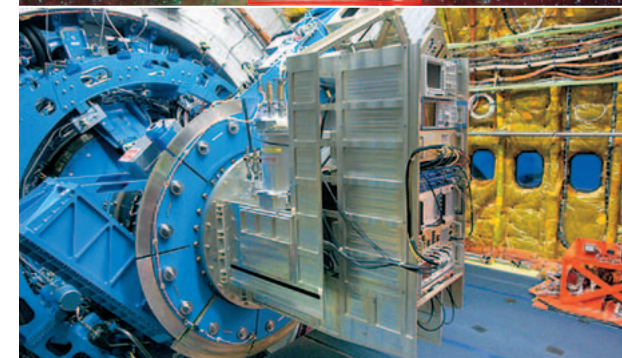
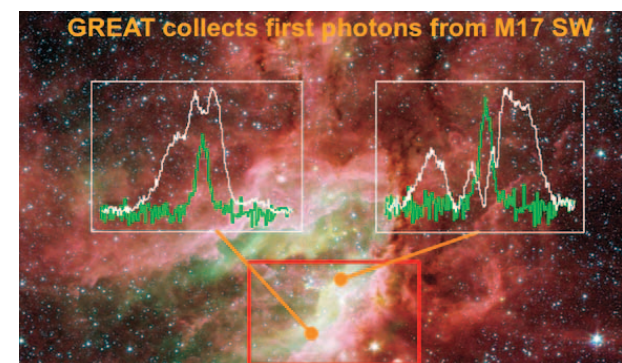
Orienting the telescope is also tricky. A ground-based telescope only needs to be aligned once; after that, the desired celestial coordinates can be entered into the control computer and the telescope moves accordingly. But SOFIA's position changes continuously, so the onboard computer must constantly receive aircraft location data acquired via GPS and, from this, calculate the required orientation of the telescope.

Just slightly behind schedule, Saturn appeared. Then, a sharp right turn to the north brought the supernova remnant IC 443 into view. For a long time, astronomers have known that a variety of chemical reactions take place there, which give rise to water molecules, among other things. The plan was to find evidence for the existence of carbon monoxide molecules as well as hydroxyl radicals and to explore the chemistry of such an environment.

GREAT is not a camera that captures impressive images of the sky like the Hubble Space Telescope. Rather, it is a spectrograph that separates the incoming infrared radiation into its spectral components. The resulting spectrum allows chemical compounds to be identified and their abundances to be determined. GREAT acquires spectra in the far infrared, at wavelengths between 60 and 220 microns. "This is not possible on Earth's surface because water vapour in the atmosphere absorbs a significant portion of this infrared radiation," explains Rolf Güsten. SOFIA is above more than 99 percent of the water vapour when flying at its maximum altitude of 13.5 kilometres, providing observation conditions that are almost as good as those of a space telescope. It has one distinct advantage, however: "We can observe using the newest instruments, whereas the technology in a space telescope is already five to 10 years old when it is launched," says Jürgen Stutzki.

Though the astronomers succeeded in detecting carbon monoxide, the signal from the sought-after hydroxyl radicals proved to be very weak. The researchers would have liked to continue observing, but the pilot had to head east. They spent 71 minutes observing the Cepheus B star forming region to determine the distribution of carbon and carbon monoxide. The latter is a common molecule in the Universe that astronomers use as a type of 'cosmic thermometer'. The temperature of the gas can be deduced from the intensity of a number of spectral lines at different wavelengths.

The observation of Cepheus B was successful. At 02:30, SOFIA veered westward onto the final leg of its flight. At this point, the astronomers had an observation window of almost four hours to study the centre of the Milky Way.



This spectrogram (top) of M17, a star forming region in the Milky Way, was acquired using the German Receiver for Astronomy at Terahertz Frequencies instrument during an observation flight on 6 April 2011. One advantage of SOFIA is that it can conduct observations using interchangeable onboard instruments.

Güsten and his colleagues detected a disc of gas rotating around the galactic core at a velocity of 100 kilometres per second. There, astronomers suspect the presence of a black hole with four million times the mass of the Sun, but precise data assessment and further observations are needed to determine the connection between this mysterious central body and the gas disc.

Just before 06:00, the pilot smoothly landed the airborne observatory. By 2014 astronomers all over the world will have another six instruments besides GREAT at their disposal – for the next 20 years, if all goes well. ●

About the author:

Thomas Bührke is a science writer and lives in Schwetzingen, Baden-Württemberg. He holds a doctorate in astrophysics and, since 1990 has worked as a freelance journalist and author in the fields of astrophysics, space and physics. He was the first journalist to participate in a science flight on board SOFIA. The image immediately to the left shows Bührke at work.

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

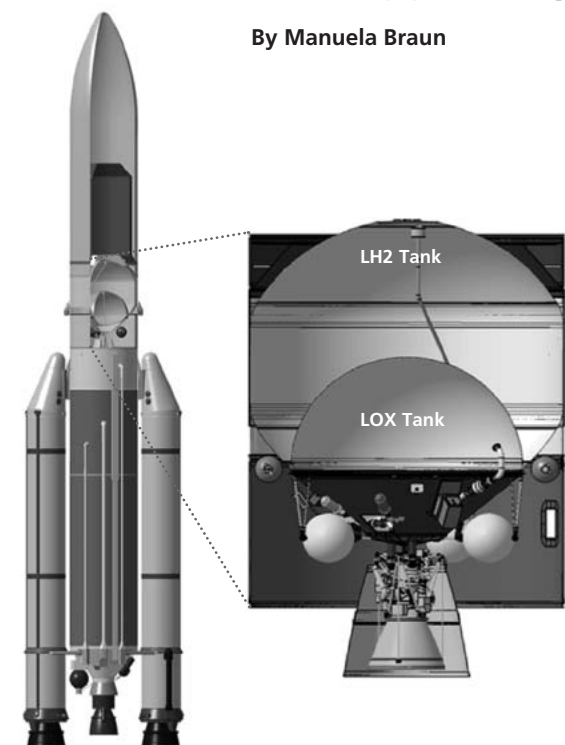
Spectrogram (foreground): © GREAT Team / NASA / DLR / SOFIA / USRA / DSI. Spitzer image (background): NASA / JPL-Caltech / M. Povich, Univ. Wisconsin.

Thunder of applause for an engine

“Attention! Attention! Twenty-minute warning for test bench P4!” The message coming over the loudspeakers sounds just like you would imagine. Definite, clear, to be respected without fail. Shortly beforehand, the fire brigade set off down the road running alongside the DLR site in Lampoldshausen to prevent pedestrians from accidentally entering the cordoned-off area. Meanwhile, in control room M8, the concentration is so great you could cut it with a knife. After several preliminary tests, the researchers are now going to reignite the Vinci engine – fitted with its complete, 2.8-metre long expansion nozzle – for the first time. The versatile Vinci engine is designed to be able to perform up to five burns as part of the new upper stage of Ariane 5 – meaning that several satellites can be injected into different orbits.

In Lampoldshausen, researchers are testing the Vinci upper-stage engine under space conditions

By Manuela Braun



Layout of the new, re-ignitable upper stage engine with its extendable ceramic nozzle.

The M8 control room is like an inhabited island in an otherwise abandoned zone. Twelve monitors on the wall show the events taking place in the deserted vicinity around the room on the first floor of the test building. No movement can be seen yet. The test bench engine and nozzle are all still. We have entered the final minutes before the test begins. A red light and a chain with a ‘Danger Area’ warning sign ensure that only the cameras are looking at Vinci – certainly no human eyes. Even though no change can be perceived, the engine and its nozzle are now being subjected to space-like conditions. Since early morning, the researchers have been preparing the test bench and its contents for the test by creating a vacuum within the multi-storey chamber. When Vinci is used in the new ESC-B upper stage of the Ariane 5, the engine will first be ignited at a speed of around seven kilometres per second and at an altitude of over 100 kilometres – where almost total vacuum is to be found.

The tension rises in M8. Test director Daniel Leiß asks short, concise questions. “Give me the values! Oxygen? Hydrogen?” Each of the 13 operators in the control room is responsible for a specific set of tasks. All the operators scrutinise their computer monitors intently, passing on the necessary values through their headset microphones. Temperature, pressure increases, pressure

Vinci – a European project

The prime contractor for the ESC-B upper stage for the Ariane 5 ME is Astrium Bremen. The Vinci engine is manufactured by SNECMA in Vernon, France. Astrium Ottobrunn is responsible for the combustion chamber. DLR is carrying out the tests on ESA test stand P4.1 in Lampoldshausen.



The area around the test stand is marked as a danger zone for the engine test and is evacuated prior to the test

drops and time data all buzz around the room. “1058 to 25 percent.” “Interface values OK.” “Go from 25 back to 15 percent.” “Pressure is 100 millibars.”

In total, almost 900 sensors measure a diverse range of variables including temperature, rotation speed and vibration. The measurement data is displayed in real time on the test team’s screens, showing green fields where the values are correct and red fields where they are not. Today, Lars Ohlenmacher is responsible for the testing timeline, which displays the sequence of test processes on a long table. Point by point he makes enquiries, enters values and times, while documenting the testing process. When the test concludes that evening and the engine has been successfully ignited twice, he will check off the final item on page 170: ‘decommissioning of test bench P4 completed following test.’

Ten, nine, eight, seven...

The one-minute warning sound can be heard throughout the whole site. All 550 employees now know that the test will be starting shortly. The site’s fire brigade is on standby. The water cannons next to the test bench point ready for use in the event of an emergency. If the M8 control room were not already hushed, test director Daniel Leiß would call for attention in an unusual way; between the telephone and the control console is a small shiny bell he could use to quickly marshall the team to order, but today there is absolutely no need. The only noise to be heard is a short sequence of signals coming from the loudspeaker. The countdown has begun. The test will begin in 10 seconds.

