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# magazine

## Making science fun

Head of the DLR\_School\_Lab Bremen, Dirk Stiefs



**Sailing through space**

The Sun as an 'engine' in Project Gossamer

**Satellite images for emergencies**



# DLR magazine 136 • 137



Portrait: Head of the DLR\_School\_Lab in Bremen, Dirk Stiefs

Here, Dirk Stiefs feels like he is in the right place. Surrounded by students who are interested in Mars rovers, rocket construction or experiments in microgravity. Each morning, when the physicist arrives at the DLR\_School\_Lab in Bremen, he knows that this day will bring something new. Enthusing people about science is his thing. He achieves this, as seen on the cover of this issue. He has also entered a few Science Slams. The 33-year-old is happy to explain science – sometimes unconventionally. You will get to know him better in the article ‘Making science fun’. Stiefs heads one of the 10 DLR\_School\_Labs; three of them celebrate their tenth anniversary in 2013.

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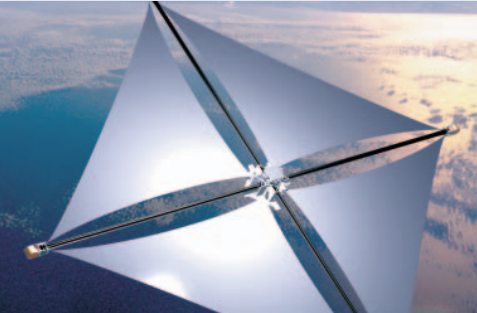


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Dear readers,

This year, not only does everything seem to happen a little earlier, it also seems to pass more quickly. The ‘fifth season’ in the German Rhineland was soon here and gone, and now Easter is just around the corner. A winter break? Far from it. The weeks are filled with, among other things, visits to DLR by prominent figures from the world of politics. The President of Germany, Joachim Gauck, bestowed this honour upon us in the company of the Prime Minister of the Free State of Bavaria, Horst Seehofer, and they were followed by the Czech Prime Minister Petr Necăs, EU Commissioner Antonio Tajani, the Turkish Prime Minister Tayyip Erdogan, and German Secretaries of State Cornelia Rogall-Grothe and Anne Ruth Herkes. Many regional politicians can be added to the above list – all in the first quarter. One could have thought that there would not be a second one.

Preparing for visits of this kind is a resource-intensive activity. Logistics, time management, presentations – all must be planned down to the last detail. But despite the stress and work that appointments of this kind may impose on a few of our institutes, visits of this nature are very important for DLR. German Federal and regional governments invest in research and enjoy coming to visit as our guests. The number of visits to the 13 DLR sites reflects the important role our research plays in society. Moreover, both sides benefit, all driven by topical political priorities. As many and varied as the visitors may be, and as diverse and wide-ranging the topics and presentations, certain political trends do tend to emerge clearly.

At present, in Oberpfaffenhofen, the topic of Earth observation and crisis information is of particular interest. DLR has taken the chair for a six-month period in the International Charter ‘Space and Major Disasters’. What that means in practical terms is the subject of an article in this magazine. We also report on DLR’s HALO research aircraft, on its flight to the Antarctic and back home. We are unveiling a vision of a solar sail to power satellites. Safe roads, railways and air travel are topical items. All of these are DLR topics that never fail to enthuse talented youngsters, as the cover image shows.

Naturally, we have far more to offer. Viewed in that light, we can count ourselves fortunate that not all these matters are at the top of the agenda for our visitors at the same time. Our scientists, engineers and managers would otherwise never get a chance to carry out their cutting-edge work. I hope that you enjoy reading this magazine – with no visitors knocking at your door, even if they are truly welcome...

Sabine Hoffmann  
Head of DLR Corporate Communications



# Perspective

## The calm before the storm

The languid serenity that emanates from the large blue-silver blades is deceptive. The ultra-strong aluminium components do not touch the ground. Beneath their mounting, they conceal a high-performance propulsion system. Once these gigantic blades start to rotate, all that remains is an aircraft model or component whose aerodynamic properties need to be investigated. Sixteen rotor blades mounted in front of the stationary stator then propel air at a maximum speed of 325 kilometres per hour directly onto the model.

The low-speed wind tunnel in Braunschweig is operated by the German-Dutch consortium Deutsch-Niederländische Windkanäle (DNW-NWB). In 2010, it obtained a new, much quieter drive unit to enable acoustic measurements. At the end of the wind tunnel (the golden area visible in the background), aero-acoustically optimised profiles ensure that air flow is carefully directed around the corner – hence its name, ‘Umlenk-Ecken’ (deflecting corners).

Image: DLR/Heinrich (CC-BY)





# Dare for more DLR!

By Johann-Dietrich Wörner



Johann-Dietrich Wörner, Chairman of the DLR Executive Board

[www.DLR.de/janwoerner](http://www.DLR.de/janwoerner)

Willy Brandt's famous call to "Dare for more democracy!" (Mehr Demokratie wagen!) was the starting point for my thoughts on the year 2013. What the former German Federal Chancellor wanted from a generally political perspective in 1969 is, on closer inspection, a statement of intent with widespread appeal. It is still valid more than four decades later, and it also applies to scientific activities. And it is especially applicable to the German Aerospace Center.

During the last five years, we have been working on DLR's self-conception and its orientation towards 'Knowledge for Tomorrow' and, in so doing, substantiating the institutional and organisational claim 'One DLR', with its precepts for everyday work. We are guided by the four 'I's – Invention, Innovation, Interaction and Internationalism. This is how the set of aggregated visions is summarised and now needs to be implemented in the various research and administration areas. Consequently, the motto 'Dare for more DLR' can and should be the primary inspiration for this implementation, or encapsulate it better. Let's exploit the opportunities that DLR offers!

Our 7400 motivated, skilled employees, an excellent infrastructure, as well as the existing connections to other research institutions and partners in industry, nationally, across Europe and internationally, offer potential that is still far from being exhausted. Vanity and demarcation with the motivation of 'protecting one's own area' are patterns of thought that should be a thing of the past. However, 'Dare for more DLR' is also valid as a challenge to the outside world. DLR aims to be a reliable, competent and fair partner for industry, science and society, and expressly invites more interaction. In understanding our responsibility, we want to use our capabilities to solve diverse problems, including global challenges.

'Dare for more DLR' is also an exhortation to the world of politics. Sociologist and social economist Max Weber already highlighted science's right to self-determination at the beginning of the last century. DLR receives considerable funds from German taxpayers. However, deriving detailed control from the terms 'legal supervision' and 'technical supervision' is not only wrong, but contrary to reason.

Instead, clear objectives should be defined that lead to qualified decision-making in each location and the appropriate actions. Obviously, this must also involve ensuring that objectives are being achieved. So responsibility is also clearly allocated here, and it should form the basis of modern management in research and administration.

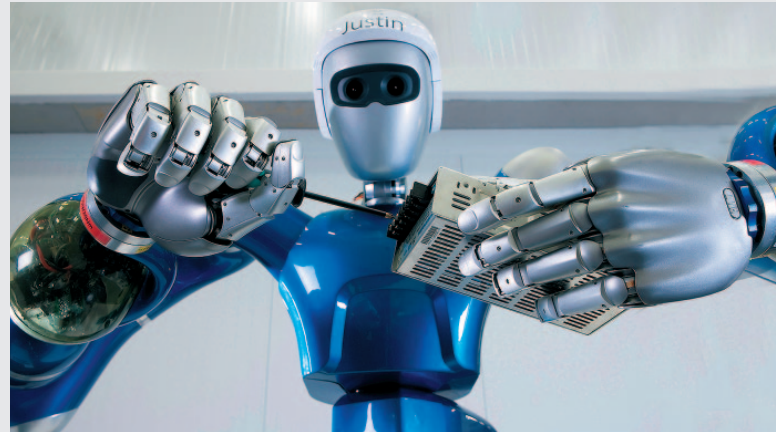
The structure and organisation of DLR make it suitable to assume such responsibility, and it is ready and able to do so. Therefore, my current call – internally and externally – is to **'Dare for more DLR!'** ●



# In brief

## Men and robots build cars hand in hand

The lightweight robots for use in space developed by DLR have properties that make them attractive for production at Daimler AG. The company has concluded a strategic cooperation agreement with robot and plant manufacturer, KUKA AG, which has been working with DLR for a long time. The focal point of this industrial partnership is the direct collaboration between people and lightweight robots in ultra-precise assembly operations. The robot acts as the operator's 'third hand', grasping delicate components and carrying out difficult tasks with great precision. The remarkably sensitive motors powering the DLR manipulator arm can improve the ergonomics of assembly workers. The lightweight robot can be positioned and set up in a way that enables it to carry out physically strenuous operations for humans, such as work above head height. In addition, the simple and intuitive procedure for working with the robot reduces programming times, which in turn improves production cycles. With their absolutely precise operating method, these lightweight robots can also help to achieve consistent high standards of quality.



DLR robots with a precise touch. Installed sensors detect the local environment and enable the robots to respond flexibly.

'Soft Robotics' is the name given by DLR scientists to the operating principle of their robots; they do not blindly follow a predefined track but instead are flexible. Sensors give them the ability to be aware of their surroundings, thus being able to respond accordingly. For example, back in the laboratories in Oberpfaffenhofen, 'Justin the robot' demonstrates his capabilities – his two lightweight robot arms incorporate the same technology to be employed in car manufacturing. They use sensors to detect every time human operators make physical contact, and can then be guided smoothly and without effort by them. If they encounter an unexpected obstacle, movement stops and the arms become flexible, enabling man and robot to work hand in hand without any risk.

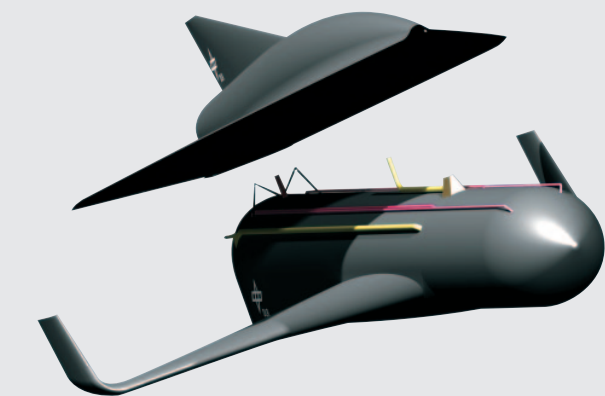
<http://s.dlr.de/3w56>



## Travel at hypersonic speed

To the far side of the world in 90 minutes? Researchers from nine countries have been examining this possibility in an EU-funded study known as Fast20XX (Future high-Altitude high-Speed Transport). The results are now being incorporated into the latest design of the DLR SpaceLiner and the Aerospace Innovation GmbH ALPHA aircraft. The SpaceLiner will be launched vertically using rocket motors. A reusable booster stage then helps the hypersonic aircraft achieve a gliding orbit above Earth's atmosphere. Once this booster stage is discarded, travellers in the passenger capsule will travel to their destination at 20 times the speed of sound. They land, some 80 minutes later, in the same way as a conventional aircraft on a normal runway. The magnitude of this project is such that scientists need to feel their way slowly forwards with the help of computer models. The SpaceLiner is nothing less than a true challenge in terms of its technological and operational parameters. The 17 partners involved in the Fast20XX study have been applying an interdisciplinary approach to examine the various aspects of this. In addition to the Institute of Space Systems, three DLR Institutes are involved: the Institute of Aerodynamics and Flow Technology, the Institute of Structures and Design, and the Institute of Aerospace Medicine.

As well as questions of aerodynamics, materials and cooling, researchers are examining flight safety and environmental impact. Scientists have been examining scenarios that might render it necessary to abort a flight and how, for example, to respond in the event of engine failure. But many questions still remain unanswered, including ones relating to the rocket propulsion and thermal protection system. A first step towards a means of transport for long-haul flights is being taken by the Aerospace Innovation GmbH ALPHA project. This spacecraft, also examined in the context of Fast20XX, is intended to launch from an Airbus A330 at an altitude of 14 kilometres with two passengers and one pilot on board, and then to fly up to an altitude of 100 kilometres. This could be accomplished within the next decade. The SpaceLiner that is to handle the transport of passengers and goods between continents is not expected to be in operation before 2050.



An artist's impression of the vision of DLR researchers – once the SpaceLiner reaches its cruising altitude above Earth's atmosphere, it discards its booster stage and switches to gliding mode.

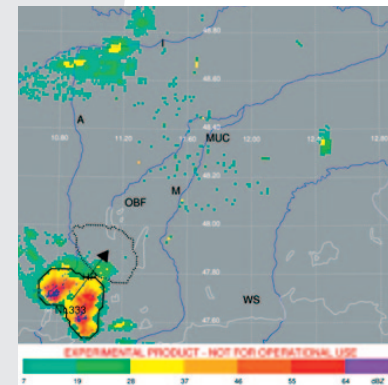
<http://s.dlr.de/202z>



## A clearer picture of thunderstorms

Thunderstorms can be dangerous, especially for air traffic. They force pilots to take evasive measures, impose restrictions on the landing and take-off capacity of airports, and can bring airport ground handling operations to a standstill due to the risk of lightning strikes. With the support of DLR Technology Marketing, WxFUSION (Weather Fusion of User Specific Information for Operational Nowcasting) has founded a company that employs the latest techniques in flight meteorology to deliver fast, comprehensive decision-making aids.

To mitigate the adverse impact of thunderstorms on air transport, it is necessary to amalgamate all available data from user-specific analyses and forecasts relating to these dangerous weather conditions. To accomplish this, scientists use satellite and radar data. This enables them to identify and track thunderstorms and to predict their arrival up to one hour in advance. The system is able to depict where turbulence, lightning strikes, ice or hail might occur. These warnings are issued in a standard international form that is easy for users to view on their displays. The 'AutoAlert' function transmits warnings to users by e-mail as soon as a thunderstorm is detected within a radius of 100 kilometres of an airport. This unambiguous, clear, real-time information about thunderstorms precludes alternative interpretations and is updated every five minutes, helping to make air traffic safer and more efficient.



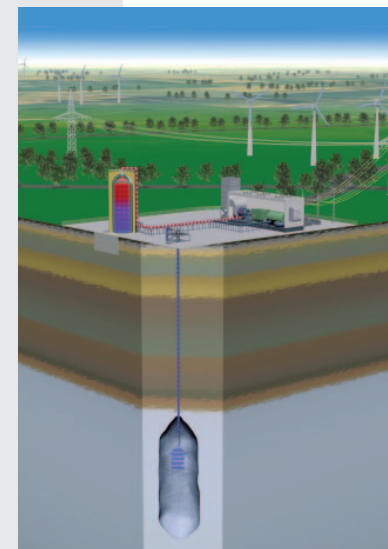
A thunderstorm cell (black contour) to the southwest of two German lakes, Lake Ammer and the Lake Starnberg – detected by the 'Rad-TRAM' (Radar Tracking And Monitoring) system developed by the DLR Institute of Atmospheric Physics. The direction of movement and the forecast for up to 60 minutes in advance is shown by a line of black dashes.

## Cost-effective storage of compressed air

How can the varying levels of wind and solar power be balanced out in a reliable and economical manner? In the ADELE project (Adiabatic Compressed Air Storage for Electricity Supply; Adiabater Druckluftspeicher für die Elektrizitätsversorgung), RWE Power is working with General Electric, Züblin and DLR to develop a technology to store energy safely, efficiently and for periods of several days. Work started on ADELE in 2010 and its successor, ADELE-ING, is now also in progress.

The aim is to continue developing the ADELE system while adapting it to changes in the energy industry – especially the current shift towards renewables. Researchers want to examine and improve the competitive prospects of adiabatic compressed air storage facilities – a real challenge. With the exception of existing pumped storage facilities, current storage technologies are simply not sufficiently economical.

At times of high power availability, both centralised and local compressed air storage facilities could compress air and store it in an underground cavern while also storing the resultant heat. At times of high demand for electricity, this compressed air can be used to generate electricity with a turbine, while at the same time recovering the stored heat to improve efficiency.



Artist's impression of compressed air storage in an underground cavern

### FLOATING WITH SUNITA



<http://tinyurl.com/bq3rqfn>

Video: NASA astronaut Sunita Williams floats through the laboratories of the International Space Station. Sleeping, working, eating, looking outside – the female commander of ISS Expedition 33 (16 September to 18 November 2012) does it all. In this video, the long-stay record holder (194 days, 18 hours in space) guides her spectators into every last corner of the ISS. Her witty explanations, complemented by facial expressions and gestures, make this tour a real pleasure. A great way to get a glimpse of life on the ISS.

### EN ROUTE IN TANDEM



[www.DLR.de/en/TanDEM-X](http://www.DLR.de/en/TanDEM-X)

The DLR website provides background information, technical data, animations and, time and again, breathtakingly beautiful images from the German radar satellite mission, TanDEM-X.

### CHRIS' SPACE KITCHEN



<http://bit.ly/15qzz9n>

In his Space Kitchen, Astronaut Chris Hadfield shows us how simple it is to make a honey and peanut butter sandwich in space, that is, with tortillas instead of bread. Find out why in this fun video provided by the Canadian Space Agency.

### MEET THE ROBOTS



<http://bit.ly/118GzVs>

Have you heard of DLR's SpaceJustin? With the IEEE ROBOTS app (0.89 €) you'll be able to learn about him and many other robots, animate them with the touch of a finger, and rate them. Are they creepy or nice? With regular updates, it is definitely a reference for anything robot. You can also follow them on twitter: @robotsapp

### TWEET!



[www.twitter.com/DLR\\_en](http://www.twitter.com/DLR_en)

Do you know about @DLR\_en? If you're on twitter, follow us to learn more about DLR and find out about our cutting-edge research. For those without a twitter account, start following us today and discover what DLR has to offer. Why wait?





# Satellite images for emergencies

The images are still vivid – waves as tall as houses striking the eastern coast of Japan on 11 March 2011, sweeping away all before them – people, roads, households, factories... The tsunami was triggered by an earthquake with a magnitude of 9 on the Richter scale – the strongest earthquake ever recorded in Japan. As it spread inland, it damaged and even destroyed several nuclear power stations. The earthquake occurred at 06:46 CET (14:46 Japan time). At 06:55, DLR staff at the Center for Satellite Based Crisis Information (Zentrum für satellitengestützte Kriseninformation; ZKI) in Oberpfaffenhofen received an automatic alert via email and SMS from the German Research Centre for Geosciences in Potsdam. Just 40 minutes after the first tremor, the Japanese government activated the Charter, and already at 09:00 German time, the first situational briefing was being held at the ZKI. Even at this early stage, it was clear that this was an extraordinary situation.

## From April to October 2013, DLR will be chairing the International Charter 'Space and Major Disasters'

By Elisabeth Mittelbach

### What is the Charter?

Under the International Charter 'Space and Major Disasters', 15 space agencies across the world offer quick and bureaucracy-free assistance in the event of natural catastrophes and major technical disasters. If the Charter is activated as a result of an earthquake, a major flood or devastating wildfires, for example, the members will provide images from Earth observation satellites as quickly as possible. This provides emergency, rescue and relief organisations with information about the extent of the damage, and offers guidance for coordinating the relief efforts on the ground. DLR has been an official member of the Charter since October 2010 and will hold the chair for the first time from April to October 2013.

Tobias Schneiderhan from the ZKI remembers the tsunami effort as if it were yesterday. "We programmed the German TerraSAR-X radar satellite immediately after the Charter was activated. The first damage assessments were carried out on the basis of the data acquired."