Vinci’s design will make it a powerpack among future upper-stage engines, making it possible to lift heavier loads into space. Currently, Ariane 5’s ECA version of the launcher can lift two satellites with a total mass of 10 tons into a geostationary transfer orbit with a maximum altitude of 36,000 kilometres. With market analysis suggesting that the average mass of satellites will continue to increase in the coming years, this is no longer regarded as adequate. As of 2016, Vinci is intended to remedy this development; using this engine, the Ariane launch

system will be able to lift an additional two tons – 12 tons in total. In addition, multiple ignitions, which is something the current HM 7B upper-stage engine in the Ariane 5 ECA launcher is not capable of performing, should also reduce the amount of space debris left in orbit. After multiple satellite orbit injections, Vinci will be able to perform one final burn that will direct the upper stage back down towards the atmosphere, where it will burn up. But to do this, Vinci must first pass a battery of tests.

Steam at several times the speed of sound

The countdown has barely ended before a loud hiss comes out of the loudspeakers. Only a mass of steam is visible on the monitor; it shoots out of the ejectors at high speed into the high altitude unit and through large horns into the open air. To ensure that the vacuum in the chamber is maintained during the ensuing ignition, four steam generators fire up. The steam draws the engine exhaust out of the test bench with powerful suction. Ten kilograms of liquid oxygen and nine kilograms of alcohol per second flow through each of the four steam generators. The alcohol is burned, generating a total output of 650 megawatts; 40 kilograms of injected water per generator are vaporised every second. Six operators monitor the steam generator units in another control room, their look fixed on the monitors in concentration. Steam is now flowing through the pipes at twice the speed of sound; ideal conditions for the Vinci test. “We will ignite the engine in 10 seconds,” says Lars Ohlenmacher. The nozzle is still just a dark body on monitors eight and nine. Finally it is time: “Ignition!” Nobody in the control room says another word.

Oxygen at a temperature of minus 183 degrees Celsius and hydrogen at minus 253 degrees Celsius flow through the cooled pipework to mix in the engine’s combustion chamber. The engine will run for 340 seconds, and 4500 litres of water per second are now being used to cool the test bench. The temperature of the nozzle exhaust jet is over 3000 degrees Celsius. On the monitor, the previously dark nozzle body, made of a special ceramic material, now glows in shades of orange and yellow. “Beautiful!” says Ralf Hupertz, the supervisor monitoring the test process, breaking the silence. Three hundred and forty seconds can be a long time when the tension is high.

Finally, the engine shuts off. The nozzle continues to glow for a brief time before everything reverts to its normal, dark grey. Hupertz takes off his headphones. “That went well,” he says, grinning with satisfaction.

Coasting phase in space

The first ignition was successful, but testing is far from over. According to Hupertz, the second ignition is the special one “because we are starting the engine and nozzle but have not yet analysed the data from the first ignition in detail.” This would not be possible in space either, so the engine, the nozzle and the test team must run the risk of something not working on the second ignition. The test bench fuel pipes are kept ultra-cold until the second ignition. What is known as the ‘coast’ phase has now begun. If this were not a test, Vinci and the upper stage would now be moving through space after releasing the first satellite, before re-igniting to continue on to the next destination.

Meanwhile, it is just before 15:00 and the working day is dragging on; the concluding preparations on the test bench began at 07:00. The technicians had their arms shoulder-deep inside the engine with its cables and wires, preparing Vinci for its trial by fire. Finally, the cameras that are subsequently used to transmit pictures to the monitors were installed inside and outside the vacuum chamber. “We have never used so many cameras for a test before,” says Hupertz. “But then, of course, we want to see precisely what is happening with the nozzle.” The previous day, the team had conducted a preparatory run with simulated tests as a final rehearsal. But a rehearsal is just a rehearsal – and a test is a test.

Silence in the control room

An hour after the first ignition, Lars Ohlenmacher again gives a signal; preparations for the second ignition can begin. “Please give the 20-minute warning now,” he says to the safety officer, who reaches for the telephone; the ritual starts all over again. “Attention! Attention! Twenty-minute warning for test bench P4,” comes over the loudspeakers in every building and

across the site. The five-minute warning follows a quarter of an hour later. On the site plan displayed on one of the computer monitors, a large proportion of the roads and paths now appear in red – access restrictions around the test stand have moved to their highest level again. Then everything happens very quickly. The engine is cooled again. The steam generators are started, and the countdown is running for the second ignition.

“We’re firing.” If the engine and nozzle run for the next 200 seconds without a problem, the Vinci team will have taken another major step forward. The big digital clock next to the 12 monitors counts off the seconds in illuminated red figures. On the screen, the nozzle is glowing orange again. A few minutes later it is all over and the nozzle starts to cool down. It remains quiet in the control room. Lars Ohlenmacher looks around. “How about a round of applause?” he asks, nodding encouragingly. It takes a moment or two, and then everyone claps. The test went without a hitch. The two representatives of French client SNECMA are beaming with satisfaction as they start to clear up their paperwork.

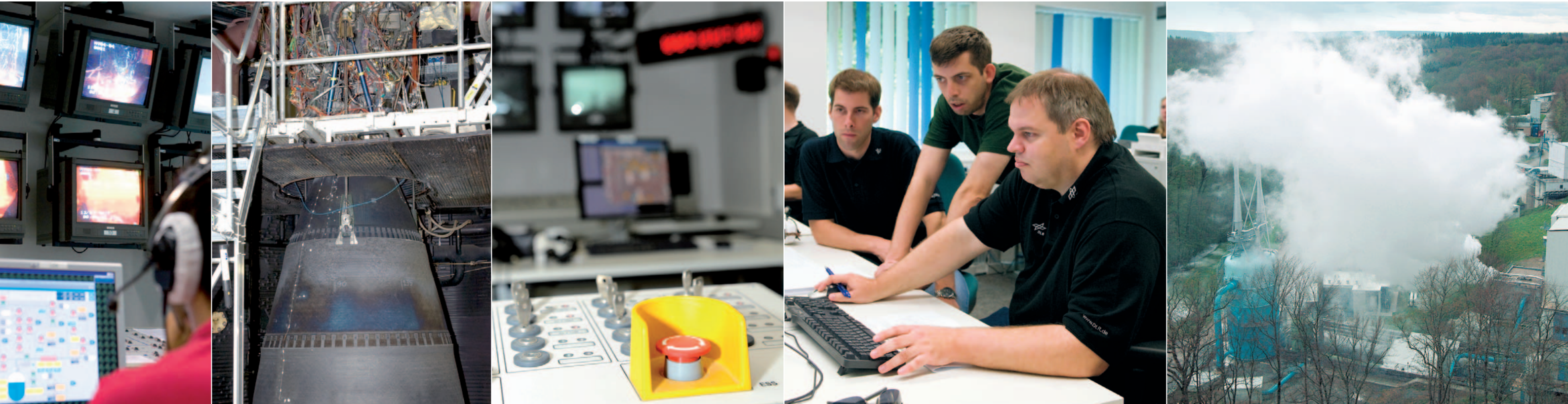
The flashing warning light at the exit of the building now switches to yellow. People can leave the control room again. The test stand itself must be reset to its pre-test condition. Sensors and cameras have recorded a mass of data that will need to be assessed and analysed in the coming days. The test day only comes to an end for the team when Lars Ohlenmacher has placed a tick in the last box in the testing timeline. The final announcement is then made across the DLR site in Lampoldshausen. “Attention! Attention! Testing finished at test stand P4!” ●

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

Researchers follow what is happening to the nozzle in the test bench via monitors in the control room. In the event of an emergency, the test director can use a red button to abort the test. Steam generators create a vacuum in the test bench, providing space-like conditions for the engine and nozzle during the firing.

Careful scrutiny by (from left to right) assistant test director Lars Ohlenmacher, test director Daniel Leiß and test supervisor Ralf Hupertz.

Large volumes of steam are needed to maintain the vacuum in the test bench, photographed here from a safe distance during an earlier test.



Getting to the runway – emission free

Quietly and without emissions, the 48-ton aircraft rolls along the taxiway. To the untrained eye, all that is unusual about it is the red colour of the nose gear and a few cables on its outer skin. An attentive observer would notice that the fan blades in both engines are stationary and might ask: 'How is this aircraft moving?' An expert would probably see that the nose gear is not standard for an A320, and deduce that it is potentially the source of the silent propulsion. In fact, the A320 test aircraft (D-ATRA; Advanced Technology Research Aircraft), belonging to the German Aerospace Center, is taxiing along at Hamburg's Finkenwerder Airport using electric motors powered by a hydrogen fuel cell.

Fuel cell powered nosewheel propels ATRA

By Josef Kallo and Dorothee Bürkle



Josef Kallo is Research Area Manager for Fuel Cell System Technology at the DLR Institute of Technical Thermodynamics in Stuttgart

The first taxiing test, which took place on 1 July 2011, marked the successful completion of an extensive international collaboration between DLR, under the auspices of the Institute of Technical Thermodynamics in Stuttgart, Airbus Germany, Airbus France, Airbus UK and Lufthansa Technik. Its success has demonstrated that a fuel cell powered nose wheel can transport a large commercial aircraft on the ground.

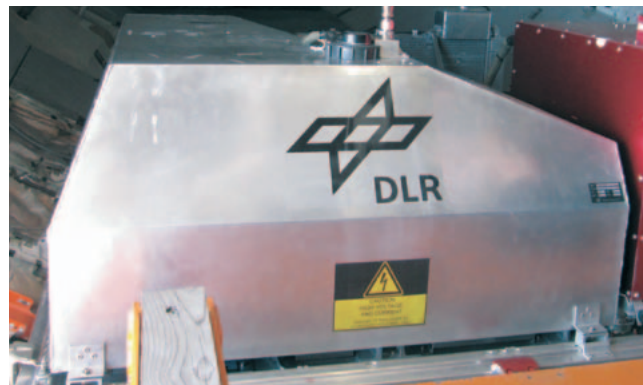
Flight powered by fuel cells will not be possible for commercial aircraft in the foreseeable future. It has so far only been achieved, anywhere in the world, by the Antares DLR-H2 motor glider. Nevertheless, the use of fuel cells in aviation holds great promise, offering interesting possibilities for reducing exhaust emissions and reliance on fossil fuels. Fuel cells also offer energy efficiency benefits. Being direct electrochemical energy converters that generate electrical power from hydrogen and oxygen, they are significantly more efficient than an internal combustion engine coupled to a generator.