The geographer, who is responsible for DLR technical and operational activities under the Charter in Oberpfaffenhofen, occasionally works as an Emergency on-Call Officer (ECO) or Project Manager (PM) at the ZKI, the centre specialising in fast-response crisis information and which is part of DLR's German Remote Sensing Data Center. Two open-plan offices with computers, monitors and a large display wall of the ZKI control centre can be seen through its glass façade. Its design is similar to that of a satellite control room. "Images acquired with the German TerraSAR-X and RapidEye satellites showed the full extent of the catastrophe in Japan," comments Stefan Voigt, who has worked at the German Remote Sensing Data Center since 2000 and has collaborated in the conceptual and operational development of satellite-based disaster relief support at DLR. "When the Charter is triggered following a disaster, our satellites are programmed or reprogrammed on the spot and pointed at the affected area," the DLR scientist explains. The Data Manager at the ZKI is responsible for sending the commands to the satellites from the DLR ground station in Weilheim, Upper Bavaria.

Behind the glass, at the DLR Center for Satellite Based Crisis Information in Oberpfaffenhofen, scientists prepare the latest maps from satellite images to assist relief services in the event of natural or man-made disasters.

The satellite images are then received at the DLR ground station at Neustrelitz, in Mecklenburg-Vorpommern, and forwarded to the ZKI. From there, they are sent to the relevant active Project Manager, who ensures that the images are assessed and processed into detailed thematic maps – as many relief



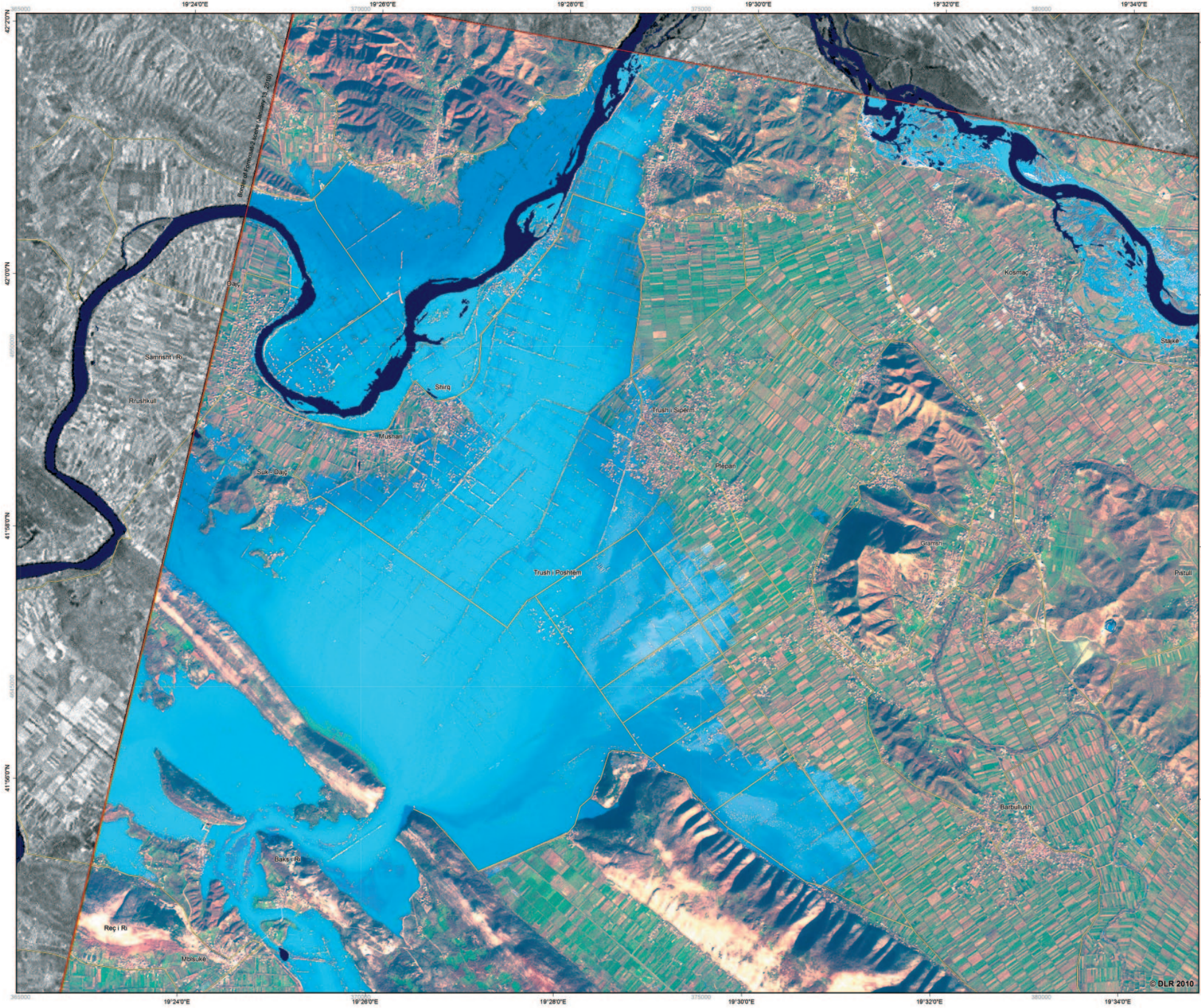
organisations and other end users are unable to work with the raw data. In the refinement process, the satellite images are analysed and crisis-related information is extracted from the data. The resulting product is a map that is easier for users to interpret; information such as the extent of the damage or possible transportation routes can be seen at a glance. DLR researchers have also supported the ZKI in assessment work for a number of Charter activations. “The advantage of satellite data is the large-scale view of the damage it provides. At the same time, we can map details down to a spatial resolution of 50 centimetres,” says Stefan Voigt, explaining the exceptional benefits of using satellite data. Hence the maps could be used, for example, to observe that the tsunami had penetrated up to four or five kilometres inland in some places. So vital information for on-site aid workers, such as damage to roads, bridges, buildings and infrastructure equipment, was visible.

In the autumn of 2012, the Charter was activated by Hurricane Sandy, among other disasters. Data from the German TerraSAR-X satellite was also commissioned for Tropical Cyclone Evan, which caused havoc in the Fiji Islands in mid-December. In this instance, DLR also took on the role of ECO. Tobias Schneiderhan requested the necessary data as quickly as possible from the various Charter member agencies. The Emergency on-Call Officer is on permanent standby for one week and, as the first expert point of contact, must immediately take critical decisions in the event of an emergency. The partners in the Charter take turns in the provision of the ECO service.

“In such a case, the Charter will have been triggered by a ‘call for help’ from an Authorised User,” he explains. The user fills out a form and sends it to the On-duty Officer (ODO). This job is carried out in shifts by staff at the European Space Agency (ESA). The ODO reviews the request and passes it on to the ECO. “The ECO is the first expert point of contact during the first three hours following the event,” says Schneiderhan. The ECO ensures that the area affected is imaged at the next available opportunity by Charter agency satellites. Then, operations are passed on to a Project Manager, who is responsible for further coordination for up to two weeks. And he adds: “We compare the Project Manager to a conductor – he or she is the central interface to the member agencies, the end users and the experts that generate the image analyses and map products from the satellite images. They document the entire process and may order more data if necessary – depending on how the situation develops in the disaster area.” ●

More information:

Charter website: [www.disastersCharter.org](http://www.disastersCharter.org)  
International Charter Universal Access: <http://bit.ly/Y7i1hp>  
ZKI [www.ZKI.DLR.de](http://www.ZKI.DLR.de)  
TerraSAR-X: [www.DLR.de/en/TerraSAR-X](http://www.DLR.de/en/TerraSAR-X)  
TanDEM-X: [www.DLR.de/en/TanDEM-X](http://www.DLR.de/en/TanDEM-X)  
RapidEye: [www.rapideye.com](http://www.rapideye.com)  
Twitter: <http://twitter.com/disasterschart>



Charter Call ID 206  
Glide No FL-2009-00266-ALB  
Product n°07

### ALBANIA - South of Shkoder - Sheet 1

**Flood extent based on Formosat**  
Situation as of January 13, 2010

Scale 1:25,000

**Location Diagrams**

**Legend**

Irrigation channel

Road network

Airfield

Water extent and moist areas on January 13, 2010

Water extent on April 4, 2009

**Extent of satellite scenes**

FORMOSAT-2 extent (January 13, 2010)

**Interpretation**

Heavy rainfall and unusually warm weather have caused flooding in the northwestern regions of Albania since January 4, 2010. The map shows the post-event water extents and moist areas around Shkoder as detected on a FORMOSAT-2 scene of January 13, 2010 and a pre-event water extent of April 20, 2009 derived by TerraSAR-X radar data. As backdrop the FORMOSAT-2 and a LANDSAT-7 image acquired on June 16, 2002 were used. Streets have been digitized on the basis of the FORMOSAT image and do not represent the complete road network.

**Cartographic Information**

0 500 1.000 1.500 2.000 2.500 Meters

Local projection: UTM Zone 34 North, Datum: WGS 84  
Geographic projection: Lat/Lon (DMS), Datum: WGS 84

Scale: 1:25,000 for A1 prints

**Data Sources**

FORMOSAT-2  
TerraSAR-X

© CNES 2010  
© German Aerospace Center (DLR) 2010  
Commercial exploitation rights:  
Infoterra GmbH

**LANDSAT-7** © USGS 2002

**Vector data** © OpenStreetMap 2010, Wikimapia 2010

**Framework**

The products elaborated for this Rapid Mapping Activity are realized to the best of our ability, within a very short time frame, during a crisis, optimising the material available. All geographic information has limitations due to the scale, resolution, date and interpretation of the original source materials. No liability concerning the content or the use thereof is assumed by the producer.

The ZKI crisis maps are constantly updated. Please make sure to visit <http://www.zki.dlr.de> for the latest version of this product.

Map produced on January 14, 2010 by ZKI  
© DLR 2010

[zki@dlr.de](mailto:zki@dlr.de)  
<http://www.zki.dlr.de>

**Center for Satellite Based Crisis Information**  
– Emergency Mapping & Disaster Monitoring –  
a service of DLR

In January 2010 the Balkans were affected by massive rainfall that led to widespread flooding. In this FORMOSAT-2 image, acquired on 13 January 2010, you can see the area around Shkoder, which was particularly affected by the floods. The dark blue colour represents the normal course of the river, while the flood plains are shown in light blue.

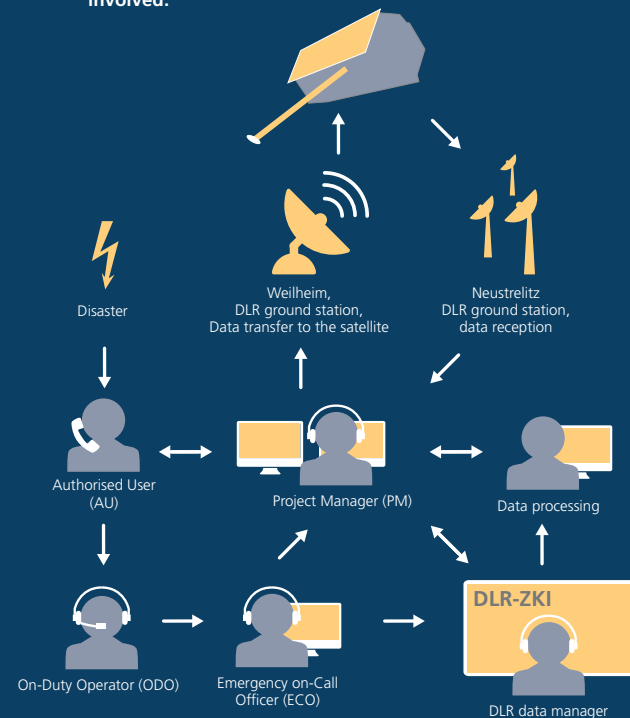
Members of the International Charter ‘Space and Major Disasters’

- European Space Agency (ESA)
  - Centre National d'Etudes Spatiales (CNES)
  - Canadian Space Agency (CSA)
  - Indian Space Research Organisation (ISRO)
  - National Oceanic and Atmospheric Administration (NOAA)
  - Argentina's Comisión Nacional de Actividades Espaciales (CONAE)
  - Japan Aerospace Exploration Agency (JAXA)
  - United States Geological Survey (USGS)
- UK Space Agency (UKSA) + DMC International Imaging (DMCii)
  - China National Space Administration (CNSA)
  - German Aerospace Center (DLR)
  - Korea Aerospace Research Institute (KARI)
  - National Institute for Space Research (INPE)
  - European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)
  - Russian Federal Space Agency ROSCOSMOS



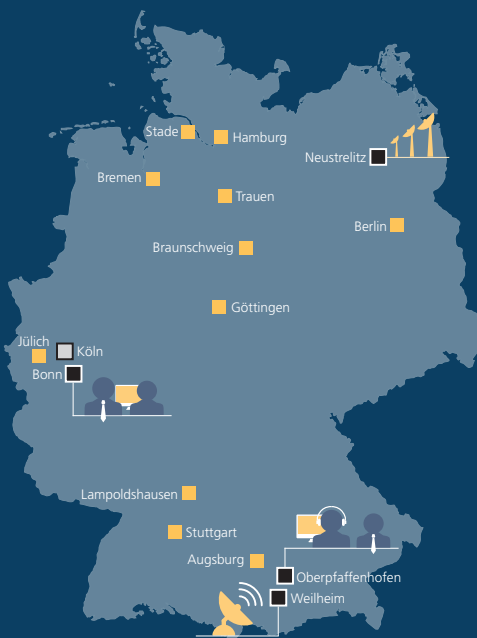
## Charter activation

Schematic representation of the sequence of events as they happen during a Charter activation when DLR is involved. In the event of a crisis, the Authorised User informs the On-Duty Operator at ESA. The request is verified and the Emergency on-Call Officer informed. These are the 'first responders' in the first three hours of the request for assistance. Then, the Project Manager is involved.



## DLR sites involved in the Charter

Four DLR sites are directly involved in the Charter activities. The Secretariat is located at the DLR Space Administration in Bonn; the Earth observation data is collected and refined at the German Remote Sensing Data Center in Oberpfaffenhofen; the ground station in Weilheim sends the corresponding commands to the satellite. The raw data collected will be received at the ground station in Neustrelitz and forwarded to the data manager at the ZKI.



At the ZKI 'control centre': some of the people involved in charter activities in Oberpfaffenhofen, including Stefan Voigt (left) and Tobias Schneiderhan (front).



Teamwork to produce the best map: the 'wizards' at the scene need the most accurate information possible – the ZKI Leaders therefore use the latest satellite data to generate tailored maps of affected areas.



Every minute counts when the Charter is activated. At the Center for Satellite Based Crisis Information, everyone knows their role, and works seamlessly together during the whole process.

Geographer Jens Danzeglocke works as a researcher at the DLR Space Administration in Bonn, and will be coordinating the German Charter presidency from April to October 2013.



# Relief – without red tape

Interview with Jens Danzeglocke, DLR Secretary in the International Charter 'Space and Major Disasters'.

## Why has Germany joined this network of space agencies for disaster relief?

When we entered the Charter in October 2010, we were pursuing an important goal in German space strategy – using space technology for the benefit of people on Earth. We also implement the United Nations' firm requirement that satellite-based Earth observation be used to protect mankind from natural catastrophes (UN Resolution 41/65).

## And what technical capabilities allowed Germany to become involved?

With the two German radar satellites, TerraSAR-X and TanDEM-X, we are currently managing two national Earth observation missions. Furthermore, at its site in Oberpfaffenhofen, DLR has the operational infrastructure to provide the data in a timely manner and with the necessary quality. TerraSAR-X and TanDEM-X data is frequently used in the event of flood disasters. The satellites can very quickly capture detailed images regardless of cloud cover or time of day, so they are ideal for mapping flooded areas. In some cases DLR also provides optical data from the RapidEye satellite, especially for wildfires. This was also the case following the tsunami in Japan in March 2011. TerraSAR-X was successfully launched into space in June 2007; from that day forward, it was just a matter of time until DLR became a full member of the Charter.

## Does that mean that DLR was involved in the Charter previously as well?

Yes. Since 2002, and through Germany's membership of ESA, we have been supporting the Charter, which was established by ESA and the French space agency CNES in 1999, as a 'junior partner'. To date, the network has been activated for more than 350 disaster events in over 120 countries. There were 40 activations in 2012, and 42 on average each year for the past five years. It is important to note that the Charter provides assistance in the event of sudden major catastrophes, not for 'predictable' emergencies or those developing over an extended period, such as a drought. The Charter is unique and is based on the 'best effort' principle, which means that every member provides its resources to the best of its abilities. The assistance is free for the user and is available around the clock.

## What is the role of the German Secretariat?

The German Secretariat is based at the DLR Space Administration in Bonn. As Secretary, I coordinate our national activities. There are 15 secretaries for the 15 Charter members. The highest body is the Charter Board. Hans-Peter Lüttenberg, Head of the Earth Observation Department at the DLR Space Administration, and Stefan Dech, Director of the German Remote Sensing Data Center at the DLR site in Oberpfaffenhofen, represent DLR here. The Executive Secretariat is responsible for the smooth implementation of the Charter procedures and develops ideas to continuously improve the system.

## What does that mean in the event of an emergency?

In that case, the Executive Secretariat validates the 'call'. The system is activated immediately thereafter. Operational activities, however, are initiated without delay after notification of an emergency so that no time is lost, but they can be revoked again by the Secretariat. For each accepted call, the Secretariat nominates a Project Manager. Last but not least, it is important to ensure that our valuable data will not be used for other purposes than those addressed by the Charter.

## To which issues does Germany want to devote its time as chair?

Our chair will begin on 16 April 2013, with a four-day conference in Berlin where all board members and secretaries will meet up. At present, our concern is that more members are joining the Charter, and that it is being activated with greater frequency. This shows the success of our work, but also makes it all the more complex. In autumn 2012 we launched the 'Universal Access' initiative, which represents a milestone for the Charter. This will allow greater accessibility to users such as emergency response authorities across the world. The Charter can be activated by authorised users. This user base is still not complete globally. At present, the main 'white areas' – those with no authorised users – are located in Central and South America, Africa and parts of Asia. With Universal Access, the intention is to eliminate, or at least minimise them. So in the light of a growing user base, the Charter members must pay even more attention to keeping the system effective and efficient, as well as controlling the conditions under which it is activated. ●



# When things get too close for comfort

On 15 February 2013, an asteroid 17 metres in size and weighing some 10,000 tons entered Earth's atmosphere at around 64,000 kilometres per hour, exploding over Chelyabinsk in Russia. The energy released was equivalent to 500 kilotons of TNT, about 30 times that of the Hiroshima atomic bomb. The resulting blast wave damaged buildings and caused injuries to around 1200 people through flying debris and glass splinters. On the very same day, asteroid 2012 DA14, 45 metres in diameter, passed only 28,000 kilometres from Earth, beneath the orbits of TV and communications satellites. Despite the dramatic combination of the two unrelated events, the collision of a large asteroid or comet with Earth is actually a very rare event. But if such an impact were to occur it could trigger the worst natural catastrophe our civilisation has ever experienced. It is worth repeating to be absolutely clear: what we are talking about here is a minuscule risk, but one linked to potentially devastating consequences. Ignoring this risk is socially, politically and also economically very dangerous; it is a subject in which global thinking and acting is vital.

## NEOShield – international defence against asteroids

By Alan Harris

Project NEOShield arose from these considerations. In 2011 the European Commission selected an international group of scientists and engineers under its Seventh Framework Programme for Research and Technological Development (2007-2013) to investigate methods of defence against asteroids. The primary goal of the resulting project, NEOShield, is to produce detailed designs of space missions to test the effectiveness of promising asteroid deflection techniques. A consortium of 13 partners, under the aegis of DLR, is being funded for a period of three-and-a-half-years from January 2012, supplementing the 4 million euros of European Commission support with 1.8 million euros of their own resources.

A near-Earth object, or NEO, is an asteroid or comet with an elliptical orbit around the Sun that comes nearer than 50 million kilometres to Earth's orbit. By comparison, the Moon orbits Earth at a distance of around 400,000 kilometres, and at opposition, Mars is around 60 million kilometres from Earth. NEOs can endanger Earth. To date, there are nearly 10,000 known NEOs, ranging in size from a few metres up to 40 kilometres in diameter.

An impact of an object with a diameter of just one kilometre could have global effects; the reason is the enormously high speed – several tens of thousands of kilometres per hour – at which the object would enter Earth's atmosphere. Even so, it is somewhat reassuring that, thanks to a few, mainly US, observatories constantly scanning the night sky for NEOs, almost every object of more than one kilometre in diameter is known and is being tracked. DLR and the European Asteroid Research Node, EARN, are contributing to cataloguing the asteroid population in the Solar System. No large NEO that could threaten our civilisation in the next 100 years or so has been discovered to date.

### When Siberia shook 100 years ago...

But how dangerous could smaller NEOs be? There are an estimated one million objects with diameters between 30 and 50 metres, but only a fraction of these have been discovered to date. An object of this size is thought to be responsible for the Tunguska event in Siberia in 1908, when more than 80 million trees over an area of 2000 square kilometres – about twice the size of Berlin – were snapped and felled like matchsticks. The devastation was probably caused by an object that entered the atmosphere at 50,000 kilometres per hour and exploded at an altitude of five to 10 kilometres with a blast equivalent to 10 megatons of TNT. Another example of the devastating effects of a small NEO is Barringer Crater in Arizona, also known as Meteor Crater. The 50,000-year-old crater remains well



Alan Harris and Line Drube, a postdoctoral researcher at the DLR Institute of Planetary Research, discuss the physics of NEO defence methods.

An asteroid approaches Earth. The NEOShield project is working towards preventing a potential asteroid impact.

Image components: NASA/JHUAPL und NASA





Image: Don Davis/Southwest Research Institute



Image: Stefan Seip



Image: Dan Durda/B62.1 Foundation and IAAA

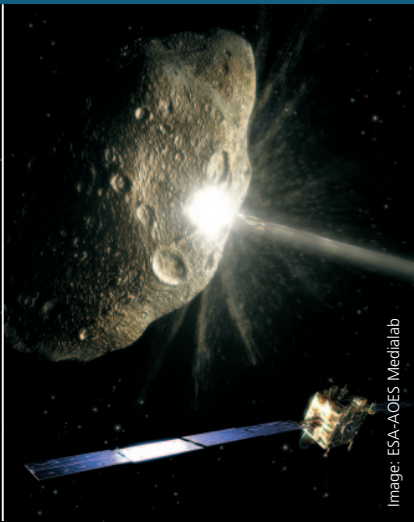


Image: ESA-AOES Medialab



Image: NASA/JPL-Caltech/UMD

Artist's impression of an asteroid impact on Earth

A NEO with a diameter of just 30 to 50 metres created the Barringer Crater in Arizona 50,000 years ago

Artist's impression of a gravity tractor with an asteroid in tow

Artist's impression of a kinetic impactor mission. The impact is observed by a reconnaissance spacecraft

A nuclear explosion is considered to be a last option to prevent a collision, in the absence of feasible alternative methods.

preserved today as a result of its location in a dry desert. Depending on their geographic location, impact craters can be rendered unrecognisable reasonably quickly due to erosion, vegetation and geological activity. As metallic meteorite fragments have been found in the crater surroundings, we can assume that the 1200-metre-wide, 180-metre-deep crater is the result of the impact of a massive metallic object. The diameter of the impactor has been estimated at just 30 to 50 metres. It should also be remembered that, statistically speaking, two thirds of all impacts occur in the oceans, where they can trigger destructive tsunamis.

Potentially hazardous objects

What happened back then in Arizona is impressive enough. According to statistical estimates, an object with a diameter of 30 metres is expected to impact Earth every couple of centuries. As today's NEO search programmes are only finding a comparatively low number of these relatively small objects, a devastating impact could theoretically occur without warning. But there are currently several very sensitive NEO search programmes underway, so we can hope that more of these menacing small NEOs will be discovered years or even decades before a potential impact.

Two NEOs that will come dangerously close to Earth in the near future, relatively speaking, are Apophis and 2007 VK184. With a diameter of around 300 metres, Apophis will skim past Earth at a speed of 6 kilometres per second and at a distance of just 30,000 kilometres in April 2029. And that is not all: because its orbit is similar to Earth's, Apophis will remain an Earth-endangering object for the foreseeable future. There is a one in 2000 chance that 2007 VK184, which has a diameter of about 130 metres, might impact Earth at a relative speed of 68,000 kilometres per hour in 2048.

Warning time is crucial

Can we defend ourselves against an asteroid impact? Current space technology offers several promising methods – assuming that the search programmes guarantee a prediction time of 10 to 20 years, and that the threatening object's diameter is no larger than one kilometre. NEOSshield partners are

dealing with various aspects of the problem, from astronomical research into the physical properties of NEOs to the development of spaceflight technologies, such as guidance, navigation and control systems, needed for a deflection mission. But there is also on-going laboratory research into the material properties of the minerals that make up an asteroid, model calculations of the asteroids' interior structure, as well as identification of NEOs suitable as target objects for deflection test missions. The NEOSshield partners are also researching a general strategy for asteroid defence – from identifying a threatening object and the sequence of decisions that must be made, through to determining the observations and missions required and deciding when and what kind of defence mission should be launched.

Three methods of asteroid deflection are being looked into at present. Firstly, the so-called kinetic impactor – a large space probe hits an asteroid at very high relative velocity creating an impact sufficient to change its orbit slightly. This method might be feasible using today's technology for objects with a diameter of up to one kilometre or so. But there are still many unanswered questions. What effects will the interior structure and porosity of the asteroid, its rotation and other physical factors have on the outcome of the mission? How must the impactor be steered to reach its target reliably and at the correct angle and speed? In this regard, consideration must also be given, for example, to the effect that movements of the fuel in the spacecraft have in the critical navigation phase just prior to impact.

A second method is to use a 'gravity tractor'. This method, which uses the weak attractive force between the asteroid and the spacecraft, may require years or decades to provide a sufficient change in the asteroid's orbit. So its usefulness would depend on having adequate warning time before a potential impact. If a spacecraft is steered into the direct proximity of a dangerous NEO, the small but significant attraction between the spacecraft and the asteroid could work like a tow rope. The probe might be able to use a solar electric propulsion system, for example, to accelerate itself and the asteroid until a sufficient change in the speed of the system, and the orbit of the asteroid, has been achieved. With adequate forewarning, changes of just a few centimetres per second or less might be enough to avoid a catastrophic impact on Earth.

Although this method is relatively slow in having the desired effect, it has one big advantage: the surface of the NEO remains undisturbed and no information of any kind about the interior structure and physical properties of the surface of the object is required. The best solution could be a combination of the two methods described, in which, for example, a gravity tractor is deployed after a kinetic impactor has struck, allowing small corrections to be made to the NEO's new orbit. In this way, it may also be possible to prevent future approaches of the NEO to Earth. NEOSshield partners are investigating how realistic this idea is and under which circumstances a gravity tractor might be deployed.

The third option might be a nuclear explosion. In particular, if time is pressing or the object is unexpectedly large, the methods described above might not be sufficient. The largest force that could be deployed to deflect an asteroid would be one or more nuclear explosions. Although this option is regarded as highly controversial, a nuclear payload might be our last hope. But what effect would an explosion in the direct vicinity of an asteroid or on its surface have in the vacuum of space? In the NEOSshield project this method is being studied in detail to provide information on its effectiveness and the circumstances that might make its deployment necessary. However, the investigations will be carried out using computer simulations; test missions with nuclear devices will not be proposed!

Asteroid defence is a global task

Because a NEO can impact anywhere in the world – there are no regions on Earth less likely to be hit than others – as many nations as possible should contribute to researching defence methods and strategies. Six countries are collaborating in the NEOSshield Project: Germany, Great Britain, France, Spain, Russia and the United States. Besides the goals set out above, NEOSshield is forging links to related international projects and initiatives to encourage international coordination in this field. In this regard, the NEOSshield Project has already established close contacts with the Near-Earth Object section of ESA's Space Situational Awareness programme and the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS) Action Team 14 on NEOs. There are also collaborations with national space organisations.

Although much greater investment and resources will be needed to launch missions to test NEO deflection techniques – not to mention an international agreement on carrying out defensive action – the EU-financed NEOSshield project is an important step. It provides an excellent opportunity to investigate how asteroids can be successfully deflected in the future. As they used to say in the Asterix and Obelix comic strips: "May the sky not fall on our heads!" ●



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

Partners in the NEOSshield Consortium

- German Aerospace Center (DLR)
- Observatoire de Paris, France
- Centre National de la Recherche Scientifique, France
- The Open University, United Kingdom
- Fraunhofer Institute for High-Speed Dynamics, Germany
- Queen's University Belfast, United Kingdom
- Astrium GmbH, Germany
- Astrium Limited, United Kingdom
- Astrium S.A.S., France
- Deimos Space, Spain
- SETI Institute Corporation Carl Sagan Center, United States
- TsNIIMash, Russia
- University of Surrey, United Kingdom

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# Making science fun

He would actually have been happy doing something artistic – being a graphic designer, for example. Or a billboard or neon sign maker. But Dirk Stiefs is here, moving chairs back and forth in the DLR\_School\_Lab in Bremen – stacking them and pushing them to the right there, and then putting them back. A photographer will soon be here to take a panoramic picture of the newest DLR\_School\_Lab. Everything must look exactly right for it – so the chairs are moved again, arranged in a semicircle this time. Stiefs is the head of the school laboratory and, since April 2011, has been involved in rocket construction and microgravity experiments, as well as small rovers that travel across artificial Martian landscapes – not art or graphic design. No two days are alike for the team consisting of Dirk Stiefs, Silke Zierenberg and up to 15 students. “Something new happens every day,” says the 33-year-old. And that makes him more than happy.

## Dirk Stiefs finds his dream job at the DLR\_School\_Lab in Bremen

By Manuela Braun



Dirk Stiefs is head of the new DLR\_School\_Lab in Bremen. Together with his team, he has developed the experiments for school groups.

The 18 seventh grade students obediently freeze for the panoramic photo. The picture is done, so it is checked off the list. But there is one last item on the agenda – launching rockets in the open air. “OK, now, everyone be quiet.” Dirk Stiefs stands in front of the exit in his white science coat. At 1.90 metres, he towers over the teachers and students around him. “On our way to the launch pad, I will stay in the front, and nobody will run past me. The handcart is at the back of the line – nobody should be behind it.” And then, a short pause, a meaningful look. The announcement, intended as friendly, has made an impact. In a relatively orderly fashion, they head to the open field from which the homemade rockets will be shot into the sky.

### Single-celled organisms as a model

The qualified physicist landed this job almost by accident. “Actually I’m a kind of slime mould,” he says. A slime mould or *Eumycetozoa* – consists of single-celled organisms that undergo multiple different, morphologically extreme phases during the course of their lives. Its physical appearance is inseparably linked to its life cycle. Dirk Stiefs laughs as he compares himself to slime mould. “Slime mould always grows where there is food.” He spreads his hands. “It’s a good tactic,” he says, nodding enthusiastically. What he means is simple – he is open to new ideas, grasps opportunities when they arise, and is not attached to tried and tested ways.

He studied physics because he could. Ultimately he completed advanced courses in physics and art at his secondary school in Wilhelmshaven. He could have been a comic book artist too, and illustrated a book while he was studying: ‘Why students procrastinate: excuses for not-yet-writing research papers.’ But making a living through art did not exactly appeal to him. He could even imagine not studying – and just becoming a bill-

Shortly before launch – the students use a homemade rocket to learn how propulsion systems work.





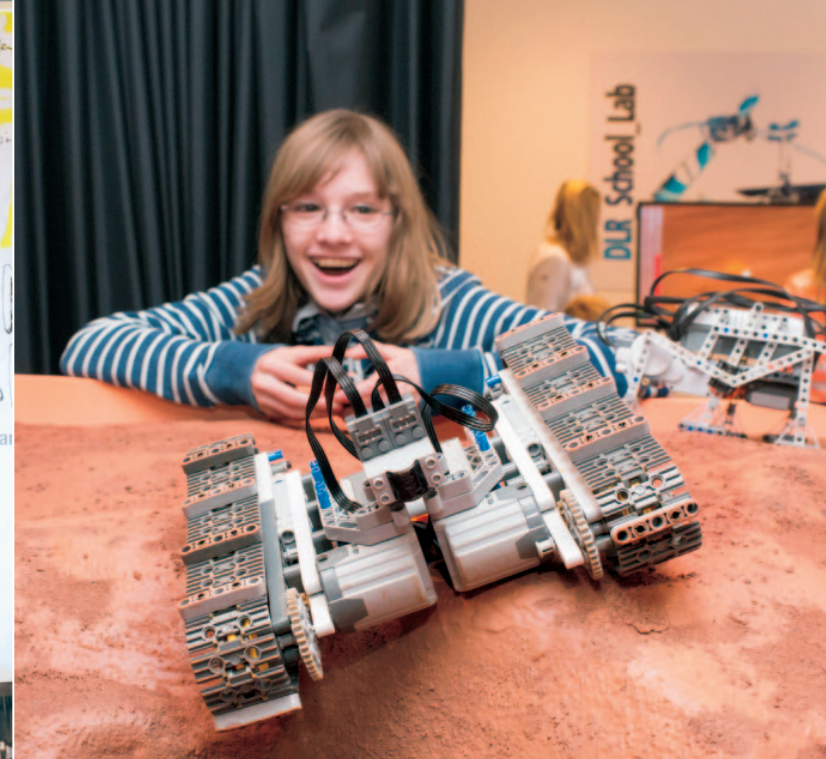
Successful field test – when the rocket flies, theory turns to practice.



The students use a thermal imaging camera to see where their bodies are emitting large amounts of heat



With Dirk Stiefs, even DLR Chairman Jan Wörner has a role to play explaining science through games.



A test drive on the Red Planet is also on the programme at the DLR\_School\_Lab in Bremen

board or neon sign maker. But careers guidance then set him on the path that brought him to DLR: “They worked out in a test that I was particularly good at logical, spatial thinking.” The result was a career that could hardly have been more linear: secondary school qualifications, a physics degree in Oldenburg, a doctorate in Oldenburg and Amsterdam, and scientist at the Max Planck Institute for the Physics of Complex Systems in Dresden. In the meantime, he qualified as a university lecturer at his university in Oldenburg. He completed 200 hours of seminars, lectures and lessons to learn how to disseminate information effectively. If he had wanted to, he could have taught at a university.

#### Countdown to launch

“But ultimately, the DLR\_School\_Lab was the right choice,” says Stiefs with certainty. “No homework, no exams, no marking! It’s all about motivating and fascinating people.” The excitement mounts among the seventh grade students en route to the launch pad. Dirk Stiefs looks a little like the cliché of the mad scientist as he marches through the snow in his white coat, wearing safety glasses. “You get the air pump, you unclamp it, and you can launch the rocket.” Stiefs has the lively students organised in a moment. “Who is going to measure the height the rocket reaches?” There is giggling and shoving among those who have not been given a task – but then it gets serious and the head of the School\_Lab starts to count down out loud. With three loops in the air, the homemade rocket makes its flight and comes back down again. The wind tugs at his white coat as Dirk Stiefs runs through the process with two more groups of students. “It’s exciting when a seventh grade student understands physics better because he or she has tried it for him/herself.” Stiefs and his team developed the experiments for the School\_Lab and tried them out with groups of school students before the launch in Bremen.

#### Mountain hares and lynxes

He has always enjoyed looking for odd, unusual things. “For my doctorate in physics, I studied mountain hares and lynxes.” But only abstractly, as is self-evident from the subject. “It’s

very hard to explain exactly what I did.” Yet Stiefs explains it. Something quickly emerges from the theory of mathematical models. “Various parameters influence the relationship between predators and prey.” His hands are in the air again. In seconds Stiefs demonstrates what a parameter range is and what this has to do with mountain hares and lynxes. He went on to refine the model at the University of Dresden, this time using parameters to illustrate bone formation and cell metabolism in the human body. The 33-year-old enjoys explaining things – in the most unusual way possible.

And that is what got him the ‘Goldene Kopfnuss’ (Golden Mindbender) award. It was why he was on the stage at the ‘kurz & klug’ Science Slam in Dresden. His topic was ‘Plagues, Pestilence and Chaos’, for which he won the plastic brain sprayed in gold. In scientific terms, this involved bifurcations in dynamic ecological networks. In practice Stiefs used juggling balls to explain, for example, how rats on an island get eaten by imported cats, and things go quite well for the cats for a while. He was on the stage again at the DLR Science Slam – using juggling to explain everything happening in his School\_Lab.

#### Juggling for the Board

Balls, a red cap, a flashlight and an empty picture frame – the previous night, Stiefs had been on a quick raid in his children’s room. Juggling turns the three balls into the flexible wheels of the Mars rover. The physicist can even use juggling to mimic the robotic arm on the LAMA facility in the Bremen Institute of Space Systems. His t-shirt reads ‘Worldsaver’. On weightlessness: “Imagine you are standing on a set of scales, then you jump out of the window with them...” Simple explanations are the best and they simply spill out of Stiefs. “Mr Wörner, you are not on the jury today, come on down.” The DLR Chairman is obliged to participate, but all he has to do is hold his arms behind his back – and the amateur juggler does the juggling for him. “Ah, but I see the Chairman can still be taught, fascination has got the better of him.” Dirk Stiefs smiles. He is rarely lost for words. But in the running for the prize in the Science Slam, he was forced to admit defeat to DLR Berlin colleague Atilla Wohlbrandt.

Some two years earlier, Dirk Stiefs still had no idea that he would soon be using juggling to bring experiments to life in his School\_Lab. At that time he had just signed his contract with the University of Dresden. “Following my acceptance by DLR, I immediately quit my job as a research assistant and vacated my flat there.” It was the right decision, he thinks. He has never regretted the move. “The School\_Lab was fully booked six months before it had even opened,” he says with pride. “It’s a dream job for me.”

#### A smiley for science

Everyone goes from the rocket launch site back to the Institute. “Don’t forget, me first, the handcart at the back, and all of you in between,” he announces for the last time. “Can we launch the rocket one more time?” begs a student. “Please?” His voice has just the right tone for begging. Dirk Stiefs smiles indulgently. “No, we have to go back now.” He tramps purposefully through the snow to the footpath. Children need boundaries, he says later. He can practise with his own kids – two and six years of age. He is now starting to get the first questions about science. “You can learn a lot from your own children,” says Stiefs.

In the Institute there is still an evaluation sheet for each student to complete. Stiefs and his team want to know whether they have awakened a fascination for science. Jackets are put over chair backs and everyone scribbles on the sheets. The School\_Lab team has made a personalised certificate for each student. Anyone who has contributed well in the experiments needs to have something in their hands when they get home. “Who has had fun today?” Hands go up everywhere. And as an extra reward they each receive a frisbee from the School\_Lab head. The last student is finally out the door. Nobody has left anything behind. Eighteen girls and boys now know more about how weightlessness occurs, how satellites can control their position and how rockets work. Silence fills the rooms of the Lab in Bremen. Dirk Stiefs calmly takes off his white coat. “Loud? Really, was it loud? I guess I didn’t notice.” ●



**More information:**  
[www.dlrscienceslam.de](http://www.dlrscienceslam.de)  
[www.DLR.de/schoollab/en/](http://www.DLR.de/schoollab/en/)



Dirk Stiefs uses a telescope to demonstrate the cosmic radiation that reaches Earth – a very different way of doing physics.