Before using a fuel cell in aviation for the first time, DLR had much to accomplish. Firstly, working along with its partner, Airbus, DLR had to verify that such a system would function under flight conditions that followed the relevant aviation standards as closely as possible. This involved developing a new fuel cell architecture that was both lighter and more robust. Another requirement was to replace all safety-related valves and pipes made of materials such as plastic and Teflon – which can become porous under pressure – with components made of metal alloys. As with all innovations in aeronautics, this was a lengthy process, because it involved meeting the highest safety requirements. At the end of the development, the result was a completely new fuel cell system.

It was not just the fuel cell system that needed to be redesigned; the electrically driven nose wheel is also completely new. It was clear from the outset that the necessary power would only be available to an optimum level if the two electric motors driving the nose wheels were embedded directly in the wheels themselves. The challenge was to fit these electric motors, each with an output of 25 kilowatts (around 70 brake horsepower in total), in the tight space within the rims of the

These nose wheels have everything – equipped with a pair of electric motors producing 70 horsepower and mounted directly in the wheel rims, they propel the Airbus A320 D-ATRA.





Securely mounted on an aircraft pallet – the fuel cell system in the A320 that powers the electric motors



High safety standards – many tests, such as this one being conducted in Stuttgart, were needed to prove that the fuel cell system was suitable for aviation use.

A320 nose wheels. Highly integrated motor designs developed by the DLR Institute of Vehicle Concepts made this possible. However, what was critical for designing the nose wheel drive was not the power output but rather obtaining the correct torque delivery from the motors. The combined stationary torque of the motors had to be sufficient to set a fully loaded A320 in motion from a standstill.

The second important element was the synchronisation of the motors and the traction control system, which has to prevent the wheels from spinning on the ground and the rims from rotating inside the tyres. The maximum torque was calculated to be around 11,000 newton-metres. In practice it was shown that 7000 newton-metres are sufficient to exceed the breakaway torque and set the aircraft in motion. Since an electric motor is bidirectional, the aircraft can move both forwards and backwards. Using the system currently being tested, an A320 can taxi from the gate to the runway at 15 kilometres per hour with its main engines shut down. The plan is then to double the performance of the electric motors, so that aircraft can reach speeds of up to 54 kilometres per hour on the ground.

A platform for the fuel cell system

The choice of fuel cell system was driven by the performance requirements, the maximum available weight and the technological maturity. Finally, a low-temperature proton exchange membrane technology was selected. During development, it was decided to use existing subcomponents from Hydrogenics GmbH, including the stack, anode recirculation pump and fan. The fuel cell unit was attached to an aircraft pallet of the type that normally holds freight containers. Using a pallet means the fuel cell is located on a stable base, creating a platform that is easy to move into the correct position in the cargo hold and securely fix at four points using the existing locking system.

The platform idea was continued throughout the entire architectural design, with the result that the first build was developed into a technology-testing platform. In addition, the platform concept offers the ability to replace individual components very quickly and facilitates the change tracking process if the specifications are not met. A further advantage of the platform concept is the classification and division of the

hydrogen-carrying components according to pressure (low pressure, up to 7 bar; high pressure, up to 350 bar) and hazard classification. In this way, particular measures could be taken in each area to maximise operational safety, to the point of developing exclusively hardware-based, quadruply redundant hydrogen sensors that can be recalibrated as required. These tasks were part of the safety analysis prepared by Airbus for the operation of the fuel cell system within the aircraft.

The initial commissioning and performance optimisation for the fuel cell system proved to be very time consuming, as the serial safety/shut-off chain alone consists of some 30 directly controlled relays and includes over 30 software parameters. Besides a hazard analysis, the safety concept included a failure modes and effects analysis and failure probability calculations for individual components. This was used as a basis for successfully carrying out operating environment stress tests, with continuous operation at temperatures from one to 50 degrees Celsius, and shock and acceleration tests at up to 16 g. The researchers accumulated experience over the course of several hundreds of hours of operation and several hundred start/stop cycles; the system proved to be robust and reliable.

Designing the fuel cell system architecture involved, not only adherence to aviation standards, but also achieving multifunctionality. On board an aircraft, a fuel cell can deliver not only power, but also clean water. During operation, up to 0.5 kilograms of water are produced per kilowatt-hour of power generated, which can simply be fed into the aircraft water system. This water does not need to be taken on board prior to departure, thus reducing take-off weight.

Less pollution and noise at airports

An aircraft powered by a fuel cell while on the ground can move quietly and without emitting pollutants – at least to the end of the runway. Taking Frankfurt Airport as an example, this will save about 18 to 20 minutes of engine operating time per take-off and landing, not including the necessary cooling and warm-up times of up to four minutes. With up to seven flights per day for an A320-class aircraft, this can equate to a saving in engine operating time of up to 3.5 hours per aircraft per day. Calculated across a year, this gives a reduction of around 800 to 1000 hours. Expressed as a volume of fuel, this offers savings of 200 to 400 litres of kerosene per aircraft per

Working together towards a common goal

DLR's research portfolio, which ranges from basic research to application-oriented development, played an important role in qualifying the overall system for aviation use. Also crucial for the project were the resources and close collaboration of the aerospace and energy institutes within DLR. Accordingly, the requirements compliance and build standard were documented at the DLR Institute of Flight Systems, in collaboration with the aeronautics development branches of DLR, Airbus and Lufthansa Technik, and together with the DLR Office of Airworthiness. The savings predictions are based on the work of the

DLR Institute of Flight Guidance. The DLR Flight Experiments organisation and ATRA management were responsible for conducting the trials. The results of this work are being used in DLR's on-going development programme aimed at replacing aircraft auxiliary power units with fuel cell systems.

In executing the electric nose wheel design, use was made of the expertise of the DLR Institute of Vehicle Concepts in Stuttgart and a number of engineering services companies such as Codtronic.



Reaching the runway quietly and without emissions – the Airbus A320 D-ATRA during the taxiing tests at Hamburg Airport in July 2011

day. Reduced engine operating time while on the ground brings another advantage, in that the intervals at which the aircraft needs to be maintained are extended, reducing costs and aircraft downtime.

If a fuel cell is used, the aircraft needs to be regularly refuelled with hydrogen. A sufficiently large tank of liquid hydrogen, located outside the aircraft's pressure hull at the rear, needs to be refilled only once per day. Regular and well-executed planning for the use of this storage capacity will be

required. Hopefully, the familiar 'chicken-and-egg' problem of a hydrogen economy (no filling stations – no consumers – no demand – no filling stations) can be resolved faster at airports than is the case with road transport. ●

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



Unusual occupation – flight test engineer

There's not much room in a modern fighter jet, so while the pilots at the controls of a McDonnell Douglas F-4F Phantom II or a Eurofighter Typhoon conduct test flights at altitudes of several thousand metres, their 'client' remains on the ground below. With extreme concentration, Ina Niewind scrutinises the display screens and test plans, speaks with the pilots and checks altitude, speed and other parameters; the testing taking place in the sky would not be possible without her. At 30 years of age, she is a flight test engineer in charge of the DLR Institute of Flight Systems field office in Manching, southern Germany. Her job involves supporting engineers of the German Armed Forces during aircraft evaluations. Along with a small team of colleagues, Niewind works for the WTD 61 branch of the Defence Engineering Service. DLR editor Lena Fuhrmann spoke with the engineer and pilot about her special occupation.

Female flight test engineers are rare breed;
DLR's Ina Niewind assesses aircraft.

By Lena Fuhrmann

When asked about her fascination with aircraft, the flight test engineer takes a deep breath: "I wouldn't know where to begin..." Apart from the extraordinary experience of flying high above the clouds, she is particularly engaged by their versatility – the wide range of missions they fulfil. "And the manoeuvrability, even of the largest transport aircraft." She's clearly in the right job: Ina Niewind plans test flights, conducts them, reviews the responses of the aircraft and the reactions of the pilot, and, afterwards, carefully evaluates the results. As the pilot's 'client' she observes the tests from the ground or – when there is room – directly from the cockpit. She is currently involved in campaigns for the new Airbus A400M transport aircraft, the Eurofighter Typhoon and the McDonnell Douglas F-4F Phantom II.

Even when following the tests from the ground, with the aircraft several thousand metres above her, Niewind feels like she is right there: "I can even hear the pilots breathing." Everything the pilot says or discusses with the crew is important for the flight test and its evaluation. "I have to push a radio button when I want to contact the pilot, as any conversations taking place in the ground station could be a distraction," she explains. In advance of testing, during the preparation of the aircraft, Niewind uses cameras to verify all pre-flight checks. Then, as the jet takes off, she scrutinises all the details on her monitors. Is the flight altitude correct? What is the aircraft's speed? Are the items in the test plan being followed correctly? If something is inconsistent, she lets the pilot know. A test flight with a Eurofighter or an F-4F lasts roughly 90 minutes.

Putting on her helmet and oxygen mask –
Ina Niewind shortly before take-off in the
McDonnell Douglas F-4F Phantom II



© WTD 61



Flight test engineer Ina Niewind with the Transall team – planning the test flight campaigns together with mechanics, test pilots and engineers.



Fast-jet flight now mastered – aircraft mechanic Otto Hartmann congratulates Ina Niewind on behalf of the team

From sky to ground

At present, Ina Niewind is more interested in the ground than the sky; a transport aircraft must be able to land on grass, so a suitable grass runway is needed. “Since the A400M has not yet been delivered, we have to use its predecessor, the C-160 Transall, as a test subject instead,” she explains. The initial tests were positive and the experiments with the A400M are now being planned in detail. The Transall also provides insights with what are referred to as airdrop tests: “Once in flight, we open the ramp at the rear and parachute-drop the loads onto the dropping area, a special site close to Manching airfield; this tells us a lot about the behaviour of the loads as they drop.” For transport aircraft tests, she is often in the cockpit herself, there being substantially more space than in a fighter. Being closer to what is happening, she can experience the effects of the tests first hand: “It is extremely helpful to be on board the aircraft.” During the current campaign she sits in the cockpit of the Transall on average once every three to four weeks. “Flying in the transporter has its own charm – it is very much a shared experience.”

Niewind came to DLR's field office in Manching, north of Munich, in 2007 as a research scientist and immediately started on her first project. Just two months later, she was already supervising a simulator campaign for the A400M. The simulator is able to advance test various manoeuvres on the ground, exposing potential problems. Although final confirmation must be provided by flight tests, a great deal can be ‘pre-flown’ in the simulator without risk. Niewind took six test pilots from WTD 61 to the DLR site in Braunschweig, where, over the course of three days, the pilots flew in virtual reality with realistic flight characteristics. “Our job was to determine whether certain flight test techniques that

had been established on highly manoeuvrable jets could be transferred to the A400M.” To achieve this, she worked with her colleagues at DLR Braunschweig, who programmed the simulator in accordance with her specifications. “The task could not be accomplished by one person alone; teamwork is very important,” she says. Niewind has now become the project manager for DLR activities associated with the A400M and is also involved in testing the Eurofighter as well as the F-4F. “The Eurofighter is a manoeuvrable jet while the A400M is a heavy transport aircraft,” explains the engineer. “Though they are very different, they share a lot of common ground.”

Training in the desert

Ina Niewind trained as a flight test engineer at the National Test Pilot School (NTPS) in California's Mojave Desert. Going back to school for four months, she attended lectures by experienced test pilots and former astronauts on the subject of flight test techniques, such as how to approach a runway correctly when conducting landing performance tests. After the theoretical instruction, the new knowledge gained by the flight test engineers-to-be was put into practice by pairing them with trainee test pilots. The programme consisted of planning test flights, conducting them and then evaluating and reporting the results. The trainee had little sleep throughout the whole course: “But I accepted this gladly,” she reminisces. “It was an extremely exciting time.”

The job of a flight test engineer is highly sought after. A little luck is called for – alongside top grades during one's aeronautical education and an employer sufficiently satisfied to be obliging. Companies give very few people the opportunity to attend this costly training course.

During her training, Niewind was unable to take part in a fast-jet flight, which she thought a pity. This changed in March 2011; she accompanied a test pilot in an F-4F Phantom II. As a qualified light aircraft pilot, and with a little help, she was able to fly the aircraft for part of the flight, performing loops and steeply banked turns. In the process, she experienced high ‘g-forces’ several times. “My muscles really ached the next day,” she laughs happily. Back on the ground her team greeted her with a bouquet to congratulate her on the success of her first fast-jet flight.

Flying a jet fighter is completely different to flying in an airliner, so she had to prepare herself. A high level of physical fitness is essential due to the accelerations experienced during flight. Niewind was medically examined, even at a neurological level – undergoing a magnetic resonance imaging scan – and had her eyes thoroughly checked. She also had to be prepared for emergencies such as a failure of the oxygen supply. “Most people think that when there is no oxygen you feel as if you are not getting any air; it is not like that,” she explains.

“Everyone reacts differently. Some people feel a tingling sensation or warmth, while others' fingernails might turn blue.” Part of her training

took place in an altitude chamber. “A number of people sit inside, all wearing breathing masks.” The air is gradually drawn out of the chamber, but those participating in the test can still breathe normally through their mask – until the masks are disconnected from the external oxygen supply. It sounds daunting, but since everyone is carefully monitored, there is no danger. Training in an altitude chamber is compulsory for fast-jet flights; if the oxygen supply is lost during flight, the crew must react immediately.

The bigger picture

Ina Niewind's workday begins at 06:30. First, she reads her emails, as her campaigns require a lot of organisation in addition to expert knowledge. She also receives many reports to check from Toulouse, the location of Airbus headquarters. She works through all of the evaluations and records her own opinion. On top of her job, Niewind is also working on her doctoral thesis, which takes a look at the bigger picture. “Part of the thesis deals with psychology,” she elaborates. “Some pilots apply more aggressive control inputs than others. The question is why this happens with pilots who have undergone exactly the same training.”

Aviation remains a male-dominated field: Niewind is the only woman in almost all of the photographs showing her past work and training. What has been her experience in such an environment? “A woman working in a ‘man's world’?” she says and laughs. It is not a question she really cares for. “Of course I have to deal with a lot of men. I recently attended a Eurofighter meeting that consisted of 35 men – and me. A colleague described me as the splash of colour. A very pleasing description, I thought.” ●



Still ahead by a nose

After a shallow approach and setting down as light as a feather before turning onto the taxiway, the Falcon D-CMET returns to DLR's special airport in Oberpfaffenhofen. Its harmonious proportions and the characteristic vertical tailfin that extends out behind it serve to make this DLR meteorological research aircraft quite unmistakable. Even after 35 years of use, it still cuts a striking figure in the sky, and the final chapter of this successful story has yet to be written...

35 years of the Falcon – an ongoing success story

By Hans-Leo Richter

The aircraft, as a measurement and research tool, has become indispensable for the natural sciences, especially for the field of atmospheric research. One of the most distinguished and successful research aircraft employed for this purpose is DLR's twin-engine Dassault Falcon 20 E, which has proven its worth in numerous scientific missions around the world.

Falcon D-CMET

The identifier 'D-CMET' hints at the Falcon's spectrum of use. The D stands for its country of registration, Germany, the C for the relevant weight category (5.7 to 14 tons) and the character sequence MET is a reference to the field of application in meteorological atmospheric research.

In the mid-1970s, DLR's precursor institution, the German Aerospace Research Establishment (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt; DFVLR) was looking for its first dedicated, high-performance aircraft for atmospheric research. Previously, the Institute of Atmospheric Physics had used externally owned and operated aircraft such as a Lockheed T 33 or a Canberra to carry out successful atmospheric research for the now-disbanded German Gliding Research Institute (Deutsche Forschungsanstalt für Segelflug; DFS). Manfred Reinhardt, one of the 'fathers' of the Falcon and head of the Institute of Atmospheric Physics at that time (1974 – 1992), remembers: "After the Institute first started taking on meteorological work for the DFS, the increasingly complex scientific problems arising from – for example, the research areas of cloud physics and atmospheric dynamics – made the use of a high-altitude research aircraft essential. Only a high-speed jet could be considered for this purpose." The Dassault tender was considered during a selection process involving two other aircraft prototypes from Europe and the United States. Then, on 16 July 1976, the Falcon – which in the meantime had been converted into a versatile research aircraft – arrived at its new home, the DFVLR facility in Oberpfaffenhofen.

"Even today, the Falcon continues to offer very good performance characteristics for its scientific duties," explains Monika Krautstrunk, Head of Flight Operations at the DLR Flight Facility in Oberpfaffenhofen. "It can reach altitudes of almost 13,000 metres, so it can operate above the vast majority of regular air traffic." What is more, in 1995 the aircraft was given more powerful and environment-friendly engines, giving it a range of up to 3700 kilometres. This means that the Falcon can fly from its base in Oberpfaffenhofen to remote deployment areas such as northern Sweden without making a stopover."

Following a measurement flight, the Falcon heads back to its home airport of Oberpfaffenhofen with its landing lights on.



© DLR/Andreas Minikin

The tip of the Falcon's nose boom, 1.8 metres in length; this is where the five-hole flow probe is located. Researchers use it to determine the direction of the airflow around the aircraft, among other things.



The Falcon's acceptance flight took place in Bordeaux on 29 September 1975, still bearing its French registration. Careful inspection reveals the final D-CMET identifier underneath.

In 2010 the Falcon came into the public eye when it embarked on a series of measurement campaigns over Iceland, where it determined the extent and composition of the volcanic ash cloud.



Intercontinental destinations are reached by making a number of stopovers. Typically, the Falcon can be equipped with a payload weighing up to one ton for a scientific mission – even though this makes the space left for its operators extremely cramped. Though the opportunities for experimentation make up for it: the scientists on board can directly measure trace gases and aerosols, for example, or collect air samples for subsequent laboratory analysis.

Outstandingly well adapted for its tasks

The Falcon underwent numerous structural changes for its interdisciplinary research applications. These included making a number of openings on the top and bottom of the fuselage, where optical measuring or observing sensors can be mounted. The most notable and literally the most outstanding change is the 1.8 metre nose boom; a five-hole flow probe at its tip provides researchers with, among other things, very accurate information about the static and dynamic pressures and the direction of airflow around the aircraft.

The Falcon has completed almost 9000 hours of flight in its 35 years of service, an amount that a commercial airliner clocks up in less than three years. The clock for research aircraft clearly runs at a different speed. The DLR Flight Facility expects roughly 250 hours of flight per year. This is because the various applications require installation of the relevant instrumentation prior to their missions and this takes some time – from a few days to several weeks.

DLR atmospheric researchers are not the Falcon's only users. Often, universities and other domestic and foreign scientific institutions participate in the missions. And from the Fourth Framework Programme of the European Commission on, the DLR research aircraft has been a major part of early-phase and intra-European EU research programmes. Consequently, the Falcon forms a part of the EU-sponsored European Fleet for Atmospheric Research (EUFAR) network, which consists of 46 airborne test vehicles from 15 countries. To date, the Falcon has been the most frequently requested research aircraft in the entire EUFAR fleet.

Very agile flight characteristics impress pilots

The pilots remain impressed by the old lady. Stefan Gril- lenbeck, an operational pilot on the Falcon, says: "The Falcon has always been a fascinating aircraft to fly. She has very good rudder coordination, is very agile during flight at low altitudes as well as at high altitudes – for example, when making wake turbulence measurements behind airliners." Robert Rahn, a Falcon pilot from day one, can only agree: "This aircraft, which was my primary workplace from 1976 to 1994, has brought numerous highlights. The Spitsbergen missions were always especially impressive. Because air traffic is almost non-existent there, pilots had the freedom of the skies to carry out all the requests made by the researchers, including low-level flights in dramatic weather conditions."

There are not many regions on Earth where the Falcon has not flown during the past few decades, helping to answer key scientific questions: Spitsbergen and Greenland in the North Polar region, Brazil and West Africa in the Tropics, Australia and Chile in the southern hemisphere. Experts at the DLR Institute for Atmospheric Physics developed complex instrumentation that could be used to capture trace gases and particulates in the atmosphere. The aircraft and measuring equipment were frequently exposed to severe climatic conditions in the course of various campaigns. During the Arctic winter in Spitsbergen, temperatures on the ground sometimes fell to minus 40 degrees

Celsius. At the other extreme, midday temperatures during research in Burkina Faso, West Africa, rose to over 40 degrees Celsius.