# Sailing through space

Yachts gliding across the water pushed solely by the wind – this is not only an elegant visual spectacle, but also an extremely effective process. Although there is no wind in space, there is a form of propulsion available round the clock, 365 days a year – the Sun. This is why giant solar sails will propel future spacecraft – slowly, but gradually increasing in speed and without the burden of a fuel tank. The objective will be to travel across the expanse of space to the very edge of the Solar System and beyond, or over the Sun's poles. These regions are not accessible, or only with difficulty, employing current propulsion systems. Researchers at the DLR Institute of Space Systems in Bremen and the Institute of Composite Structures and Adaptive Systems in Braunschweig are designing the ultra-fine solar sails that will unfold once in space on especially lightweight, but nonetheless very sturdy masts.

## 'Gossamer' – using the Sun as a propulsion system

By Manuela Braun

At the large table in the Integration Hall of the Institute of Space Systems, a pump is running, drawing the gleaming silver solar sail onto the table. There is no other way to pick up this incredibly fine fabric; even a single quick movement would cause the material to flap up into the air before slowly landing again almost weightlessly. It runs across the fingers like water and is almost imperceptible. The polyimide film is just 0.007 millimetres thick, but is nonetheless remarkably resistant to tearing. With immense care, Patric Seefeldt and Siebo Reersheim cut the silvery material into strips and then glue them together to form a sail that will enable a spacecraft to glide through space.

The first big test for the Gossamer project is scheduled for 2015; then, four masts will unroll in space while sails deploy to a size of five by five square metres. The spools on which the masts and sails were wound will be discarded once their work is done. What is left is a five-by-five-metre ultra-lightweight

structure; the combined weight of the sails and masts is less than 1.5 kilograms. This discard concept distinguishes the European Gossamer project from its US and Japanese competitors. Once deployed, particles of sunlight – photons – will collide with the sail and Gossamer 1 will set out on its journey. After this, Gossamer 2 and Gossamer 3 will embark on their sailing trips across space at two-year intervals – with larger sail areas, greater mass, and methods to steer the spacecraft while under sail.

### Thrust with solar power

At least, this is what department head Tom Sprowitz has in mind. "Gossamer 1 is intended to prove that it is possible to deploy a structure of this kind in space." The pressure is on, because if Gossamer 1, the pilot project, were to fail, prospects of further attempts would be small. "For this reason, what we have to do is show that solar propulsion is a technology worth pursuing and that it works." The principle is simple – the photons collide with the aluminium-coated sails, and the collision and ensuing rebound transfer momentum thus deliver propulsion. Instead of heavy fuel tanks with a limited capacity, solar sails enable scientists to leverage the inexhaustible power of the Sun – and dispense altogether with heavy tanks.

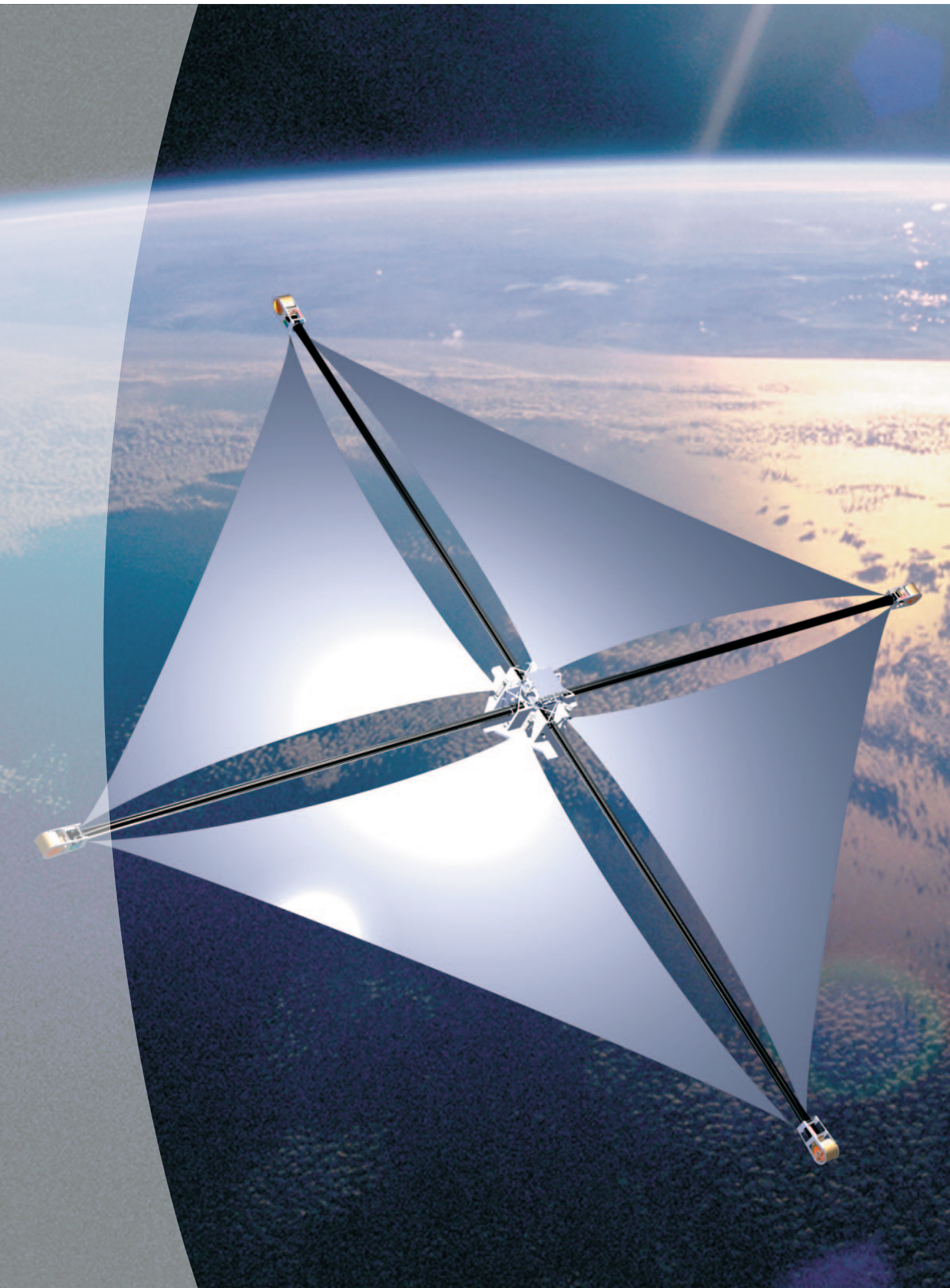
Although the propulsive force is extremely small, by virtue of acceleration over a period of several months, speeds in excess of 100 kilometres per second can eventually be reached. That makes it possible to conduct missions to the very limits of the Solar System – or even further afield. Since this 'space yacht' does not need to gather slingshot momentum from planetary flypasts, scientists can plan the launch, and indeed the entire mission, independent of the movements of the planets.

### A concept on the test bench

To enable this ultra-lightweight unit to complete its flight through space without malfunctioning, scientists are conducting initial implementation tests on the ground. What properties do



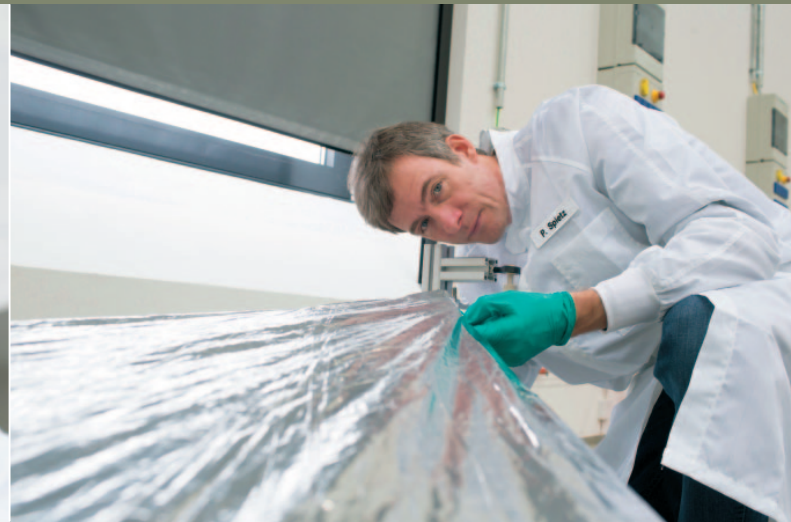
Working on the 'engine' of the future – Patric Seefeldt holds up a model of the solar sail.



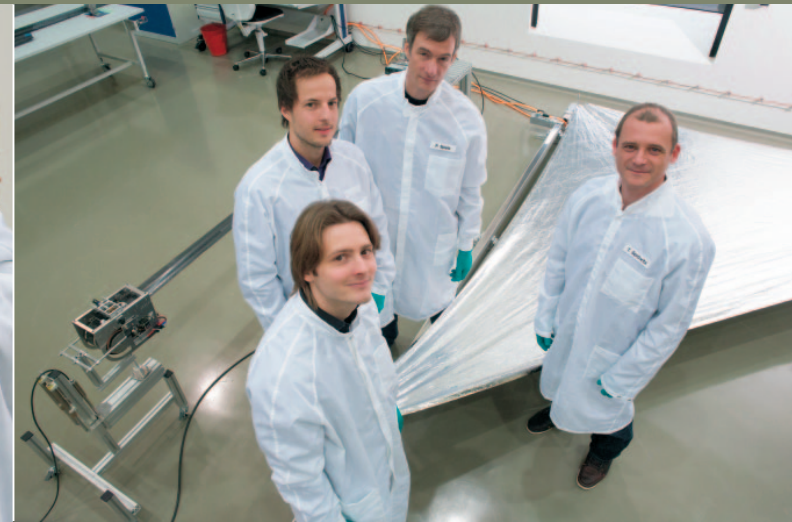




The masts that support the sails during flight must be both strong and flexible. Tom Spröwitz, Head of the System Conditioning Department at the DLR Institute of Space Systems knows that carbon fibres impregnated with liquid resin are suitable.



Project leader Peter Spietz examines the delicate edges of the solar sail. The material is just 0.007 millimeters thick. This feather-weight must be handled with caution.



The Gossamer team: (left to right) Patric Seefeldt, Siebo Reershemius, Peter Spietz and Tom Spröwitz want to send their first solar sail into space in 2015.



A sophisticated mechanism to unroll the mast in microgravity. In the integration hall in Bremen, the researchers test the smooth operation of this technique.

the sails need to have? How must they be folded and stowed for transport? How is it possible to ensure that they will deploy correctly after launch and that they will deliver propulsion throughout missions of extended duration? On the suction table, the first thing required is craftsmanship. The initial step is to stick one-metre wide strips of polyimide film together to make a giant sail. After this, the edges of the fine material are folded over and stuck down, and a reinforcing thread is inserted in the edges of the sail. As the sails deploy down the length of the mast, it is this thread that will impart the necessary stability to the structure. "Then the sail needs to form a kind of package," explains Spröwitz – a space-saving package that can be rolled up on two spools. Without the suction table to restrain the light material for the team headed by Project Manager Peter Spietz, this would be a very difficult task.

Eventually, the job is done; on carriages, the two spools deploy outwards along two rails arranged at right angles to one another. The scientists keep a careful eye on the sail as it unfurls evenly. The slightest malfunction could cause the carriages to jam on their rails. Up in space, however, no malfunctions are allowed; the speed of the carriages must match and the spools must not snag. Only then can the space yacht tap into the power of the Sun and set sail. After launch, several cameras on board the craft will transmit images to Earth – of the successful deployment of sails, as well as any problems that may arise during this premiere in space.

#### Feather-light mast

The mast test bench is located just a few metres from the test facility that scientists are using to put the deployment of their solar sail through its paces. The masts are also lightweight: "A one-metre mast weighs just 40 grams, not even as much as half a bar of chocolate," says Marco Straubel from the DLR Institute of Composite Structures and Adaptive Systems, whose team developed the masts and the unrolling mechanisms. To ensure that the material remains stable and flexible, carbon fibres are impregnated in liquid resin. Once the resin hardens, a mast is created with walls just one tenth of a millimetre thick and incredible bending properties. "Just like a spring, they always return to their original shape."

These masts need to withstand a great deal before they even begin to support the unfurled sails on their flight through space. Rolled up on electrical spooling mechanisms, the launch constitutes the first serious test, as they are subjected to forces equivalent to 50 times the force of gravity. An aluminium structure would perhaps be more robust, but it would weigh too much and would greatly limit the acceleration and speed of the solar yacht. "The heavier the structure is, the less performance the thrust from solar radiation can deliver. The alternative would be to make the sails even bigger to compensate for the increased mass."

#### Test in microgravity

The mast and unrolling mechanism experienced microgravity for the first time during a parabolic flight in 2009. Straubel starts up the video. The scientists tested a variety of methods for unrolling the masts over the Bay of Biscay. Uncontrolled deployment, with the assistance of air pressure and finally the newly-developed unwinding mechanism. As though drawn by a tiny thread, the electric motor deploys and reels out the mast behind it. After a few seconds the motor disengages from its mast as intended. Smiles all round for the researchers – the test could not have gone any better. Eight metres of mast unreel within five or six seconds. "During the parabolic flight, we only had a limited time for the experiment. Up in space, the masts are deployed more slowly – that is much safer."

In their Integration Hall in Bremen, the scientists are, of course, unable to escape gravity during testing. However, they have developed their own gravity compensation system that enables them to support the deployment mechanism, cancelling out its weight. Problems that can be detected and resolved on the ground should not pose a hazard once in space. "For example, we tested how the masts behave when being unrolled quickly or slowly," says Bremen-based scientist Tom Spröwitz. The scientists then went on to test sails and masts separately. The next step is already clear: "We want to unroll a mast and, at the same time, deploy two sails." This all helps to bring the researchers one step closer to their goal – the first space mission.

#### A roadmap for outer space

Once Gossamer 1, with its 25 square metres of sail and its four masts, orbits Earth and continues on to plot its course into space successfully, the bar will have been raised for the ensuing missions; two years later, there are plans for Gossamer 2, with a sail area of 20 by 20 metres, to set sail 500 kilometres above Earth. Cameras on board will document how this craft can be steered. To accomplish this, scientists will use cables to alter the position of weights inside the hollow masts. This, in turn, will relocate the centre of gravity of the spacecraft and alter its flight direction. On this mission, the craft will weigh less than 60 kilograms. Gossamer 3 will follow in 2019, this time with 50 by 50 metres of sail, in an orbit more than 10,000 kilometres from Earth. "None of these flights will carry a scientific payload – Gossamer is solely a technology demonstration mission," says Spröwitz.

Before any next step can be contemplated, the gleaming silver sail will have to survive yet one more gruelling test – in a facility in Bremen, it has to withstand space-like conditions. The Complex Irradiation Facility (Komplexe Bestrahlungseinrichtung; KOB), bombards the aluminium-coated film with a mixture of protons, electrons, ultraviolet and vacuum-ultraviolet light, as well as sunlight. "We want, of course, to use Gossamer on long-duration missions, which means we need to know precisely how the material will change in the process," says Spröwitz. The extremely thin material from which the sails are made needs to demonstrate that it does not degrade over extended periods of time and is ready for a sailing trip into the vast expanses of space. ●



**More information:**  
<http://s.DLR.de/tiu1>



On the suction table, the team cut and glue the delicate film to create the sails. A thread in the outer edge then ensures that the deployed sail will have the correct tension.



# Finding Goldilocks zones

As of 31 January 2013, 862 extrasolar planets have been discovered. In a circular polar orbit at an altitude of approximately 900 kilometres, CoRoT (Convection, Rotation and planetary Transits) has been searching for planets orbiting other stars. The CoRoT space telescope has been in orbit since 2006, and has found 28 new planets using the transit method. The number of discoveries, however, is not the primary focus for the scientists in Berlin. Rather, it is the fascination of finding out more about these distant worlds. Here, a key parameter is the planetary density.

## Wanted – habitable, extrasolar planet

By Melanie-Konstanze Wiese

The rate of discoveries is increasing. Even though news of the detection of an extrasolar planet is far from being a sensation these days, it still enthuses planetary researchers. What can such planets tell us? How did the Solar System evolve? How different or similar are these planetary systems to our own? Such questions are the concern of Head of the Extrasolar Planets and Atmospheres Department at the DLR Institute of Planetary Research Heike Rauer and her team.

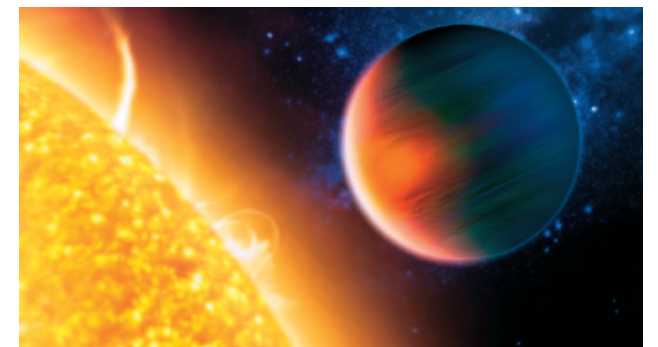
In their quest, the scientists employ the transit method. The principle is relatively straightforward – when an extrasolar planet passes between its star and the observer, the perceived brightness of the star diminishes. This effect can be thought of as a kind of mini-solar eclipse. Transits within the Solar System, like that of Venus on 6 June 2012, are more easily observed from Earth because of their proximity. But observing the transit of an exoplanet is much more challenging due to its distance from Earth. The transit can only be inferred by measuring the light curves of the host stars. Rauer's team is investigating precisely this – looking at more than 170,000 stars.

### Rocky planet or gas giant?

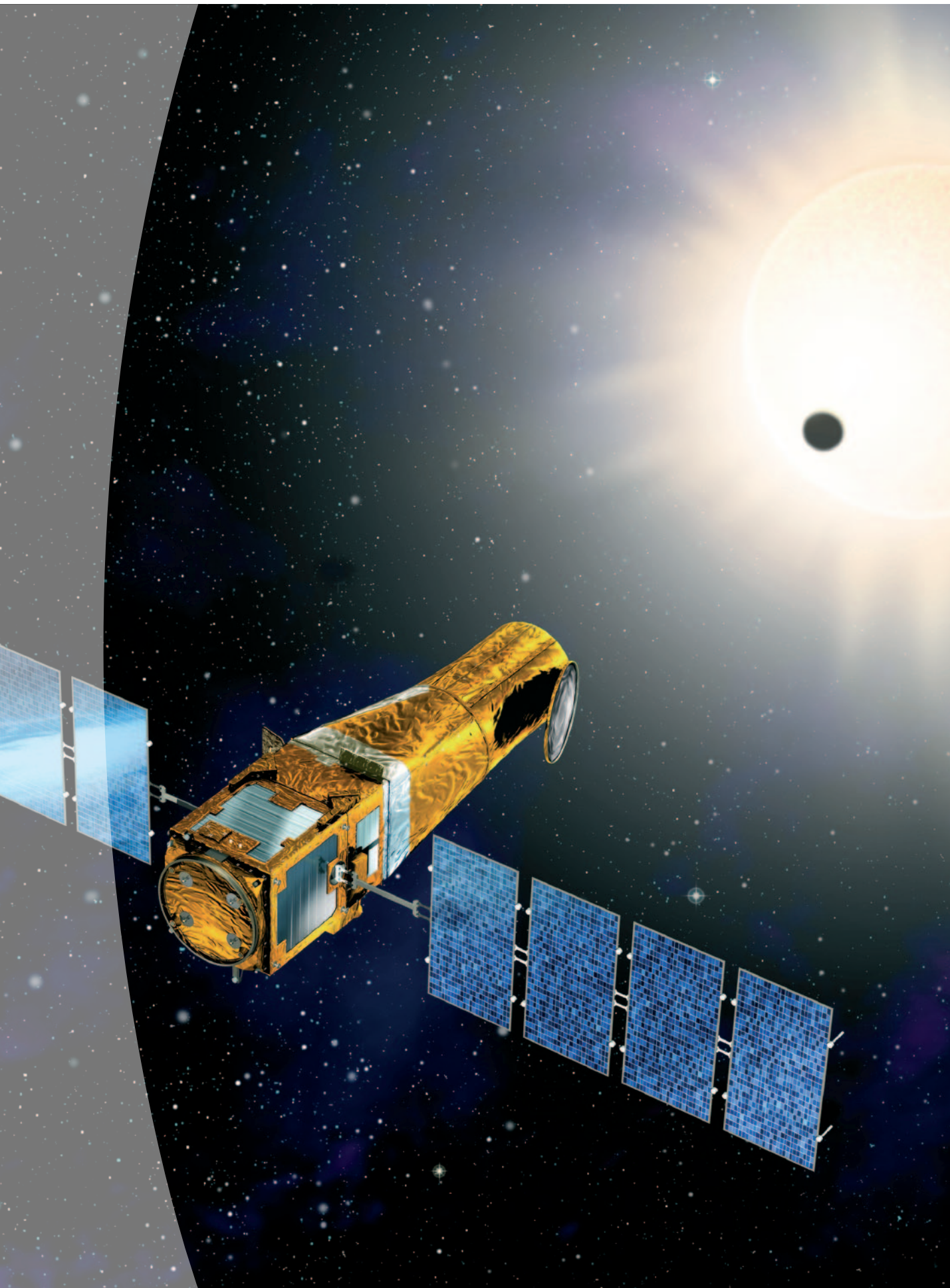
While the detection of extrasolar planets is an endeavour in itself, the real power of transit light curve analysis lies in the wealth of information they provide about both the planet and star. For example, they can give an indication of the size of the planet. By measuring the decrease in the measured brightness of a star as a planet transits its disk, it is possible to determine the planet's size relative to the star. The amount of starlight blocked by the planet is proportional to its cross-sectional area.

## The CoRoT satellite

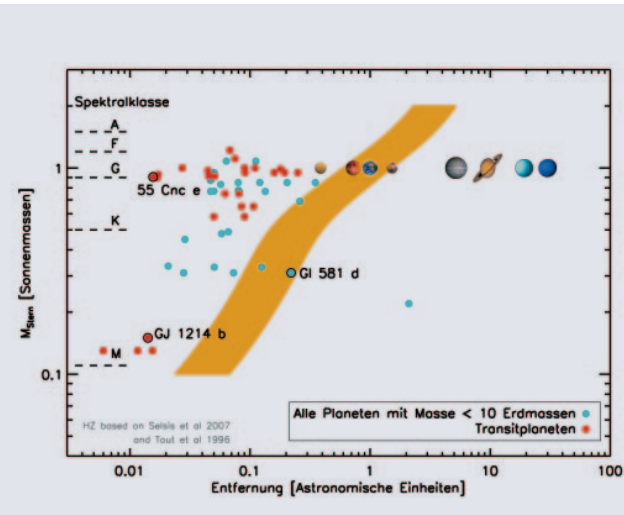
CoRoT is an astronomical satellite that measures variations in the brightness of stars at optical wavelengths. CoRoT was launched into its polar orbit from the Baikonur Cosmodrome by a Russian Soyuz-Fregat rocket on 27 December 2006. The CoRoT space mission is operated by the French space agency CNES with the participation of Austria, Belgium, Germany, Spain, Brazil and the European Space Agency.



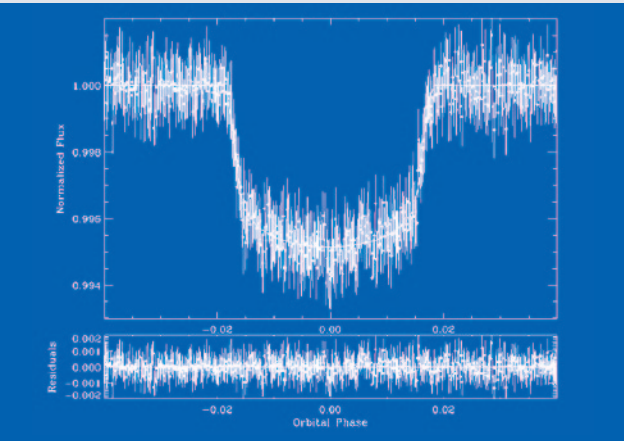
Researchers are on the lookout for planets within their star's Goldilocks zone – not too cold and not too hot.



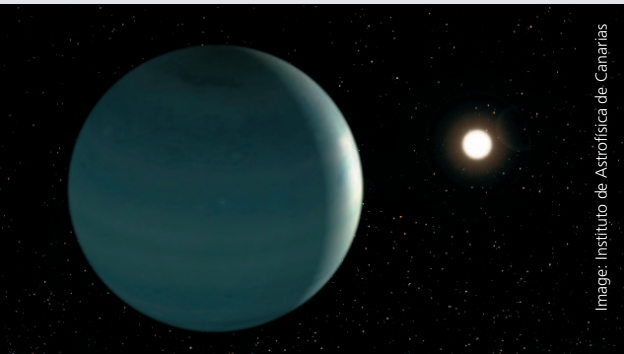




This diagram shows all the discovered exoplanets with a mass less than 10 Earth masses (as of September 2012). The horizontal axis shows the distance to the parent star and the vertical axis stands for the mass of the parent star. The planets of our Solar System have been incorporated for comparison. The yellow band indicates the range of the habitable zone for the various spectral classes.



Transit light curve of the star CoRoT 3a. The drop in the brightness of the star CoRoT 3a, produced by the transit of the planet CoRoT 3b, is clearly visible.



The exoplanet Corot-9b has an orbital period of 95 days. Unlike the previously discovered planets, the distance to its star is relatively large, and the temperatures are moderate.

Once the planet's orbital period and duration of the transit event have been determined, the orbital radius can be calculated. The transit data also helps to determine the inclination of the orbital plane, by recording the transit duration and times at which the planet 'enters' and 'exits' the stellar disc, known as ingress and egress times. If the planet does not pass across the centre of the disc, the transit time will be shorter when compared to a planet that does pass through the centre of the disc. Thus, the inclination of the orbit can be calculated using the shape of the transit curve. The mass of the planet can be estimated using the transit data and measurements of the host star's radial velocity, made using other telescopes, as it moves in response to the gravitational pull of the orbiting planets. Once estimates of the mass and the radius of the exoplanet are available, the average density and surface gravity can be derived. And this is where it gets interesting – the density is a key parameter for enabling conclusions to be drawn about the composition of the planet, such as whether it is gaseous or rocky. The researchers are focusing on rocky planets because their physical properties might make them suitable for the existence of life as we know it. Indicators of life as it arose on Earth could be, for example, an atmosphere, liquid water, tectonic activity or a magnetic field.

To date, the above techniques have been used to determine the parameters of 292 extrasolar planets. Of these, 69 have been classified as 'super-Earths', as their mass does not exceed 10 times that of Earth. Some of these might be rocky planets with liquid water on their surface, providing conditions suitable for life, as we know it. A prerequisite for the existence of water is that the planet lies in the habitable zone, also referred to as the 'Goldilocks zone'. Such planets are neither too near to nor too far from their parent star – outside this zone, water will either evaporate or freeze. An appropriate atmosphere is also favourable.

Looking for the right candidate

Few super-Earths located within their planetary systems' habitable zone have been found to date. The system around Gliese 581 might be such a candidate. Gliese 581 is about 20 light years away, and is orbited by at least four planets, three of which are known to be super-Earths. One of these, Gliese 581d, could be located within the system's Goldilocks zone. If its atmosphere is sufficiently dense and contains high enough concentrations of greenhouse gases, a planet meeting some of the conditions for life, as we know it, will have been found. Due to the inclination of its orbit, it is difficult to study its atmosphere and it is not possible to obtain a transit light curve. So, unfortunately, the researchers have yet to determine whether it could harbour life.

This means that the search for extrasolar planets remains exciting and it must be hoped that the rate of new discoveries continues to increase rapidly. The CoRoT mission was intended to start its second extension in March 2013. The French space agency CNES and its partners, including DLR, decided this in October 2012. However, on 2 November 2012, CoRoT suffered a computer failure that is preventing it from retrieving data from its telescope. Attempts to work around this problem are continuing, but if CoRoT is no longer able to return data from orbit, the satellite will still have left behind plenty of work for the team at the Institute of Planetary Research. The planet we are looking for may already be among the thousands of candidates – a rocky planet located in its system's Goldilocks zone. ●



More information:  
<http://s.dlr.de/984j>  
<http://smc.cnes.fr/COROT/>

Extrasolar planets detected by CoRoT

(January 2013)

Name	Mass [M-Jupiter]	Radius [R-Jupiter]	Period [Days]
CoRoT-1b	1.03	1.49	1.50
CoRoT-2b	3.31	1.47	1.74
CoRoT-3b	21.66	1.01	4.26
CoRoT-4b	0.72	1.19	9.20
CoRoT-5b	0.467	1.39	4.04
CoRoT-6b	2.96	1.17	8.89
CoRoT-7b	0.023	0.15	0.85
CoRoT-7c	<0.0264	-	3.70
CoRoT-7d	0.052	-	9.02
CoRoT-8b	0.22	0.57	6.21
CoRoT-9b	0.84	1.05	95.27
CoRoT-10b	2.75	0.97	13.24
CoRoT-11b	2.33	1.43	2.99
CoRoT-12b	0.917	1.44	2.83
CoRoT-13b	1.308	0.885	4.03
CoRoT-14b	7.6	1.09	1.51
CoRoT-15b	60	0.8	3.0
CoRoT-16b	0.535	1.17	5.35
CoRoT-17b	2.45	1.02	3.77
CoRoT-18b	3.47	1.31	1.90
CoRoT-19b	1.11	1.45	3.90
CoRoT-20b	4.24	0.84	9.24
CoRoT-21b	2.53	1.30	2.72
CoRoT-22b	<0.15	0.52	9.76
CoRoT-23b	2.8	1.05	3.63
CoRoT-24b	<0.1	0.33	5.11
CoRoT-24c	0.13	0.44	11.76

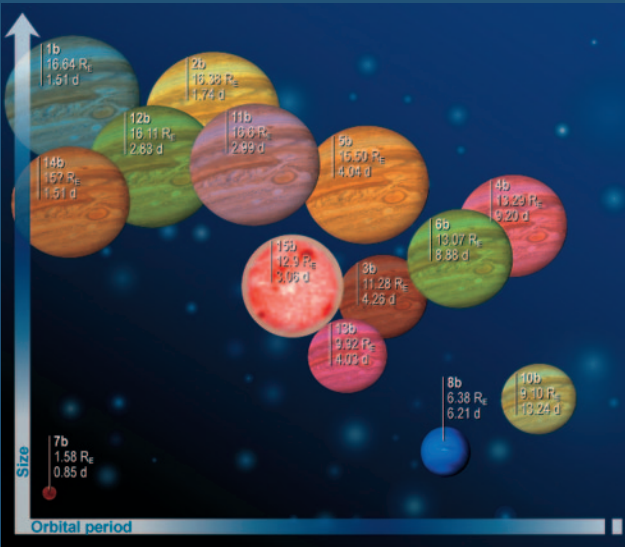
Evidence of the second planet, CoRoT-7c, was provided by the transit measurements of CoRoT-7b. The existence of the second planet was confirmed by radial velocity measurements. However, scientists have been unable to determine the radius from the data acquired. CoRoT-7c is not transiting its parent star.

One Earth mass = 0.00314 Jupiter masses

One Jupiter mass = 317.83 Earth masses

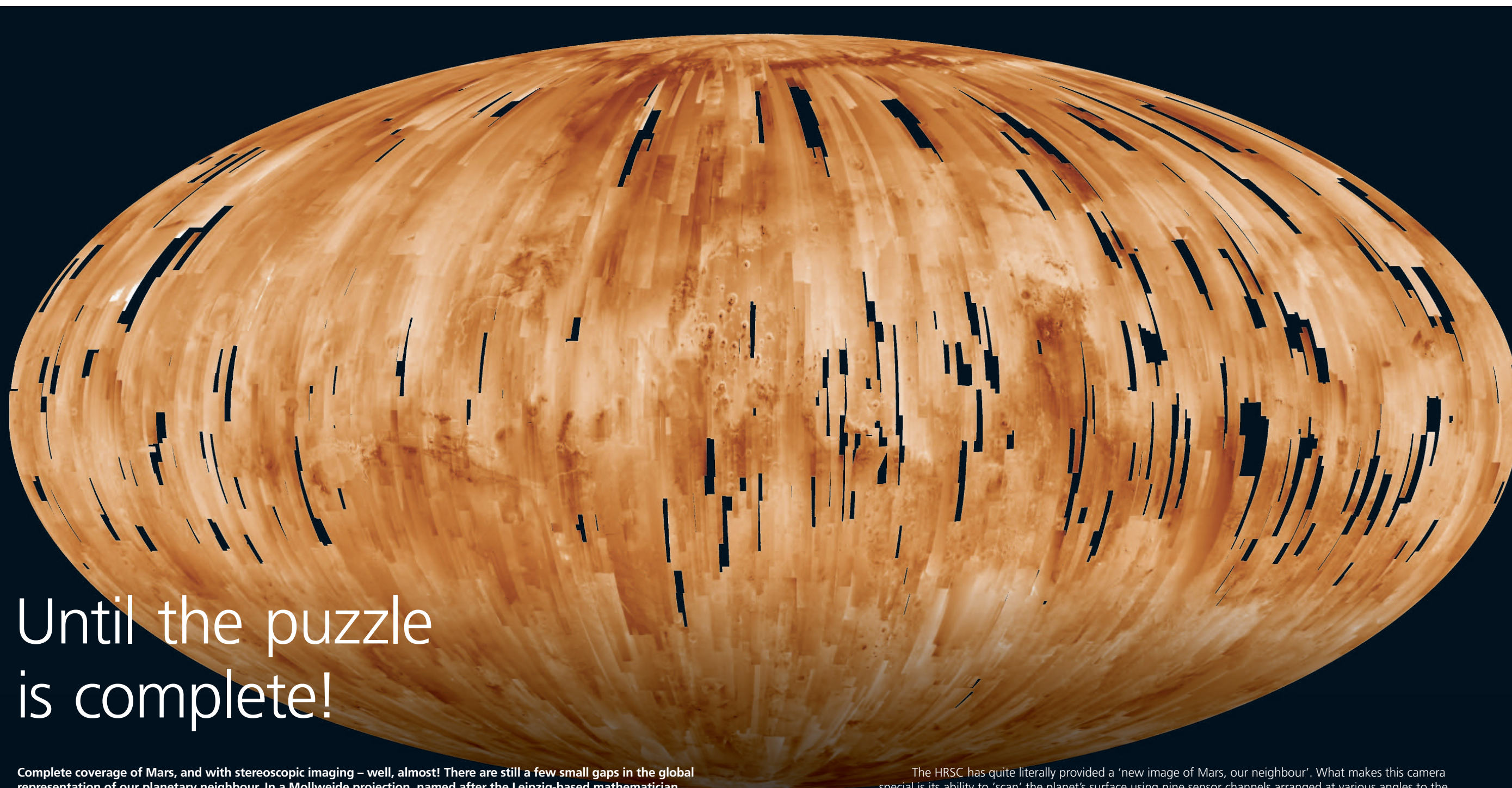


In early 2009 researchers discovered the first rocky planet outside our Solar System with the European CoRoT space telescope. CoRoT-7b was the first super-Earth with a known radius.



The first 15 exoplanets found by CoRoT, and later confirmed.





# Until the puzzle is complete!

Complete coverage of Mars, and with stereoscopic imaging – well, almost! There are still a few small gaps in the global representation of our planetary neighbour. In a Mollweide projection, named after the Leipzig-based mathematician and astronomer, Carl Brandan Mollweide (1774 - 1825), these last gaps can be seen clearly. All of the usable image strips acquired using the nadir channel of the High Resolution Stereo Camera (HRSC) on board the Mars Express spacecraft, a channel with its field of view perpendicular to the surface of Mars, are projected by scientists onto an elliptical surface in which parallels of latitude are displayed as straight lines and meridians as portions of ellipses. For design purposes, the monochrome, black and white, image strips are assigned a colour that approximates Martian reality. Due to the presence of haze and dust in the atmosphere, not all images are of the same quality; many areas have been recorded several times, from various altitudes and with the Sun at different angles of inclination, which explains the differences in contrast and brightness.

DLR's Institute of Planetary Research in Berlin operates the High Resolution Stereo Camera. There, the image data is processed systematically and made available to more than 50 scientists of the HRSC team from Europe, the United States and Japan, and their co-workers – and it is also prepared for the data archives of ESA and NASA. The leadership for this science team is also based in Berlin, at the Freie Universität.

The HRSC has quite literally provided a 'new image of Mars, our neighbour'. What makes this camera special is its ability to 'scan' the planet's surface using nine sensor channels arranged at various angles to the direction of the orbiter's flight. From this image data, it is not only possible to obtain large-format images with a resolution of down to 10 metres but also to generate colour photographs and, most importantly, to derive digital terrain models of the Martian surface. Before HRSC, global topographical mapping of a planet had never been accomplished using image data.

On 2 June 2013, 10 years after its launch, the Mars Express spacecraft will have orbited Mars almost 12,000 times. The spacecraft follows an elliptical, quasi-polar orbit and HRSC was switched on during more than 3500 of those orbits. By the end of ESA's first planetary mission, currently planned for 2014, the last gaps in the HRSC map of Mars will have been filled. ●

Ulrich Köhler



More information:  
[www.DLR.de/en/Mars](http://www.DLR.de/en/Mars)



# Knowing what would happen if ...

Greenpeace International has not been making things easy for Thomas Pregger, a project leader in the Department of Systems Analysis and Technology Assessment, and his team at the DLR Institute of Technical Thermodynamics in Stuttgart. The systems analysts have been developing the global energy scenario 'Energy[R]evolution' under contract to Greenpeace. The research shows what safe and sustainable energy supply in 2050 could look like. The client set out extensive framework conditions for the scenario: progressive global phasing out of nuclear energy and carbon fuels, strict limitation of biomass, oil and gas consumption, a significant reduction in carbon dioxide emissions through the use of renewable solutions, while taking into account the natural limitations of our environment.

## Energy systems analysis – an ever better view of the future for energy supply

By Dorothee Bürkle

"I can, of course, make any basic assumptions in a scenario; however, we must always address the question of whether these are realistic and will lead to a consistent development path," says Thomas Pregger, describing the difficulty of the task. When systems analysts create a target-oriented scenario, they look from a specific point in the future, where certain goals are expected to have been met, back to the present. In this way, for example, an energy supply that involves up to 80 percent renewable energies can be assumed as a target. The researchers use this 'backcasting' to look for, or rather, to compute the necessary investment and actions we need to consider today to achieve the desired situation in the future. "This means that the scenarios are not prognoses for the future; rather they show which steps must be taken to achieve certain goals. Hence, we are describing a potential path and its consequences for the political world and energy policy," Pregger says, describing his area of activity.

### Looking back from the future helps in the search for the right path

Before Pregger and his colleagues get started, they collect data on the current situation. Statistics from the International Energy Agency (IEA), the World Energy Outlook or the Federal Ministry of Economics are fundamental to the energy scenarios. Among other things, the researchers are interested in the following parameters: the gross domestic product, current energy consumption, the generation facilities, anticipated economic and population development, renewable resources and the expected

changes in price for technologies and energy sources. "Our analysis work basically starts here, because often the various data sets do not match each other well," says Pregger of this phase of the task. For example, the international statistics for energy consumption do not have any separate figures for industry, commerce and private households. "In such a case, we run a comparison with national statistics or research and use this to prepare our data before we feed it into our scenario database."