On the trail of transport emissions

The ASTAR and POLARCAT measurement campaigns in the Arctic (see box) focused on researching the long-range transport of emissions from North America and Eurasia to the polar regions. These can affect the local climate. The subjects of research in the Tropics for the TROCCINOX, SCOUT and AMMA missions were powerful thunderstorms that can transport trace gases from ground level to high altitudes in just a few hours and within which lightning can form nitrogen oxides. The measurement flights in Chile for the INCA project were part of an interhemispheric experiment, and involved investigating the formation and microphysical properties of high-altitude ice clouds (cirrus clouds) in the North Atlantic Ocean to the west of Ireland to compare them to those in the South Pacific to the west of Chile. The survey area over the North Atlantic is heavily affected by emissions from air traffic and other sources that originate from human activity, whereas the comparative measurements in the southern hemisphere were carried out in a region with very clean air.

Numerous scientific campaigns required measurements to be taken at the Falcon's maximum ceiling of some 13 kilometres. However, there were also missions in which it needed to fly just 30 metres above the ocean. This was necessary for the QUANTIFY project, for example, in which air measurements above the English Channel were taken. More than 500 container ships and tankers traverse this shipping corridor between France and Great Britain every day. Researchers on board the Falcon investigated the emissions from these ships and studied their propagation to the coastal regions.

"The Falcon will continue to be in demand for international projects," asserts Hans Schlager of the DLR Institute of Atmospheric Physics, who has already led numerous flight campaigns using the Falcon. "In November 2011 we flew to Malaysia to investigate the influence of biogenic halogen compounds on the distribution of ozone."

Another prominent use of the Falcon has involved measurements using a LIDAR system. This is a method similar to radar for remote optical measurement of atmospheric particles or molecules, except that the researchers use a laser beam instead of a radio signal. Such measurements, performed by the DLR Institute of Atmospheric Physics, represent a long tradition for the Falcon. As far back as the late seventies, the ALEX system was being used to carry out the first measurements using an aircraft, a technique that was unique in Europe at the time.

Benefits for satellite development

The DLR Falcon has a great advantage – the three 50-centimetre apertures in its fuselage. These enable high-precision LIDAR measurements to be carried out simultaneously above and below the aircraft. LIDAR measurements made using the OLEX system in the Arctic stratosphere at altitudes of up to 30 kilometres have made a substantial contribution to research into polar stratospheric clouds, which play a crucial role in the formation of the polar hole in the ozone layer. The LIDAR system has also proven its worth in 'ground-truthing' the accuracy of satellite measurements and in contributing to the development of next-generation satellite instruments. The great versatility of the Falcon in terms of instrumentation and worldwide deployment enables it to fly precisely underneath a wide range of prototype satellite sensors in numerous locations around the world, regardless of the time of year.

“In the early days, LIDAR measurements taken on board the Falcon made important contributions to environmental and climatic research,” Gerhard Ehret from the Institute of Atmospheric Physics explains. “In the DFG SAMUM project in 2008 and 2009, Saharan dust samples were taken in locations near to and far from the source region in the desert. Together with other sensors on board the Falcon, these measurements provided information about the atmospheric haze caused by desert dust and on the concentration and size distribution of dust particles as a function of distance from the source region. This information is important for assessing the climatic impact of desert dust on a global scale.”

Inside the volcano plume

The Falcon became famous outside the science community in the spring of 2010. It was refitted for an elaborate measurement campaign in just a few days, and used a Doppler wind LIDAR system over Iceland and central Europe to determine the extent and composition of the ash cloud ejected by the Eyjafjallajökull volcano, which had brought European commercial aviation to a near-total halt. The flights provided a mass of data for precise analysis. Another mission of particular international interest for environmental reasons, conducted a few years ago as part of the ‘Pollution from Air Traffic’ joint research project, concerned a measurement campaign as complex as it was unusual. Flying directly behind a commercial aircraft such as an Airbus A310, a Boeing 737 or an A340, DLR researchers determined the pollutant content of the engine exhausts and were able to use these in-situ measurements to demonstrate the interactions between pollutants in the condensation trails and the resulting cirrus clouds.

Falcon – yesterday, today – and tomorrow? Although the very modern HALO research aircraft, a Gulfstream 550, has recently joined the DLR research fleet, this does not mean that the Falcon will be retired. Certainly, HALO can fly higher and farther, and this aircraft can carry around three times more scientific payload as well. Nevertheless, DLR scientists at Oberpfaffenhofen are not alone in being unwilling to do away with the celebrated aircraft. For many missions the smaller Falcon is more versatile and faster to re-equip. Furthermore, DLR has the sole use of this flying test vehicle, whereas with HALO there are many financial partners whose missions must be incorporated into the operational plans. Hence, Monika Krautstrunk stresses: “We are retaining great flexibility to carry out projects at any time using the DLR-owned aircraft. Another advantage is that many of the instruments are already authorised for use on the Falcon and do not need to undergo a separate development process. This allows us to approve and implement modifications on and in the aircraft, a process that normally takes several months, depending on the scope of the modification.”

Furthermore, there are no technical objections to its continued use. Because of its relatively low number of flying hours, the usability of this versatile aircraft is far from being exhausted. Krautstrunk concludes: “Until HALO is being used at its full capacity, the Falcon will remain the most important atmospheric research aircraft at DLR.” ●

More information:
www.DLR.de/Researchaircraft



The measurement aircraft has heated inlets near its nose, through which ambient air is fed to temperature and humidity sensors during flight.

Temperatures as low as minus 40 degrees Celsius are not uncommon in Spitsbergen – a tough test for the Falcon and its crew



This is no ordinary aircraft; a nose boom, inlets on the aircraft's outer skin for various measuring instruments and sensors underneath the wings make the Falcon one-of-a-kind.

United by their pride in the research aircraft that has been proven over the course of decades: (from left) Monika Krautstrunk, Head of Flight Operations at the DLR Flight Facility in Oberpfaffenhofen, Ulrich Schumann, Head of the DLR Institute of Atmospheric Physics, Oliver Brieger, Chief Technical Officer of DLR Flight Experiments, Stefan Grillenbeck, current pilot of the Falcon and Robert Rahn, Falcon pilot from day one.



Glossary

- ASTAR** Arctic Study of Tropospheric Aerosol, Clouds and Radiation
- POLARCAT** Polar Study using Aircraft, Remote Sensing, Surface Measurements and Models, of Climate, Chemistry, Aerosols and Transport
- TROCCINOX** Tropical Convection, Cirrus, and Nitrogen Oxides Experiment
- SCOUT** Stratospheric-Climate Links with Emphasis on the Upper Troposphere and Lower Stratosphere
- AMMA** African Monsoon Multidisciplinary Analyses
- INCA** Interhemispheric Differences in Cirrus properties from Anthropogenic Emissions
- QUANTIFY** Quantifying the Climate Impact of Global and European Transport Systems
- LIDAR** Light Detection and Ranging
- ALEX** Aerosol LIDAR Experiment
- OLEX** Ozone LIDAR Experiment
- SAMUM** Saharan Mineral Dust Experiment
- DFG** Deutsche Forschungsgemeinschaft
- HALO** High Altitude and Long Range Research Aircraft

Anniversary in the land of the penguins

An oven in the kitchen, a table and chairs from a Swedish shop, and a television, DVD player and sofa in the living room. These furnishings would be nothing unusual were they not found in one of the most remote places on Earth. The O'Higgins Antarctic Station, operated by DLR, has been defying the temperatures and wind on Antarctica's Schmidt Peninsula for the past 20 years. Outside is a nine-metre antenna for receiving satellite data, while a small team of researchers from DLR's Remote Sensing Data Center, the German Federal Agency for Cartography and Geodesy and Chilean partner Servimet occupies the interior of the station.

DLR's O'Higgins Antarctic Station turns 20

By Manuela Braun

O'Higgins Antarctic Station

DLR owns the German Antarctic Receiving Station and is responsible for satellite operations, management, infrastructure and logistics. The station is currently receiving data from the TerraSAR-X and TanDEM-X radar satellites; when necessary, the O'Higgins team actively assists the GRACE satellite mission. DLR is currently preparing to support the Canadian NEOSat mission. The German Federal Agency for Cartography and Geodesy uses the DLR antenna as a radio telescope.

The nine-metre antenna at the Antarctic O'Higgins station operates even in extreme wind conditions. The base is very popular among the penguins; here, they find shelter from the icy gusts.

It is not the freezing temperatures that make life and work so difficult for the researchers at the German Antarctic Receiving Station at O'Higgins, claims station manager Robert Metzger. The temperature during the southern winter, between June and September, can drop to minus 20 degrees Celsius in the worst of cases. In the summer thermometers can rise to a balmy five degrees however, and it can even rain. "But the wind is much worse." Winter winds gusting over the 35 interconnected containers of the O'Higgins station at 180 kilometres per hour can be daunting; during storms their speed can reach 250 kilometres per hour. "Wind speeds of 150 kilometres per hour can blow you away as soon as you step outside," cautions the station manager, who works in the Antarctic regularly. When the katabatic winds from the colder interior of the continent reach the station, the team is better off staying inside the containers. Even the penguins near the research station are glad that the DLR satellite dish has a solid foundation – they huddle tightly together to find shelter in the lee of its concrete block.