At this point the researchers also define the limits for their scenario. What natural resources in terms of wind power or biomass, for example, are available in a country or region? How can the expansion of renewable energies be represented with the most stable market growth possible? What is the potential for community and district heating? When all this has been determined, the energy balance calculations can begin in a scenario model, where the physical and economic interrelationships between the input variables are determined. One of the tools the DLR researchers work with to achieve this is the Modular Energy System Analysis and Planning (MESAP) tool from Seven2one Informationssysteme GmbH in Karlsruhe. A very detailed description of renewable energy sources is produced using the ARES model (Ausbau Regenerativer Energiesysteme – Development of Renewable Energy Systems), which the department has developed itself and is constantly expanding.

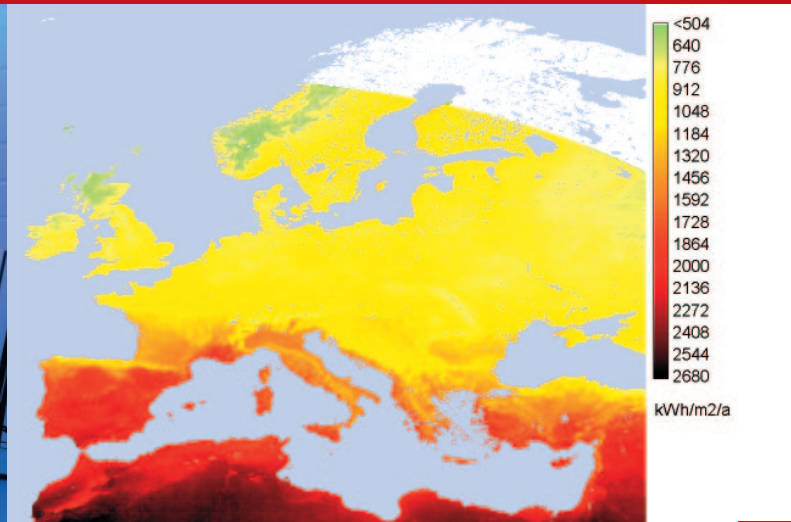
Based on the additional capacity of the various energy technologies, the programme determines the required investment, the costs incurred, the level of long-term economic benefit and the effects this has on a country's power and heat generation costs. Even so, the researchers do not regard the scenario programme as a black box. They constantly check the path from the initial situation to the one desired for the future, critically scrutinise whether the additional capacity of a specific energy technology is realistic, and determine whether the need for energy will actually be satisfied at that time. "It's a long route for us to get to a coherent scenario. We change and recompute the parameters up to 50 times until we finally arrive at a self-consistent, reliable scenario," says Pregger, describing this step of the process. The researchers generally compute a number of paths. Hence, they have generated multiple scenarios for their pilot study on energy supply in Germany up to 2050. The main scenarios are principally oriented towards the primary goal of the Federal Government's energy policy, which is a reduction of at least 80 percent in greenhouse

As well as the Greenpeace 'Energy[R]evolution' study, the DLR systems analysts have, in 2012 and under a contract from the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, published the '2011 Pilot Study' and a study on employment development in the renewable energy sector. With funding from the Federal Ministry of Economics and Technology, they have produced a study on potential developments in electric mobility by 2050. During the course of this year the researchers will publish a Mediterranean Solar Atlas, comprehensively describing the potential for solar energy in the Mediterranean countries for the first time.

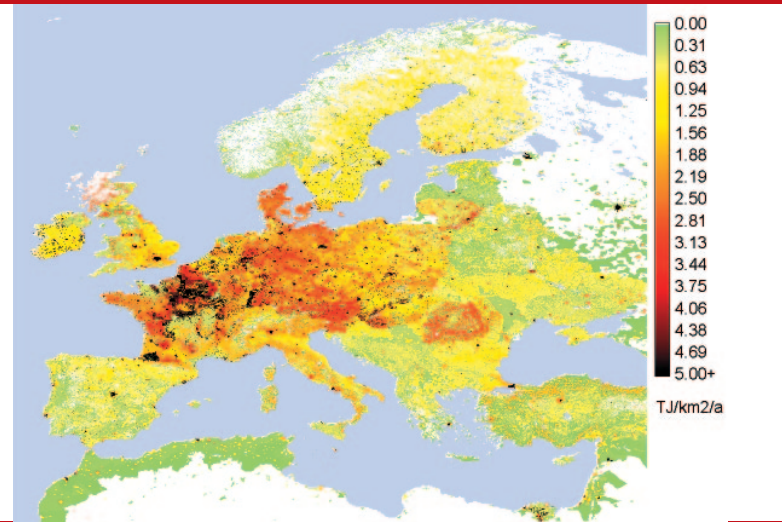




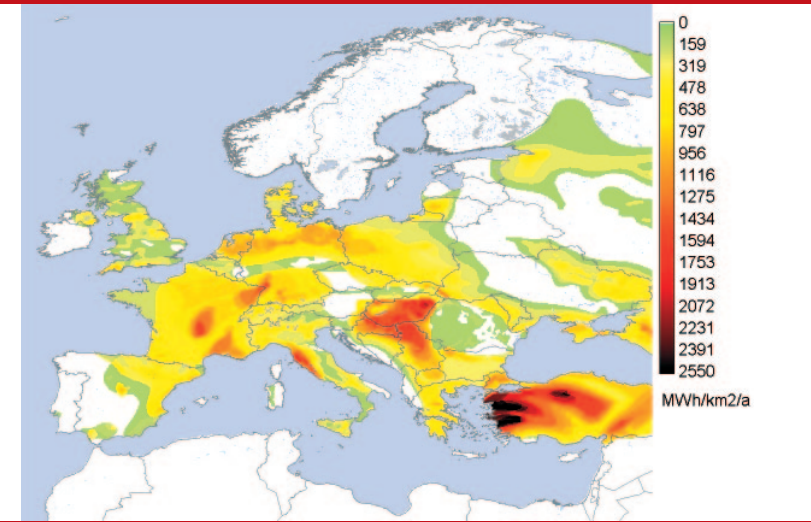
How can an energy network between North Africa and Europe be established? What is the best energy mix for this? The DLR systems analysts have researched this for the first time. These studies form the basis for the DESERTEC concept, which the DESERTEC Foundation and the DESERTEC Industrial Initiative are working on today.



Solar energy resource – total horizontal irradiance, in kilowatt-hours per square metre per year. Total irradiance is the sum of direct and diffuse irradiance. In desert regions, this is more than twice than in central Europe.



Biomass resource – sum of the energy potential, in terajoules per square kilometre per year. Using biomass as a stored energy source, renewable energy can be produced to compensate for fluctuations in solar and wind power generation.



Geothermal energy generation: total potential at depths of 2000 to 5000 metres, in megawatt-hours per square kilometre per year. It can supply heating and process heat and power. Geothermal power generators are frequently operated as base-load plants due to the large investment needed for their construction.

gas emissions by 2050. But to do this they assume there will be various developments in, for example, electric mobility. In addition, the researchers have computed the development path for reducing greenhouse gases by 95 percent. "Using the various scenarios, we get a range of potential developments and understand how important individual technologies are for the Energy Transition," says Pregger, describing the benefits of this process.

#### Energy modelling – an unbiased look into the future

Unlike scenario computations that assume specific targets, optimisation modelling leaves the results that will be arrived at open. With the REMix (Renewable Energy Mix for Sustainable Electricity Supply) modelling programme, the systems analysts can reliably draw up minimum-cost energy supply systems that are economically viable under the respective cost assumptions. The computations for this are complicated, as REMix compares the power demand and the potential energy supply for individual countries or for the whole of Europe for every hour over the course of a year. In the case of a large region or a high temporal resolution, these calculations can sometimes take several days. With the REMix modelling tool, the systems analysts are currently focusing their research on whether and how realistic the scenarios they have computed are. For each year of the scenario, they can check the extent to which the complex of power plants computed in the scenario can meet the energy demand and how many storage units are required. "We can make sounder predictions in our scenarios with the optimisation models," says Yvonne Scholz, who developed REMix for her doctorate. She also knows the limitations: "The quality and usability of the results depends largely on the parameters and basic assumptions entered. We have to carry out our computations with numerous parameter variations to get sound predictions." This means that, even with the optimisation models, numerous iterations are needed on the way to a realistic model of the energy requirement for the future.

#### How did DLR end up performing energy systems analysis?

How did the German Aerospace Center end up computing scenarios for future energy supply? If anyone knows, it's Joachim Nitsch, who established the department in 1975:

"During the first oil price crisis, the whole world suddenly started researching energy. Politicians 'woke up' and put money into it. DLR – at that time still the German Research and Experimental Institute for Aviation and Space (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt; DFVLR) – had a great deal of expertise to undertake such research projects, both for developing various energy technologies and for theoretical systems analysis." Commissioners of the initial studies included German Federal Education and Research Minister Hans Matthöfer, who had been interested in the potential of developing renewable energies since 1977, and the State of Baden-Württemberg, which commissioned a major study into the prospects for energy supply in the 1980s. In these initial studies, DLR researchers also investigated the potential of hydrogen in the energy system. "From the outset, our department consisted of engineers and physicists. The advantage of this was that our studies were always very close to the technologies, and we could estimate what was possible and what was not with great accuracy," recalls Nitsch. And today, with economists, geographers and a social scientist in the team, there are still regular exchanges with the engineers regarding the possibilities of individual technologies, according to Nitsch. "And there is also the occasional argument when we view the situation differently. This close feedback with the researchers is what makes systems analysis at DLR unique."

Other milestones for systems analysis in Stuttgart are the main studies into possible development strategies for renewable energy sources in Germany, which DLR has been producing for the Federal Environment Agency since 1998 and for the Federal Environment Ministry (BMU) since 2004. DLR researchers were able to build on the foundation studies on 'Energy Supply for the Future' carried out in 1990. This was followed by international studies (again done under contract to the BMU) such as Trans-CSP (Trans-Mediterranean interconnection for Concentrating Solar Power) and MED-CSP (Concentrating Solar Power for the Mediterranean Region), which looked into developing an electricity network between Europe, the Middle East and North Africa. The DESERTEC Foundation and the DESERTEC Industrial Initiative continued these studies. This is because they have set themselves the goal of delivering such an energy network. "DLR has been establishing an ever broader foundation for studies into energy systems since the early 1970s. The modelling has reached a peak with the REMix tool;

furthermore, we can now map the heat sector very well and analyse the resources for renewable energy sources both globally and domestically," says Joachim Nitsch in praise of his former department.

The systems analysts have not developed any preference for a specific technology yet: "Future energy supply will be a combination of various technologies, depending on the potential available in a country," says Pregger, adding: "Scenarios are not just standard off-the-shelf tools. We have our experience to draw on, and if a client's requirement does not follow a consistent development path in our eyes, it will be discussed." This was the case with the Greenpeace scenario, where the researchers could not feed in all the basic conditions with the client's exact specifications. This meant that they could not adhere to the strict path for gas consumption, which assumed that no new reserves would be tapped. "To manage the transition to a renewable supply while at the same time making the least possible use of biomass, gas will have to continue to play an important role as a source of energy in the long term," notes Pregger. With the addition of new

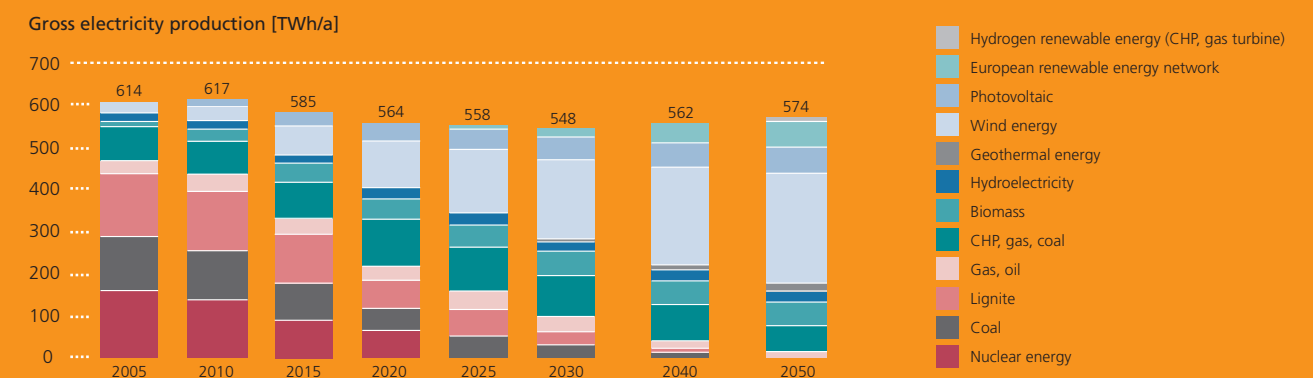
gas reserves, the DLR researchers were able to use various scenarios to illustrate a coherent development path, at the end of which more than 80 percent of primary energy will still come from sustainable sources in 2050, even as the global population continues to increase at a steady pace.

Our energy supply is changing; the expansion of renewable energy sources is progressing and, at the same time, reserves of oil, gas and coal are becoming limited. With the Energy Transition, politicians have decided that Germany will rely on renewable forms of energy in the long term. Nobody can look into the future of energy supply, but energy scenarios like those being generated by the DLR systems analysts provide important bases for decision-making by politicians and economists. ●



**More information:**  
[www.DLR.de/SystemsAnalysis](http://www.DLR.de/SystemsAnalysis)

#### Development of gross energy generation in Germany according to the 2011 Scenario A (average expansion of renewable energies; use of biofuels, electric mobility and hydrogen in transport).



Since 2004, the DLR researchers have been working on studies for the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), to see what the energy supply in Germany might look like in the future. The scenario illustrated here shows the development with an average speed of growth in renewable energies until they reach 85 percent of power generation.



# Studying the low-speed flight regime

An aircraft delivers holidaymakers and business travellers to their destination swiftly and directly. Just prior to the arrival at destination, pilots and aircraft are faced with a set of very specific requirements. The aircraft must remain stable in the air during the low-speed approach. DLR is collaborating with Airbus to study this low-speed flight regime for civil aircraft in the HINVA (High-lift IN-flight VALidation) project, to explore the potential benefits in terms of quieter approaches, shorter landing distances and higher passenger capacities. To accomplish this, scientists employ dedicated flight-testing, wind tunnel experiments and computer simulations.

## Researching at maximum lift and minimum speed

By Ralf Rudnik and Falk Dambowsky

### HINVA – Simulation and flight-testing go hand in hand

Since numerical methods and modern high-performance computers allowed the analysis of realistic high-lift configurations about 15 years ago, research has concentrated on gaining a detailed understanding of the complex aerodynamic phenomena involved, and on ways of improving the numerical processes. Primarily, this took place within European projects. Right from the start, DLR played a prominent role – not least because of the significance of high-lift systems for the Airbus site in Germany. Until recently, the experimental data for comparisons between measured and computed data originated from wind tunnel testing. Assessing all of this research work, it became apparent that comparisons with wind tunnel test results alone would not be sufficient to deliver the level of precision needed to determine aerodynamic high-lift performance or to further develop numerical processes. Restrictions on size and the influence of wind tunnel walls and model mountings are factors that prevent the achievement of these goals. As a consequence, extended validation was required, allowing verification of predictions against flight test data – reason enough to start the HINVA project in 2010.

The DLR A320 Advanced Technology Research Aircraft, ATRA, glides gently across the fields on its final approach. A glance out of the cabin window reveals that slats and flaps on the leading and trailing edges of the wings are being deployed. This event is accompanied by a gentle whirring from the electric actuation motors, while the wings appear to have double the width they had during the cruising portion of the flight. The undercarriage locks down into the landing position. Still travelling at 200 kilometres per hour, ATRA crosses the fence around its home base in Braunschweig – finally, it touches down on the runway.

An occurrence observed by passengers on a daily basis conceals an engineering masterpiece. The wings on large, modern passenger aircraft are designed for high speeds, around 850 kilometres per hour, while cruising at altitudes of about 10,000 metres. During approach and landing, they reveal a different capability – the flight crew keeps the aircraft airborne over the last few metres of its flight at less than 250 kilometres per hour. This is accomplished by utilising an aerodynamic trick – the magic phrase employed by aircraft engineers is ‘high-lift system’. With it, they refer to the various mechanical flaps on the wings that are deployed during take-off and, above all, when landing an aircraft, together with their complex control system.

The decisive factor here is an increase in the curvature of the wing and its surface area, which delivers more lift. The third act in the performance increase for low-speed flight is devoted to the aircraft pitch attitude – to increase lift, the pilot pulls up the nose, reaching up to 10 times the angle it adopts at cruising altitude. During this process, the flap and slat system ensures that high angles of attack can be reached without stalling of the wing.

The gaps that open between the slats on the leading edge of the wing, the main wing and the trailing edge flaps play another key role in the performance of a high-lift system. All of these elements must be precisely aligned with each other to achieve the optimum high-lift configuration. The simulation of this complex situation at the limits of the flight envelope in terms of maximum lift remains an enormous challenge.

Port wing of the ATRA research aircraft with pressure measuring strips visible as reflective silver strips





ATR during final preparations for flight testing in front of the Test Flight Department building in Toulouse



DLR project team in the ATR cabin during a test flight



Starboard wing with deformation markers and specially patterned foil during a test flight over the Pyrenees

Computer models and wind tunnel testing need flight test data to improve their reliability.

#### Experimental campaign in Toulouse

To further investigate the delicate aerodynamic interaction of wings, flaps and fuselage more closely, researchers from the DLR Institute of Aerodynamics and Flow Technology travelled to Airbus in Toulouse in April 2012, accompanied by the DLR A320 ATRA research aircraft. During the collaborative HINVA project, a ten-strong team from DLR and Technische Universität Berlin worked alongside flight-testing specialists from Airbus to prepare the test aircraft for its forthcoming mission. This test preparation period lasted four months, during which scientists applied several hundred sensors across the entire outer skin of the aircraft.

The pressure measuring system is a striking feature, comprising light alloy strips just a few millimetres thick that the researchers stuck to the port wing and the horizontal stabiliser. These strips feature over 400 pressure-sensing holes and tube connections. To identify the most appropriate positions for these pressure strips and their individual holes, as well as related instrumentation, the partners performed an extensive series of computer simulations within the framework of the HINVA project.

Researchers prepared the opposite (starboard) wing for deformation measurements. They glued special markers to this wing and applied a 'speckle pattern' to the flaps. The camera system installed inside the cabin comprised six single cameras to record the deformation of the whole starboard wing and its flaps by evaluating the patterns and marker movement during flight.

In addition to these markers, the starboard wing was also fitted with 440 'flow cones' – cone-shaped plastic components each attached to five-centimetre long threads. These evenly distributed flow cones align with the local flow during a flight and reveal flow separations on the wing. To record these flow and separation patterns, the same 'six-eyed' camera system was used. In addition, temperature sensors from TU Berlin were applied to two wing sections. These films detect where the boundary layer condition is laminar, offering lower drag but also a higher tendency for the flow to separate.

With these cameras, markings and wing sections fitted with sensors, researchers from DLR, Airbus and TU Berlin had one common goal in mind – they wished to gain a better understanding of the aerodynamic properties of a modern commercial aircraft like the Airbus A320 in an extreme flight regime, namely at and beyond maximum lift. Although maximum lift conditions are not being utilised during regular flight operation, they represent the key to slower and quieter landing approaches. On commercial aircraft equipped with electronic flight control systems, an acoustic warning is given to the pilots sufficiently in advance of reaching maximum lift conditions. Together with this warning, the on-board computer immediately reduces the angle of attack and increases thrust to ensure safe flight conditions. Nevertheless, maximum lift performance data is indispensable as a reference data for certification of the aircraft and determining the borders of the flight envelope.

#### To the limits of what is possible

To explore the maximum-lift flight regime, specially trained Airbus test pilots flew DLR's A320 ATRA together with its elaborate sensor systems right to its aerodynamic limits.

On 24 July 2012, the time had finally arrived. The first ATRA flight for the HINVA project was ready to take off. Once in the air, the researchers checked and calibrated all the instruments. All sensors proved their full operational capabilities despite extreme temperature fluctuations – in excess of 50 degrees Celsius on the ground, down to far below freezing at altitudes of almost 6000 metres.

The aircraft then conducted its measurement campaign, comprising 10 flight tests that took it through more than 120 stall manoeuvres. To reach the range of maximum lift, the test pilots had to shut down the automatic safety system and fly the ATRA in a special direct flight control mode. During such test flights, the test pilots raised the nose of the ATRA until a significant loss of altitude was experienced immediately after maximum lift conditions were reached. The machine dropped its nose again and the pilots had to recover to level flight conditions. The particular challenge for the flight crew in the cockpit is to carry out the manoeuvre in a very controlled way, if possible without any lateral movements. The highly experienced Airbus test pilots – thoroughly familiar with stall manoeuvres from the performance flight testing – succeeded in doing this on almost all test flights.

The experiments also provided a special highlight for some of the DLR researchers in Toulouse. In agreement with the Airbus flight testing engineer and test procedures, they were able to experience these spectacular flights on board; the measuring system had to be monitored and fine-tuned by specialists while in the air. Also one of DLR's test pilots was able to familiarise himself with this manoeuvre from the co-pilot's seat.

The test pilots ran the stall tests in landing configuration as well as with flaps retracted. They also varied altitude and speed between the individual manoeuvres. All in all, the scientists now have a very unique and well-stocked database at hand. It will certainly take a few years to complete a thorough evaluation.

#### Further experiments in the wind tunnel

In the course of 2013, researchers on the HINVA project are planning to conduct measurements with a model in the European Transonic Wind Tunnel (ETW) in Cologne, where they will simulate the A320 high-lift conditions. For this, they will use data from test flights to configure the newly built wind tunnel model to achieve a very high level of precision. A second supplementary flight test campaign involving DLR's ATRA research aircraft is planned for early 2014 at Airbus in Toulouse.

Knowledge gained from the test flights and wind tunnel experiments conducted within the scope of the HINVA project will greatly improve the ability of computer models and wind tunnel testing to provide reliable predictions in high-lift situations. Precise calculations of the high-lift performance are an important part of the 'jigsaw' when developing new commercial aircraft. ATRA data from the current test flights will certainly find its way into improved future aircraft; flying more slowly and quietly than they do today into airports around the world. ●

#### About the author:

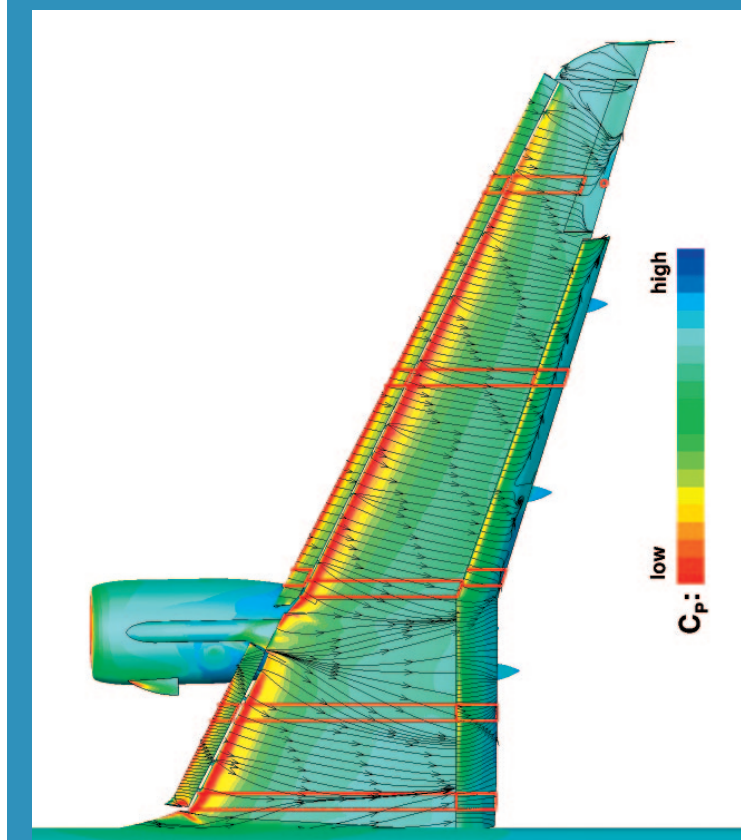
Ralf Rudnik is in charge of the HINVA collaborative project and is head of the Transport Aircraft branch at the DLR Institute of Aerodynamics and Flow Technology.



**More information:**  
[www.DLR.de/AS/en](http://www.DLR.de/AS/en)



The HINVA project team with Airbus test pilots and test flight engineers after the first flight of the campaign



Computer simulation of the flow on the upper surface of the wing. The positions of the pressure strips are marked in red.

ATR surrounded by access platforms in the Airbus hangar





# Powerful powder

Automobile manufacturers around the world are working on fuel-efficient vehicles. There are a number of ways of achieving this – increased electrification of motor vehicles, fuel-efficient engines and use of waste heat from combustion engines. Using thermoelectric generators (TEGs), heat that would otherwise be lost in the exhaust system can be converted into electrical energy, creating a significantly improved energy balance for modern vehicles. DLR is investigating.

## Functional materials for vehicle thermoelectric technology improve the energy balance

By Reinhard Sottong

The Department of Thermoelectric Functional Materials at the DLR Institute of Materials Research is collaborating with partners from the automotive manufacturing and supplier industries to make thermoelectric generators available for standard use in vehicles. Their aim is to create highly efficient thermoelectric materials and generators for use at temperatures of up to 400 degrees Celsius. In Project TEG, funded by the German Federal Ministry of Economics and Technology, DLR and its cooperating partners, BMW and EMITEC Gesellschaft für Emissionstechnologie mbH, have managed to develop a cylindrical TEG for integration into the exhaust gas heat exchangers of diesel engines. At the 2012 International Thermoelectric Conference, DLR's poster contribution on this topic was awarded best application from among 300 or so presentations.

The DLR researchers used lead telluride for the first prototypes and demonstration models. This is a high-temperature material with the best availability and technological maturity to date. However, lead-free functional materials must be found for this technology to be used widely. For this reason, ongoing research work is increasingly focusing on TEG module technology based on materials from the class of skutterudites. The electrical and mechanical properties of these functional materials are being researched and

optimised at DLR. The researchers are aiming to increase the material efficiency and make the modules suitable for long-term use. They are directing their attention specifically towards raw materials that can be produced with adequate throughput and fed into the development and manufacturing stages. This is something that has so far proven to be a practical hindrance for the industrial application of thermoelectric systems. Manufacturing the materials in glass vials is certainly a suitable method for laboratory research, but is too complicated and expensive for mass production.

Using this technique, thermoelectric materials can only be synthesised in quantities of significantly less than 100 grams per batch. It is for this reason that the scientists at the Institute of Materials Research are investigating other manufacturing routes that will allow for greater material throughput. They see one possible technique in atomising the molten thermoelectric material, a process that is already used for many materials at industrial scales. Now that lead telluride has been synthesised, doped and atomised to produce powder in the test facility, the current challenge facing the DLR team is to be able to carry out the atomisation of skutterudite materials with the required quality. In subsequent stages, this process will be optimised in terms of the quality of the materials to provide the basis for industrial manufacturing of large quantities of thermoelectric powder. Preparations are now underway, with the support of DLR Technology Marketing, to transfer this technology. In-depth discussions are being held with a European industrial partner on scaling up the technology for a pilot production line. The progress being made suggests that DLR researchers will be able to make a significant contribution to the establishment of thermoelectric systems. This would make vehicles more efficient by exploiting their excess heat. ●

### About the author:

Reinhard Sottong works in the Department of Thermoelectric Functional Materials at the DLR Institute of Materials Research in Cologne. Thermoelectric generators for motor vehicles are the subject of the physicist's dissertation.



**More information:**  
[www.DLR.de/wf/en/](http://www.DLR.de/wf/en/)

Thermoelectric generator module used to convert excess heat into electrical power



Equipment for atomisation of materials, with which DLR researchers are developing the processes for manufacturing thermoelectric powders.





# Mystery in the land of the elk

Travelling by rail in Europe is not always tranquil – especially when a high-speed train has to stop at a border because the locomotive or even the driver must be changed. The reason for this is that European countries use different train control systems. The single European Train Control System, ETCS, should help here. With RailSiTe® (Railway Simulation and Testing), DLR has an approved testing laboratory for such systems. It is currently doing work for the Swedish rail network, among others.

To enable railways to operate smoothly, DLR transport researchers are simulating stretches of track

By Lennart Asbach

With RailSiTe®, the DLR Institute of Transportation Systems has the only accredited ETCS test laboratory in Germany. The DLR researchers can use RailSiTe® to simulate entire rail journeys using real on-board computers from various national manufacturers, enabling them to analyse all communications between the track and the train, and from the signalman to the train driver. Safe, fast travel on trains is only possible if the technology functions flawlessly at all times.

Incompatibilities between the different devices used could arise, as ETCS is being developed by various manufacturers. A train from manufacturer A might not run on a track equipped by manufacturer B. In Sweden, infrastructure operator Trafikverket has already experienced this exact problem with stretches of line that are already in operation; the trains regularly malfunction after travelling for a few hundred kilometres on one of the new ETCS stretches. The cause of this could not be determined in live situations, so it was time to call on Braunschweig-based RailSiTe®.

For this task, the railway laboratory was enhanced with the Swedish rail system's control and safety technology, and an on-board computer from a Swedish locomotive was integrated into the simulation. The laboratory environment now interacts with the train computer on all available interfaces. In this way, the Swedish computer 'feels' its way on a journey across Sweden and is exposed to critical situations that might occur on a real stretch of track. There is no need to see the outside when conducting the tests. The virtual train journey through Sweden takes place with no scenery and no elk.

The aim of this test is to reproduce malfunction scenarios and find the cause of the fault. The track data is extracted from journey recorders on the Swedish trains called 'Juridical Recording Units' (JRUs) using a newly developed method. The JRUs continuously record all relevant input and output as well as motion



Lennart Asbach in the RailSiTe® simulated cab

parameters. This formal journey data is transferred to the scenario using DLR tools. Once the scenarios have been created, train computers from other manufacturers will also be tested for interoperability with the track in the laboratory. Functional discrepancies can then be detected under laboratory conditions.

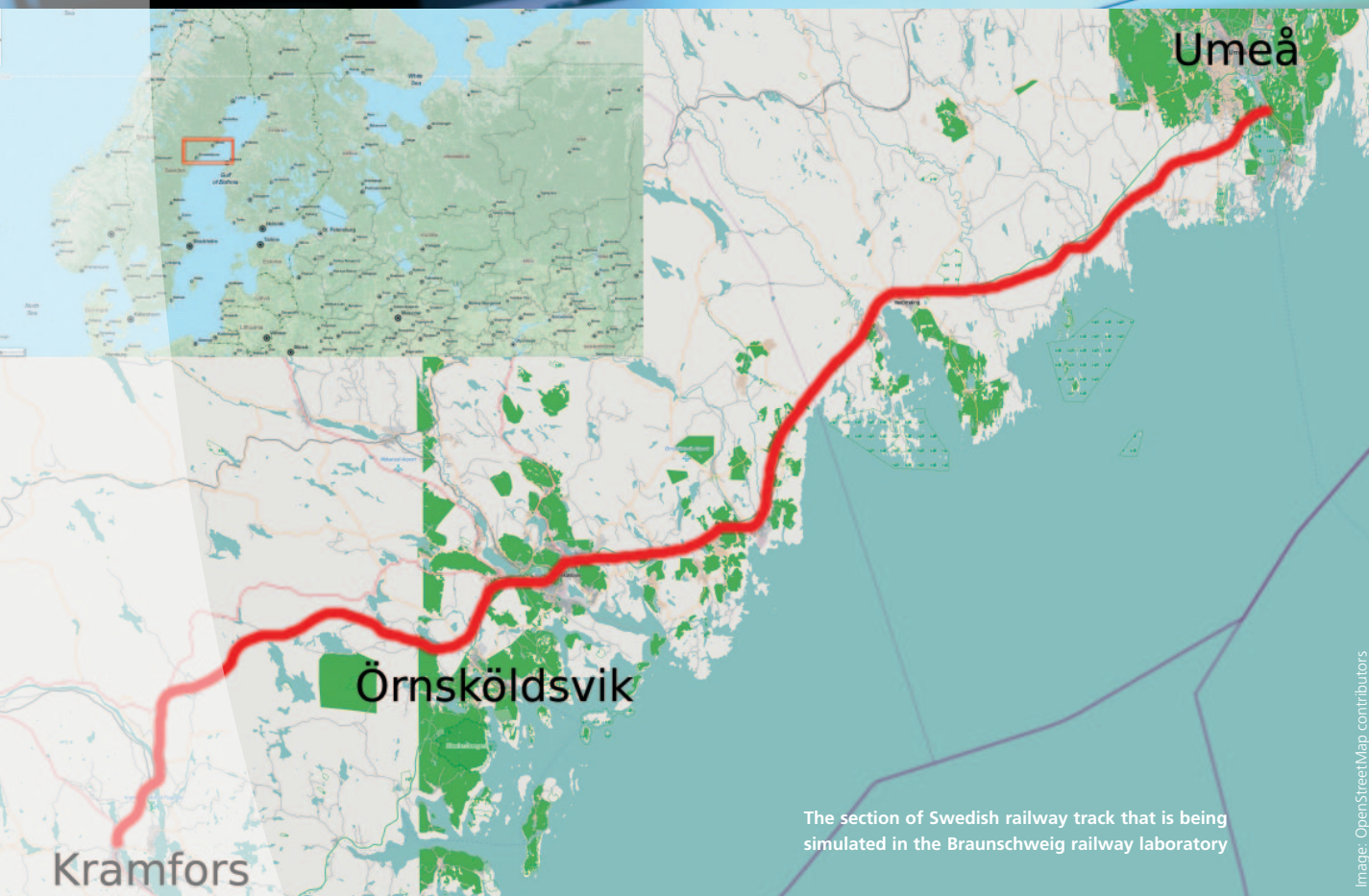
Let's just hope that the elk that are missing from this simulation don't turn out to be the main cause of the malfunctions... ●

## About the author:

Lennart Asbach is an engineer in the railway department at the Institute of Transportation Systems in Braunschweig. He researches and develops new methods and tools for simulating and validating future railway control and safety technology.



More information:  
[www.DLR.de/ts/en/](http://www.DLR.de/ts/en/)



The section of Swedish railway track that is being simulated in the Braunschweig railway laboratory

Image: OpenStreetMap contributors





# Rock-dwellers transform waste

A few plants, lava rock from the Eifel Mountains, two plastic tubes, a glass container, water, fish – and organic waste. That is all you need to create a self-contained life support system. C.R.O.P., or Combined Regenerative Organic food Production, is designed to break down organic waste and use the resulting metabolised products to produce food. This technique is already working, on a small scale, in the foyer of the DLR Institute of Aerospace Medicine in Cologne, where researcher Jens Hauslage and his team regularly harvest tomatoes. The C.R.O.P. biofilter will soon be tested in a greenhouse near Bonn to see whether it can work on a larger scale, as well to determine its suitability for applications in harsh environments on Earth or in hostile conditions during long-duration space missions.

## DLR researchers develop the C.R.O.P. biofilter

By Manuela Braun

The participants in this experiment are very small; in fact, they are so tiny that they are invisible to the human eye. Jens Hauslage taps on the glass tubes of C.R.O.P. There is nothing to see except water trickling over the wet rocks from the Eifel Mountains. "But inside, a war is being waged. A battle for the best nutrients," he says. Everything appears calm in the lava gravel, but a look under the microscope reveals quite a different story. Over 70 species of bacteria, fungi and other single-celled organisms are fighting with one another on the surface of and inside the numerous small cavities in the porous rocks – waging a hard struggle over the waste material that the water circuit in the C.R.O.P. system continuously flushes over them.

"We are using this competition between organisms to reduce the time needed for recycling." The nutrients that are desirable for the bacterial kingdom in the rocks are often harmful to plants and people. Ammonia, for example, which is too strong for soil, plants and the human nose, is one of the more sought-after nutrients for many bacteria; what those bacteria excrete after consuming it is an important nutrient for plants, which would be lost without the closed circuit of the C.R.O.P. system. This all happens without needing a lengthy detour via a compost heap – the standard way of recycling organic waste into fertiliser. "Could you imagine a compost heap on the International Space Station?"

Once it has been primed with a spoonful of soil, life explodes inside the rocky biofilter. Here, the bacteria demonstrate how adaptable they are in their struggle for survival – regardless of the type of waste material in the biofilter, there are always organisms that can use that exact material as food and break it down. This occurs in the two one-metre-high tubes of the C.R.O.P. test unit. "Through the microscope, the bacteria world in the rocks looks like a real chamber of horrors," the biologist says. "Mites, worms – they all feel comfortable in the various micro-climates in the gravel." The numerous pores in the rocks have a total surface area roughly the size of two football fields. Plenty of habitats for a vast range of single-celled organisms with a variety of diets – regardless of whether they prefer living with oxygen on the surface of the rocks or without it, inside the porous Eifel rocks. And in the event that the filter should ever dry out, it would still not be the end of the dynamic biofilter – the bacteria would simply go into hibernation and spring back to life once the water returns.

### In the beginning there was a murky soup

Jens Hauslage carefully plucks the old leaves from the tomato plants, opens the tube cover and dumps the leaves on the wet rocks. "It's a kind of plant cannibalism – we feed tomato leaves to the tomato plants," he says, laughing. "The nutrients in a tomato leaf are exactly the ones that a tomato needs – so we





Fresh food for the bacteria – Jens Hauslage picks off old leaves and throws them in the biofilter. There, hungry bacteria are waiting to be fed.



The biologist regularly harvests mini tomatoes that have been fertilised by recycled waste in the C.R.O.P. biofilter



Carefully monitored recycling enables the young plants to sprout

put them back into the system via the biofilter.” It begins to smell of fresh tomatoes in the foyer of the Institute. The nutrients obtained after being percolated through the biofilter are good for the Micro-Tina – a variety of tomato that was bred for space by Utah State University. Hauslage checks the most important values of the water on a digital display – the pH is OK. The conductivity, which provides information on the amount of nutrients in the water, is satisfactory. In the tank below, several tilapia fish take refuge behind the tubes. The Tilapia also eat waste – and store its nutrients in their bodies. Hauslage calls them ‘nitrogen-reservoirs’. “These fish are tough.” Their excrement goes through the biofilter, is used by the bacteria, and passed into the water as nutrients.

The biofilter has already demonstrated its capability in initial tests. Diluted urine, finely shredded plant waste, chopped food residues – these are all things that the bacteria in the tubes have broken down and used. The more frequently this murky sludge flows over the rocks and their inhabitants, the cleaner and more concentrated with nutrients it becomes. Six litres of gravel can convert two litres of urine into valuable nitrates in only three days. Intestinal bacteria are reduced considerably because the climate in the C.R.O.P. system makes their life difficult – they die and their remains are consumed and recycled by other bacteria. The C.R.O.P. team – Jens Hauslage, Kai Waßer and Gerhild Bornemann – has already used the nutrient-rich water produced by the biofilter to fertilise peppers, lettuce, tomatoes, cucumbers, basil and parsley. They have used the enclosed life support system to grow tomatoes and chilli plants – from seed to fruit. A start has been made, and now C.R.O.P. will be further developed at the DLR :envihab (environmental habitat) research facility. The team wants to determine which substances can be broken down, the efficiency of the biofilter, where it might be used and how a functioning system for agriculture, for example, can be derived from the laboratory system.