The unknown continent of Antarctica

The German Antarctic Receiving Station (GARS) was established at O'Higgins in 1991. The first station manager was Klaus Reiniger. GARS O'Higgins was established to relay data from the newly-launched European ERS-1 Earth observation satellite. Since the satellite did not have the on-board capacity to store all the imagery collected by its radar until it crossed European territory once more, this data had instead to be downloaded to a nearby receiving station. A small peninsula in Antarctica offered a site; the Schmidt Peninsula has a rocky and therefore solid foundation for the station and its antenna. Just as importantly, the Chileans had already established an infrastructure to serve their neighbouring General Bernardo O'Higgins Station; this could be used for transporting





When approaching DLR's O'Higgins station by air, the red buildings are visible, while the white antenna is hardly distinguishable.

equipment, the team and their provisions to the new base. Another advantage was that the combination of DLR's new Antarctic receiving station, the long-established US McMurdo Station and the Japanese Syowa Station provided the opportunity to obtain complete satellite coverage across the Southern Continent for the very first time. "Twenty years ago, Antarctica was still an unknown continent," says Robert Metzger. For the first time, the movement of the ice and its dynamics could be observed from space and reliably downlinked to Earth on a regular basis. One challenge was the construction of the receiving antenna, which, even in extreme winds, must remain precisely aligned to track the satellite as it passes overhead. Built without supporting struts and tracing a streamlined shape that does not create turbulence, the antenna can remain operational in winds reaching up to 180 kilometres per hour. "The antenna is the only one of its kind in the world," says Metzger proudly. "We only put the dish into its emergency configuration during extremely severe storms; otherwise, it functions without interruption."

The polar station is staffed 24 hours a day, 365 days a year, by a total of four people, two DLR researchers and two Chilean colleagues. Things were different in the 1990s; the team was only on site during the Antarctic summer, from October to March. When the ERS-2 satellite and the German TerraSAR-X radar satellite were launched, the DLR station found itself with additional tasks to perform, but, even then, the station worked unmanned and autonomously through the Antarctic winter. This changed in January 2010, when preparations began for DLR's TanDEM-X mission, in which two radar satellites orbit the Earth in formation to create a three-dimensional elevation model of Earth's surface. Since then, two DLR engineers have formed part of the O'Higgins team in Antarctica all year round, monitoring data reception, sending commands generated by the German Space Operations Center to the satellite and forwarding the resulting observations that the satellites transmit to Earth back to the operations centre in Oberpfaffenhofen. This Earth observation mission has given the station heightened significance: "For the formation flight of the satellites, it is critical to contact them on a regular basis – every hour and a half," says Metzger.

Adventurous arrival

Other receiving stations can request extra personnel as needed, but this is not so easy in Antarctica. Anyone going there must first reach Punta Arenas, on the southern tip of the Chilean mainland. From there, they must travel to King George Island, just off the Antarctic coast, on a Chilean or Brazilian Air Force Hercules transport aircraft. The final leg of the journey is

made on board a Twin Otter, an aircraft fitted with skis for landing. Prior to its arrival, the team onsite prepares a landing strip on the glacier above O'Higgins Station. When the weather is bad, no form of transport can be used; nature ultimately decides when travel is possible. In rare cases, the team can alternatively travel by ship from Punta Arenas via the Drake Passage, a notoriously stormy route that is also in turn renowned for its incidence of seasickness. However, during the southern winter it



A 'Twin Otter' belonging to the Chilean Air Force, will fly the O'Higgins team to a glacier near the station. The last kilometre to their workplace, will be travelled on board a snowmobile. When the weather is not favourable, the scientists must be patient, as flights are only possible in good conditions.



Sharing a meal with their Chilean colleagues is one of the highlights during the stay at the DLR station in Antarctica. Companionship is extremely important when living in isolation.



The O'Higgins team monitors the satellite data received 365 days a year. The team's duties include sending commands to the satellite's control center in Oberpfaffenhofen.

is often difficult to transport the polar station crew to and from their place of work. If a flight is postponed, it means only one thing for the current crew – they will have to remain at O'Higgins for another three or four months.

In addition to the station manager Erhard Diedrich and the logistics manager Marcelo Morais, the O'Higgins team at the German Remote Sensing Data Center includes nine members that rotate in shifts to Antarctica; the Uzbek Ruslan Artemenko, Frenchman Pierre Lagadrilliere, Swede Ulf Lindh, Kirghiz Alexander Scherbachenko and the Germans Ralf Reissig, Michael Specht, Werner Ziegltrum, Alfons Zimmer and Robert Metzger himself. The team is international but has long years of loyalty to O'Higgins in common. For example, Alfons Zimmer, former station manager, has notched up a total of four years at the polar station during the past 20 years. "The work is not easy," says Metzger. When you spend months at the other end of the world, surrounded by penguins and leopard seals, monitoring an antenna, contact with family and friends via telephone and internet is limited: "But even so, it is possible for us to stay in touch."

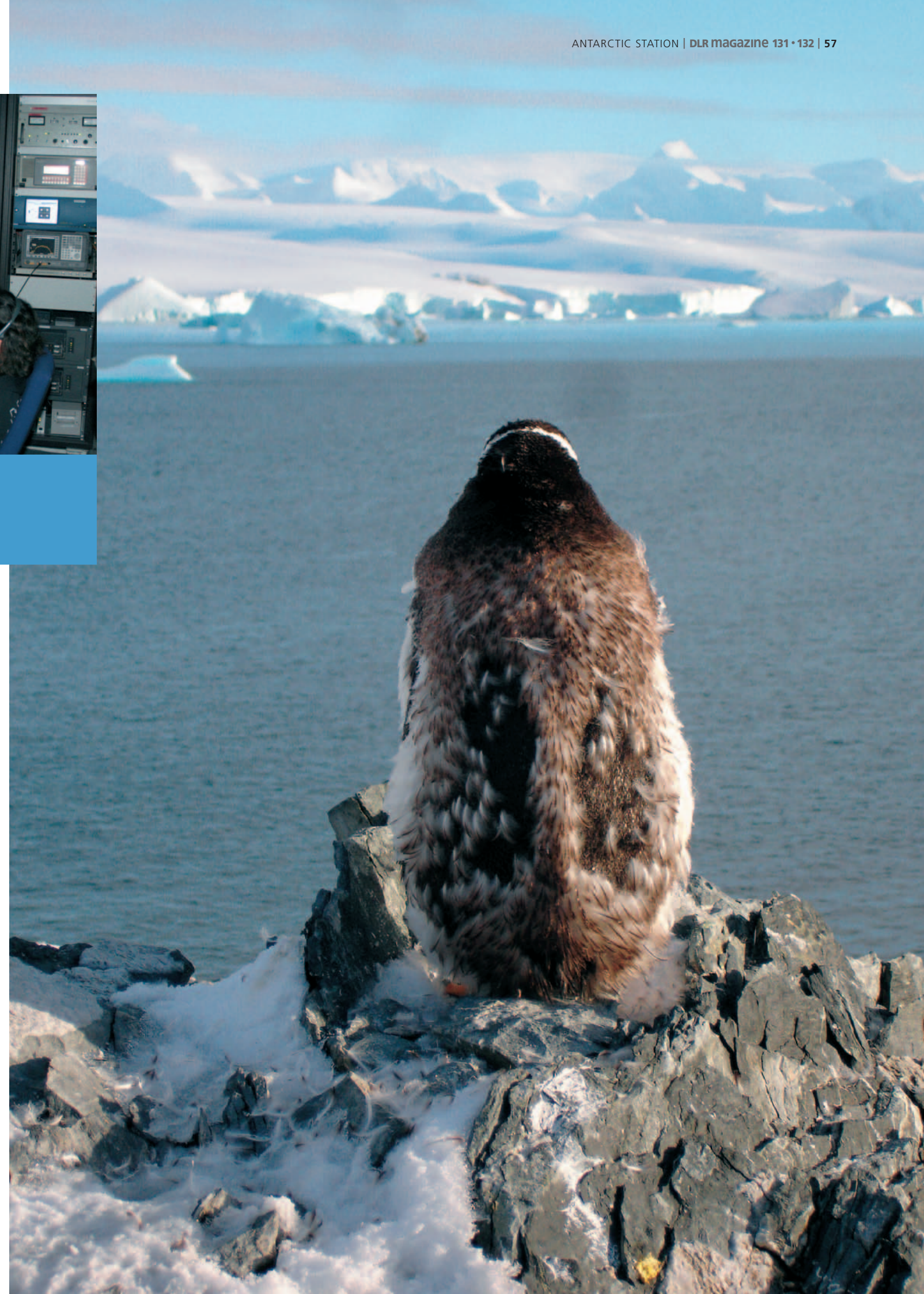
Researcher, caretaker and chef, all in one

In Antarctica, engineers are more than just engineers; they are also cooks, snow clearers and, when sea salt forms a crust on the dish, antenna cleaners. The station is self-sufficient; it obtains power from diesel generators, processes salt water into fresh water and has its own waste treatment plant. Metzger shows photographs he has taken during his stays at O'Higgins. One quickly forgets that the simple kitchen and its table are surrounded by the nearby Mount Jacquinot, glaciers and the ice shelf. The supply cupboard is filled with piles of tinned food, non-perishable food items and drinking water that a Chilean ship brings to the station. Fresh produce is only available when the next team comes in for a change of shift and unpacks the groceries from Punta Arenas – salad, fruit, everything that the onsite staff have been missing in recent weeks.

The workload is heavy and free time is limited. "But that is a good thing, because you do not have time to be overly thoughtful," says the station manager. The members of the team depend on one another during their stay as a team of two in close quarters at O'Higgins. Consisting of 15 interconnected containers, the main station building is not particularly large. The entire peninsula is just 300 metres wide and 200 metres long. Going for walks in the surrounding area can be dangerous. "You can only go out if you take a radio or go with a partner." Concealed crevasses in the ice could turn a quick stroll into a dangerous downward excursion. At least some variety can be found during a visit to the neighbouring Chilean polar station; there, the DLR researchers can use the gym. "It is very important that all the team members get along well." As Metzger explains, this is not just a matter of technical competence, but of interpersonal relations too: "You have to be able to accept the other person's quirks."

Fascination for a remote world

Dealing with Antarctica's remoteness and cramped living conditions comes down to each individual. Books, films and music are available for the crew. "The highlight is cooking and eating together," says Metzger. But shift work on the Schmidt Peninsula is not for everyone: "Many want to come and visit, to experience Antarctica, but staying for several months is something only a few people will consider." A stay at O'Higgins is almost comparable with a mission to space, with non-negotiable teamwork, limited space to retreat to, limited contact with the outside world, and an external environment that is inherently hostile to life. "If a person cannot get excited about a world like this, there is no point sending them there as a team member," says Metzger. Then he flicks through the photographs of O'Higgins and the natural environment. It is hard to pick out the transition from land to sea in the white of the ice shelf and the sea ice. Thick layers of snow lie on the station containers and a puffed up penguin looks out at the water almost meditatively. It is a very different world in which DLR listens to satellite signals 365 days a year. ●





The art of spaceflight

At the close of the year marking the fiftieth anniversary of human spaceflight, we examine this legacy from a rather unusual perspective, where "space is refracted by the prism of art." The KUNSTHALLE wien in Vienna did just this in a highly acclaimed exhibition this year, as did its curator, an astronaut, a scientist and a science administrator, whose individual view-points are shared here.

After half a century in parallel orbits, human spaceflight and art met at an exhibition in Vienna

By Peter Zarth



Installation at the KUNSTHALLE wien. From left to right: Simone Leigh, *Back and Forth (Uhura)*, 2008 / Tom Sachs, *The Crawler*, 2003, Sammlung Thaddaeus Ropac, Salzburg-Paris / Mariko Mori, *Genesis (Soap Bubbles)*, 1996, Ringier Collection, Switzerland / Virginie Yassef, *Box Jellyfish*, 2004, Courtesy GP&N Vallois, Paris. Image: Stephan Wyckoff

Keith Tyson, *Studio Wall Drawing: 2006 – Zero duration from emission to absorption... to live and die is to shine*, 2006 Mixed media on watercolour paper 157 x 126 cm

What kind of art do you have in your workplace? There is a photograph of pianist Clara Haskil in astronaut Gerhard Thiele's office. Photorealistic paintings of atomic mushroom clouds by artist Dona Jalufka hang in the office of Christian Köberl, Director of the Vienna Natural History Museum. And during his time as Director of the European Space Policy Institute, the current Head of the European Space Agency's Policies Department, Kai-Uwe Schrogl, owned a large-format painting reminiscent of 'the Big Bang and the Universe'. In the office of Manuel Ströhlin, from the Vienna 'Art&Science' Society, we find walls covered with art by old masters and members of the young avant-garde. For some, art seems to be purely decorative; for others, art must be aesthetically attractive while at the same time provocative; for a third group, art is a wall-filling highlight set against an otherwise spartan workspace. For those who have accepted art as their calling, its presence goes without saying. Certainly, none of the people we are talking to here questions the value of art.

The presence of art in scientific settings is not surprising. Hardly anyone would be surprised by artwork in the offices of astronauts and scientists. But visualise the opposite situation for a moment; suppose that renowned artists were to hang space flight related items on their studio walls. This might be something to set tongues wagging.

Astronauts in art

Now we are in the midst of art rather than in an office – an exhibition at the KUNSTHALLE wien: 'Space. About a Dream'. To celebrate the passage of 50 years since the first manned spaceflight, we are given a guided tour of the exhibition by its curator, Cathérine Hug. Accustomed to deep thinking about the relationship of art with her surroundings, she has successfully applied this pensiveness to science and aerospace. This Swiss woman works closely with artists who portray scientific themes or make use of scientific techniques or configurations in their art – and as a result she also collaborates with the associated scientists. Cathérine Hug has worked with well-known artists including the new star of the French scene, Loris Gréaud, the icon of US art history Robert Rauschenberg and Turner Prize winner Keith Tyson.



Mariko Mori, *Genesis (Soap Bubbles)*, 1996, Duratrans print (3-dimensional) in light box, 180 x 120 x 35 cm, Ringier Collection, Switzerland

Effectively, Cathérine Hug is an astronaut of art. She wants to explore “the aesthetic and socio-political utopias the notion of space is still able to unleash today.” And because space is universal, it takes in the everyday here and now, as well as the distant realms of existence. Her approach to space in a nutshell: “It is about raising questions rather than giving answers.” Through the work she has gathered here, Cathérine seeks to inspire open-mindedness to new discoveries, an everyday matter in the scientific field.

Separate realities

The works of art on show in this exhibition give the impression that space and art are relative strangers who nevertheless have something in common; perhaps unfamiliar or sometimes estranged siblings. Space is not a field where art is much spoken of, taken into consideration mainly as decoration – a soothing background for long-stay astronauts, for example – and rarely as something to say upon the subject of space travel itself. Things are a little different on the other side of the divide: spaceflight is anything but taken for granted in art, and has become one of its subjects. Why?

Art scholar Ströhlin can certainly give an insight to the relationship between these two estranged siblings: “Art and science are not separate realms of reality. Rather, these worlds are determined by the various ways that we encounter them in our everyday lives, in the attempt to orient ourselves and make our own picture of reality. There are many ways of relating to the world. Art might not be essential for science and technology, but it is for those of us who live in a world dominated by science and technology; without art we would be lacking one of life’s necessities.”

It can be argued that art and science come together exactly where they are uniquely different. Both are based on and favour experience, though each in its own different way. The natural sciences are based on objective experience, in so far as it is measurable, quantifiable and, under identical conditions, exactly reproducible. Art, on the other hand, focuses on just that experience, inevitably connected with each person’s physical and sensory experience, which is always individual, subjective and open to interpretation. Both art and science are part of not just reality, but also the nature of people and their lives – the general and the particular, the regular and the irregular, the unambiguous and the ambiguous. One must not reduce the one to the other, as both, in all likelihood, together create the whole.

Spaceflight is art

Is spaceflight art and art spaceflight? Scientist and former space shuttle astronaut Gerhard Thiele, now Resident Fellow at the European Space Policy Institute in Vienna and involved in diverse cultural activities, gives a clear if somewhat uncommon answer: “Yes, spaceflight is art.” Thiele exemplifies this with an anecdote from Dana Ranga’s ‘Story’, a documentary on astronaut Story Musgrave. When asked to identify his profession, and after careful exclusion of all other labels, Musgrave states: “Yes, I am an artist. In a way.”

Is art spaceflight? Thiele moves on, beyond this question: “Spaceflight is homecoming.” Stepping away from everything we know gives us the opportunity to see our world and ourselves in a completely different light. The same is true for art in every form: when art touches us then something happens to us and we must engage with it. “An intense discussion about

an object opens new perspectives. It also happens when, inside a given space, I go to a new and different place. This is exactly what we do in spaceflight. We open up new points of view.” Thiele refers to one of the works in the exhibition, the installation ‘Soldiers of Light’ (2005) by Jen Liu. This video projection shows a group of people within which it appears that one of the figures is performing slight hops up and down. Each figure seems to be associated with an instrument and a sound. All appears to be in unison and, nevertheless there is an ever so slight counter movement within the figures hopping up and down. Over time, and one by one, each figure changes its rhythm and therefore becomes more prominent than the others. Thiele states: “From absolute differences something common is generated.” And he asks, “What does a human do in art? Almost always, he is pushing against limits, trying to move beyond boundaries. Art and spaceflight challenge us to look beyond alleged certainties.” He is silent, and then says: “This work of art is like my flight into space.”

An open game

Kai-Uwe Schrogl takes a pragmatic approach, labelling art as ‘playful’. He has certainly hit on one of the essential features of art, and with his sharp intellect one can assume that he, not only had the mathematical practice of game theory in mind, but was actually alluding to it directly. During his time at the European Space Policy Institute, he sought to build bridges to art and the humanities, with the intention of introducing space travel into fields other than just the classical technology sectors. Schrogl’s definition of politics is accordingly as open as art; it is no accident that the policy institute regularly holds art exhibitions on its premises. Spaceflight can produce art; this is not an alien concept for Schrogl, though he cautions that the reverse opinion is “pure nonsense.”

Art and science need no explanation

“I have always been interested in scientific outreach activities.” Christian Köberl might give the impression that the reason his own institution participated in the exhibition was because he wanted to reach a new target audience. That is one reason, but Köberl is thinking on a deeper level. Modern science is interesting, exciting, relevant and important. It breaks boundaries. With this latter thought he draws the first comparison with art. Is science art? Köberl does not have to think for long, because he has a clear opinion, possibly a surprising one. “Science and art share the same characteristic that differentiates humans from animals: curiosity. Animals don’t create art for their own sake: art brings joy and science drives us to find answers. Art and science are, therefore, related, but definitely not identical.”

Köberl continues, “Science and art must be approached in a similar way – with an open mind. Once you know what you are looking for, there is nothing to discover anymore.” More precisely, “what is important with art is that it needs no explanation.”

Art creates art

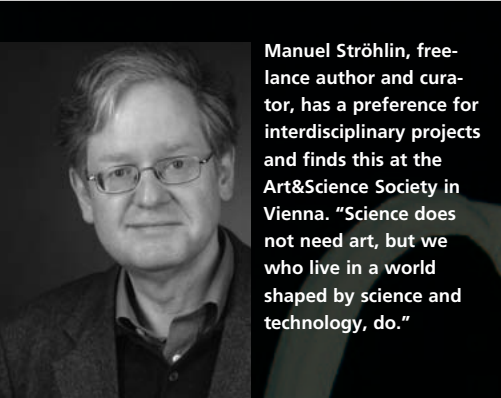
The curator does not entirely agree with this last statement. Indeed she would add a small but significant word: “Art does not necessarily need explanation.” After two hours, the tour is coming to an end. Surprisingly, it has raised more questions than answered them. Art has aroused curiosity and managed to create something new. The placement and type of artworks were carefully thought through, the curator explains. Many of the visual artists included music, tone and sound in their work. “Sound in space is a new concept,” Hug says, “but it is extremely difficult to deal with sound here.” She has a musical background, but finds it difficult to explain the idea of acoustic overlay. “Sound has no boundaries, it permeates the entire room; it cannot be planned with precision, because the simulation software does not yet exist – but herein lies the beauty of surprises.”

She is silent and looks around. “I am delighted.” Perhaps she is wondering about how her exhibition is viewed and interpreted, about the hard-to-define intersection of art and spaceflight. This would not come as a surprise. Cathérine Hug is a thoughtful person. ●

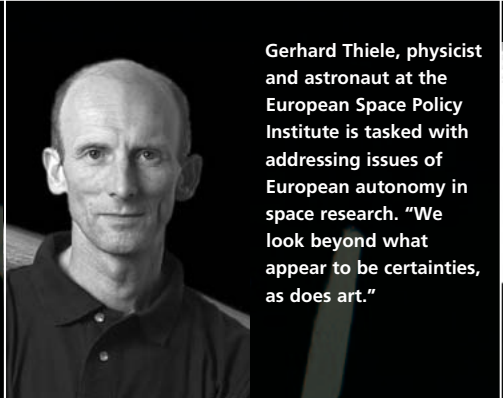
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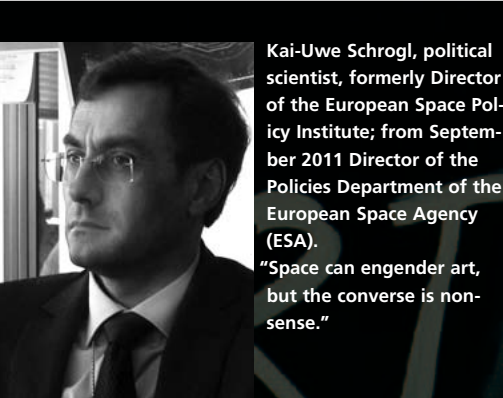
Andy Warhol, *Moonwalk (1, pink)*, 1987, Silkscreen on paper, 96,5 x 96,5 cm, Ronald Feldman Fine Arts, Inc., New York



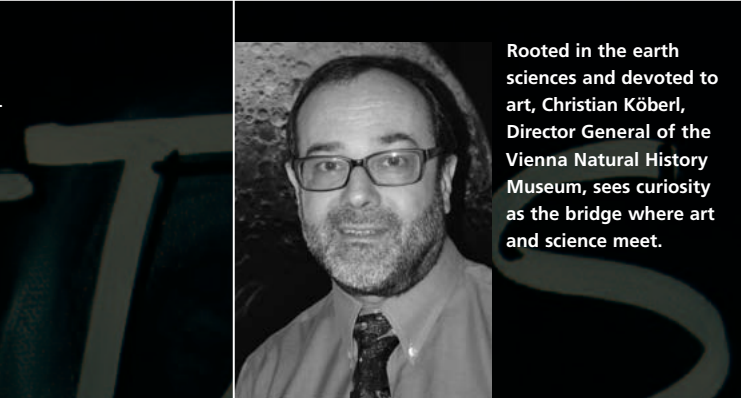
Manuel Ströhlin, freelance author and curator, has a preference for interdisciplinary projects and finds this at the Art&Science Society in Vienna. “Science does not need art, but we who live in a world shaped by science and technology, do.”



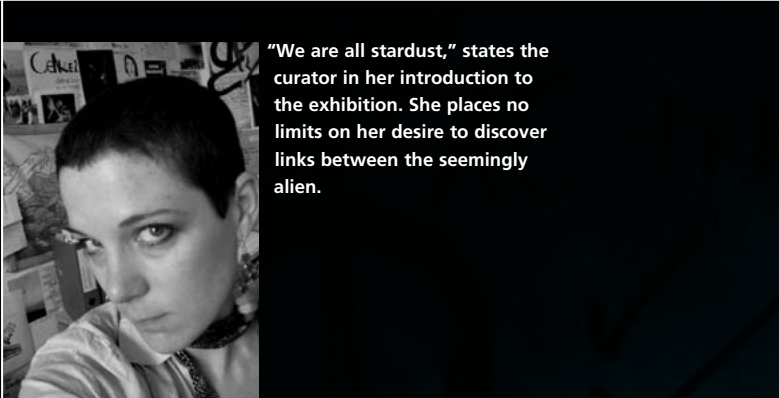
Gerhard Thiele, physicist and astronaut at the European Space Policy Institute is tasked with addressing issues of European autonomy in space research. “We look beyond what appear to be certainties, as does art.”



Kai-Uwe Schrogl, political scientist, formerly Director of the European Space Policy Institute; from September 2011 Director of the Policies Department of the European Space Agency (ESA). “Space can engender art, but the converse is nonsense.”



Rooted in the earth sciences and devoted to art, Christian Köberl, Director General of the Vienna Natural History Museum, sees curiosity as the bridge where art and science meet.



“We are all stardust,” states the curator in her introduction to the exhibition. She places no limits on her desire to discover links between the seemingly alien.

Reviews

Earthly beauty from the cosmos



When astronauts return from space, they always enthuse about one thing – the view of Earth. Very few people are lucky enough to see our planet from such a great distance. But everyone can find a good substitute in **Mission Earth – Our planet explored by satellite (Ullman publishing)**.

The course of the Irrawaddy River in Myanmar (formerly Burma), as seen through the ‘eyes’ of the Envisat satellite, the Easter Island group as viewed by radar satellite TerraSAR-X, turbulent air masses over the South Pacific, the shadow of the Moon over the Sahara desert during the solar eclipse on 29 March 2006. Even at first glance, one discovers unusual views and fascinating topics, and also benefits from the unique view of planet Earth enjoyed by satellites. They make it possible to perceive the force of gravity in 3D – the depressions in the ground across Mexico City and the extent of flooding on the Mississippi River are all clearly visible.

Author Dirk H. Lorenzen gives a detailed explanation (and with translations into several languages) of what the ‘armada of specialist satellites’ can achieve. He raises awareness about the fact that data from space can provide important information about life on Earth. The only point of criticism is that, for the most part, the satellite imagery fails to completely illustrate precisely what is being explained in the text, and it does not provide relevant photographs from each satellite mission. This should not, however, prevent anyone from feasting on the colours, shapes and vast array of information provided.

Manuela Braun

Living in space

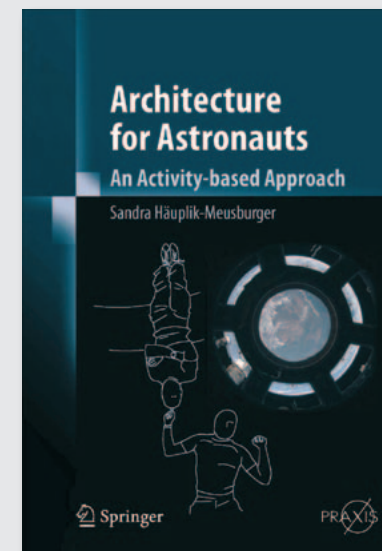
Where do people, space and objects come together in an extraterrestrial environment? How do astronauts relate to each other and their environment during missions?

Architecture for astronauts: An Activity-based Approach provides insights about the various man-made habitats: the Apollo Spacecraft and Lunar Module, the Space Shuttle Orbiter and the Space Stations. From the goals and scientific objectives to the daily activities in each of the astronauts’ lives in space, this book takes one on a guided tour of the different modules, how they were designed and for what purpose.

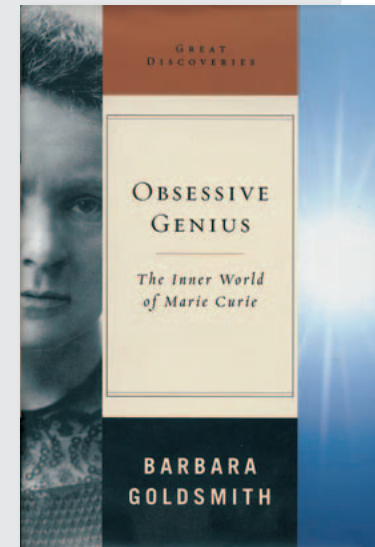
Those living and working in extraterrestrial habitats are exposed to extremely harsh conditions, not only environmental, but also social and psychological. The architecture and design on habitable environments poses a great challenge as the technical specifications required for launch vehicles and spacecraft are very strict. These constraints make the symbiosis between the environment and its users crucial. In this book, **Sandra Häuplik-Meusburger** portrays these constructions from the viewpoint of human activity. It provides an overview of the architecture and configuration of these habitats, and highlights specific issues affecting their layout and their relation to the spatial and temporal distribution of human activities, including sleep, hygiene, food, work and leisure.

For those curious about life and work in space, the author also collected direct feedback from the astronauts and cosmonauts themselves regarding their daily activities. The personal experiences shared by these users make this book unique. Whether one is interested in space or architecture, or interested in human spaceflight, this book provides a great in-depth analysis that foresees the direction that design will take in the coming years.

Karin Ranero Celius



The good fortune and suffering of a female researcher



The legacy of a certain female researcher runs like a ray of light through the chapter headings, documenting just one thing – **Obsessive Genius, The Inner World of Marie Curie**. ‘The Chemistry of the Invisible’, ‘She is Very Obstinate’, ‘All My Strength’, ‘The Making of a Myth’. It is rare for a biography to be written with such a powerful combination of excitement and historical fact. With amazement and occasionally even incredulity, one works one’s way (like the protagonist herself once did) through the lifetime and work of Maria Salomee Skłodowska, who later found fame as the only woman to win two Nobel Prizes, and indeed become the first woman to ever receive this great honour. The US historian and journalist **Barbara Goldsmith** has written an insightful portrait, painstakingly researched, even to the extent of viewing documents still contaminated with radioactive materials.

After working your way through these 230 pages, you gain a feeling that is difficult to explain for what it was that drove this young girl to work on her education day and night, what moved her as a young woman to dedicate all her thoughts to a very broad field of study and then, later and under the toughest imaginable physical conditions, to investigate radioactivity, regardless of the implications. The book brings us close to this complex, passionate and altogether persistent personality, courageous and proud as she was, but also vulnerable and prone to melancholy. At the same time, the book communicates science in a comprehensible and emotional way. Superb.

Cordula Tegen

Training book for space travel

Communicating in another language for those who have been working in aero-space for many years does not pose a problem. For people starting out on a career and those who do not work regularly in this field, it is somewhat more difficult to make themselves clearly understood. **HANSER** has recently published a training book written by John Nixon entitled **Modern English for Aeronautics and Space Technology**. In a concise and cogent manner, it not only communicates the basics, but also provides a good set of illustrations. The technical terminology is not just translated. Instead, terms are explained with the help of illustrations and are shown in their technical context. This is a good basic work for beginners, a useful guide for professionals and also a valuable reference.

Andreas Schütz



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.

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Dorothee Bürkle, Manuela Braun, Martin Fleischmann, Lena Fuhrmann, Hans-Leo Richter, Andreas Schütz, Marco Trovatiello and Peter Zarth

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

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