#### Tests in the greenhouse at Bonn University

A change of location – between Rheinbach and Meckenheim, in the :agrorhort research organisation on the Klein-Altendorf Campus of Bonn University, is an 800-litre canister that smells of cabbage. Ten kilograms of shredded cabbage are added to this C.R.O.P. system each week, where they are converted into a nutrient-rich fertiliser by the bacteria in the rocks. After just one day, the strong smell of cabbage disappears, and two to three days later, the cabbage residue is broken down. The water tank is now filled with a fertiliser fluid that contains the nutrients from the decomposed cabbage, ready for the next generation of plants. The scientists have also turned tomato leaves, apples and lettuce into fluid in the filter. “The biofilter meets reality here,” says Thorsten Kraska from Bonn University. In collaboration with the ‘Regionale 2010 :gardens of technology’ project, :envihab and :agrorhort are investigating whether the C.R.O.P. filter will also prove successful on larger scales and not just in the foyer of the DLR Institute. “Producing one head of lettuce a month is of no use to anyone. We need to address larger scales.”

Thorsten Kraska opens the door to one of several 40-metre-long greenhouses. Rows of tomatoes and lettuce are being grown here for research purposes. Hoses feed water to each individual root system; heating tubes and lamps provide optimum conditions for each plant. For Kraska and Hauslage, this is primarily about one thing – finding and dealing with C.R.O.P.’s teething problems, so the biofilter can make the transition to practical usage. Too much tomato foliage or cabbage residue will clog the pumps that flush the waste and water over the rocks. Leaf diseases in an enclosed system like C.R.O.P.

would recirculate in the fertilising water. Which plants tolerate the nutrient-rich water best? “If we can’t do it here in the greenhouse, we can’t do it anywhere,” says Kraska.

The main aim is to directly use the plant waste from the greenhouse inside the C.R.O.P. biofilter, instead of burning it – so its nutrient-rich water can be reused to fertilise the plants. In this way, waste can not only be usefully recycled, but the use of conventional fertilisers can be reduced. Even manure can be ‘improved’ with C.R.O.P. before being used to fertilise fields. The bacteria in the unit could break down toxic ammonia into nitrates. Until now, soil bacteria in the fields have carried out this work – a burdensome task for farmland.

#### Agriculture, polar research station, space

Using C.R.O.P. in agriculture is just one of the visions that Jens Hauslage and his team want to realise. “Nothing can adapt as quickly as bacteria,” says Hauslage in praise of the inhabitants of the C.R.O.P. filter. Medications and hormone products in drinking water could be specifically broken down with the biofilter. In urban areas, the biofilter system would ensure that, for example, urine is quickly broken down and its nutrients recycled. “A four- to six-metre-long tube with a diameter of 50 centimetres would probably suffice for a 10-person household.” Industrial wastewater and sewage sludge could be pretreated cost-effectively by biofilters. Since C.R.O.P. produces plant fertiliser from waste, it is not dependent on its environment. For this reason, engineers from the DLR Institute of Space Systems in Bremen are developing an automated plant cultivation container. Such containers would be ideal for crisis areas, hostile, harsh regions, research institutes such as Antarctic stations or even for use in space.

At present, DLR scientists are working towards testing the self-contained greenhouses under space conditions and exposing them to varying levels of weightlessness in a satellite on the scheduled Eu:CROPSIS space mission. “Waste from apples is still being disposed of on the ISS, even though it contains important nutrients such as nitrates and phosphates,” says Hauslage, critically. “Also, even though the astronauts’ urine is being used for water recycling, the nutrients are being thrown away.”

#### Eventually, plastic-digesting bacteria

There is one more dream – that someday, bacteria will even be able to break down plastic. “You smash your laptop into small pieces, put it in a biofilter and the plastic is simply broken down,” imagines Jens Hauslage. Bacteria that eat plastic? “They are so enormously adaptable – we should definitely be exploiting this.” For Hauslage, the conventional compost heap has become obsolete. It is much too cumbersome, much too difficult to control. Hauslage is sure that the wet composter, where bacteria break down and use components in the water, is the future. “Water is the new soil.” ●



More information:  
[www.DLR.de/envihab/en](http://www.DLR.de/envihab/en)



The core of the C.R.O.P. life support system are the tubes, each filled with lava rocks. Bacteria consume waste in the tubes. The metabolic products are a valuable source of nutrients for the plants.



The biofilter has already proven its worth in the laboratory at the DLR Institute of Aerospace Medicine. The :agrorhort research institute is now testing the system on a larger scale.





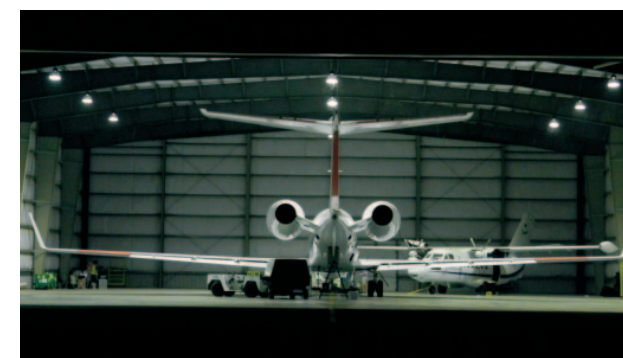
# To the Antarctic and back – in ten days

The HALO (High Altitude and Long Range) research aircraft, which was handed over for science operations in August 2012, has returned from its first long-distance mission. To validate global climate models, HALO completed measurement flights in the northern and southern polar regions, from the Norwegian island of Spitsbergen to the edge of the Antarctic continent, in just 10 days. Managed by DLR, a team of 40 scientists and engineers from Helmholtz centres and universities studied the distribution of trace gases and specific transport processes in the atmosphere. As part of the ESMVal (Earth System Model Validation) measurement campaign, cross-continental sequences of measurements were made and observations carried out from ground level up to an altitude of 15 kilometres in the troposphere and lower stratosphere.

## Long haul with HALO

By Hans Schlager, Steffen Gerns and Andreas Schütz

10 September 2012, Oberpfaffenhofen



The HALO research aircraft at Cape Verde during one of the few stopovers during the measurement mission

**08:00 local time:** Filled to the ceiling of the cabin with scientific equipment, HALO sits on the runway with engines running. The rising noise of the engines disrupts the sunny morning as DLR's Gulfstream 550, D-ADLR, sets off towards the southern hemisphere; or, to put it more precisely, towards the southern polar region – on its first intercontinental measurement campaign. The crew, together with the scientists and engineers, face a 10-day journey with some 65 hours of flying. Ten days that will be technically and physically demanding, during which they will travel to Cape Town via the Cape Verde Islands.

The first stage of the scientific measurements begins after a test flight in Oberpfaffenhofen. The tranquillity in the cockpit is deceptive; weeks of preparations, from planning the flight-paths and discussions with scientists through to technical briefings, are now behind the cockpit crew. The success of the mission depends not least on their skills. In three days, things will get serious.

13 September 2012, Cape Town

**03:45 local time:** The first group gathers in the foyer of the Park Inn Hotel for the trip to the international airport. This team is about to prepare the instruments for the flight into the southern polar region. The flight crew will leave two hours later. It is still winter in Cape Town, and heavy rain is falling as they leave the hotel. There are numerous anxious glances at the sky; hopefully the rain will ease up before take-off. If the air inlets and optical windows for the instruments on HALO get wet during take-off, problems with ice could occur at high altitude, rendering the measurement results unusable. Once at the

The Southern Ocean, covered by ice to the horizon. The crew is fascinated by the view from HALO's windows.

## HALO – a joint project

The HALO research aircraft is a joint initiative involving German environmental and climate research institutions. HALO is supported by grants from the Federal Ministry for Education and Research (BMBF), the German Science Foundation (DFG), the Helmholtz Association (HGF), the Max Planck Society (MPG), the Leibniz Association, the Free State of Bavaria, the Karlsruhe Institute of Technology (KIT), the German Research Centre for Geosciences in Potsdam (GFZ), the Jülich Research Centre and the German Aerospace Center (DLR).





From the Cape Verde islands in the Atlantic off the coast of West Africa, the route carried on to Cape Town. HALO on the taxiway at Sal International Airport.



The HALO cockpit during the mission – even for DLR test pilot Michael Grossrubatscher, it was a very special mission.

Diversion on the night flight – fashion show in a survival suit

hangar, they start work immediately. Not much is said at this early hour. The hand movements are almost automatic. Only the coffee machine in the hangar is not still, running at full speed. Two units must be filled with liquid nitrogen that will cool the detectors to a temperature of minus 196 degrees Celsius. And it was not easy to get liquid nitrogen in Cape Town.

In an office next to the hangar, the latest weather forecasts are downloaded from the Internet. The weather towards the South Pole is good, with no headwind. HALO's flight to the edge of the Antarctic continent must be planned in such a way that, in the event of an engine failure or a loss of cabin pressure, they can make it back to South Africa safely, at low altitude, by following the appropriate return flight path. An emergency landing in Antarctica is not an option – it would be too much of a risk.

**06:00 local time:** The cockpit crew arrives at the airport from Cape Town. Because of the planned flight time of more than 10 hours, careful attention must be paid to their maximum permitted working hours. A sudden wave of anxiety rises shortly before HALO rolls out of the hangar. Two of the instruments on board are not working properly. Several colleagues work feverishly on the devices. It is no longer possible to get through the cabin. There is no unnecessary panic, just no room for any mistakes. Only bits of what is being said can be made out. Finally all the equipment is working correctly. The weather has relented as well – the rain has almost stopped, which makes things easier. HALO is taken to be refuelled, and the crew must head to passport control at the other end of the airport. There is some surprise among the participants, but this flight to Antarctica with no stopover is regarded as an international departure by the South African authorities.

**08:00 local time:** There is a tense atmosphere in the cabin during take-off. The scientists look at the instrument monitors, which are showing housekeeping data. Is all the equipment working properly? After half an hour their faces relax – everything is OK. As HALO approaches the Antarctic continent more than four hours later, there is time to take a look out of the window. The Gulfstream is now flying at an altitude of almost 15 kilometres. Beneath the aircraft, endless ice sheets and several low cloud fields can be seen. A deep blue sky stretches out above the white surface, making for a breathtaking view.

The ground team can track the flight path via a satellite link and stay in contact with the on-board crew. HALO reaches the air masses of the southern polar vortex. The ozone hole forms here at this time of year; it is caused by chlorine and bromine compounds, emissions of which are now banned. The HALO instruments are measuring an increased concentration of

hydrogen chloride, which is formed by chemical processes in the ozone hole. Thin, elongated tongues of air, known as air mass filaments, have detached from the polar vortex – very interesting. The tension dissolves; the scientists on board and on the ground are in high spirits in light of the data sampled.

The hours on the flight back to Cape Town pass slowly. Tiredness spreads through the cabin. Time for a change; laughter ripples through the cabin as student Isabell Krisch, who is using this measurement flight to get a bit closer to obtaining her Master's degree, tries on an orange survival suit.

**18:30 local time:** After more than 10 hours in the air, HALO lands safely in Cape Town. At a short debriefing in the hangar, everyone agrees the effort has paid off. The mission has been followed in great detail from afar – at the Berlin Air Show. The flight was followed online for hours. Relief spreads there as well, when it becomes clear that D-ADLR is safely back. After the mission, the crew and aircraft have had a lot taken out of them.

Late in the evening in Cape Town, everyone meets for a beer on the hotel's roof terrace. The view of Table Mountain from here is marvellous. Someone remarks: "We have a truly amazing and exciting job."

15 September 2012, Cape Town

**08:00 local time:** The return flight to Oberpfaffenhofen takes off two days later, over the Indian Ocean. First, HALO flies nonstop to the Maldives, past Madagascar and over the Seychelles. Here, a large storm has to be given a wide berth. Shortly before leaving the cruising altitude of 14 kilometres, there is a breathtaking view – the Milky Way, like a painting on the night sky; countless meteors and sporadic sheet lightning in a distant tropical storm make for a truly surreal atmosphere.

As the crew lands at Male International Airport, they are greeted by temperatures of over 30 degrees Celsius. The high humidity of the tropical air immediately causes condensation to form all over HALO. The nearly 10-hour flight at high altitude and a temperature of minus 70 degrees Celsius has completely cooled down every surface. Even the next day, water droplets continue to fall from the wings.

18 September 2012, Male

**08:00 local time:** Three days later, HALO takes off from Male on the penultimate leg of the journey, over Oman, Saudi Arabia, Syria and Lebanon, and on to Cyprus. Syrian airspace

was flown over at the greatest possible altitude for safety reasons, and the descent to Larnaca only started once over Lebanon. Two days later, the news broadcast confirm that this flight plan was exactly the right one; there were heavy air strikes by the Syrian Air Force in the regions HALO flew over.

19 September 2012, Larnaca

**08:30 local time:** The last flight leg takes HALO from Larnaca, past Crete, over Sicily past the smoking Mount Etna to Corsica, then turning north to head back to Germany.

**16:00 local time:** HALO lands at its home airport in Oberpfaffenhofen.

Thanks to meticulous logistical preparation, the commitment of all those involved and a bit of good luck, HALO was able to demonstrate its outstanding capabilities on this first major trip. Even with all the external instrument attachments, the research aircraft travelled at altitudes of up to 15 kilometres for long stretches – as far and high as had been dared to think possible during the aircraft's design phase many years earlier. Also, HALO proved itself to be very reliable; it was possible to take off for every flight according to plan.

At the end of the ESMVal mission, everyone involved met up in the hangar in Oberpfaffenhofen for a final debriefing. This measurement campaign had been planned for a long time. Numerous technical and logistical problems had to be overcome. But now there are happy faces all around, without exception. Bring on the next mission... ●

About the authors:

Hans Schlager is head of the Atmospheric Trace Species Department at the DLR Institute of Atmospheric Physics in Oberpfaffenhofen and leads the ESMVal flight missions. Steffen Gemsa is a member of the DLR Flight Experiments Facility in Oberpfaffenhofen and is a DLR test pilot.



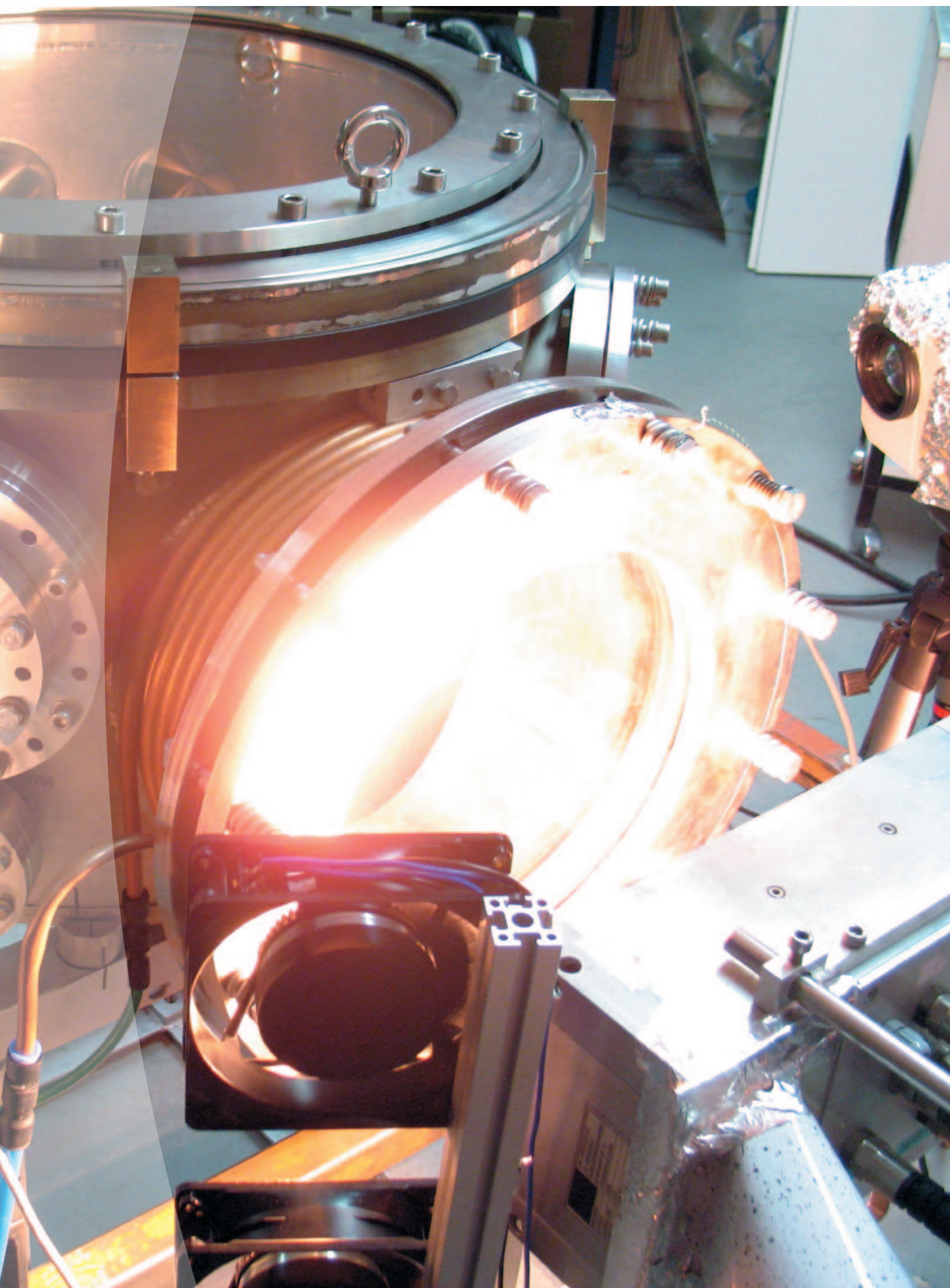
More information:  
<http://s.DLR.de/06qi>



From a cruising altitude of 15 kilometres, the curvature of the horizon is discernable.

HALO lands in Cape Town. The measurement flight over the Southern Ocean is complete.





# Outer space in the lab

When the large vacuum chamber is moved out of the cellar of the solar furnace building and into the testing area, a very special experiment is about to take place. What is under investigation is not related to renewable energy, but rather has to do with space applications. Components for spaceflight have been tested at the DLR Solar Furnace in Cologne for a decade and, since 2007, in the high-flux solar simulator as well. Why? Since the components to be investigated will be subjected to space conditions in future, it makes more sense to use the Sun as the source of energy, instead of fossil fuels or lamp arrays. In tests of individual components such as solar cells, insulation layers or protective covers, this mostly involves the ability to resist the severe, prolonged thermal loads and exposure to ultraviolet radiation that occur in space. The DLR researchers' customers are European spacecraft manufacturers, such as EADS Astrium in Toulouse, Thales Alenia Space and the European Space Agency, ESA.

## Space experiments in the DLR Solar Furnace

By Gerd Dibowski

When vacuum technology was introduced to the solar furnace at DLR's Cologne site over 10 years ago, the DLR engineers had a vision. After coming into contact with scientists at the DLR Institute of Space Physics, the idea of using the solar furnace for space experiments came to life. In the solar furnace, relatively large areas are exposed to high levels of radiation, and the solar spectrum can be quite closely reproduced. Other space simulation facilities, however, allow irradiances of just a few solar constants and only use lamps.

The first space experiment goes back to a collaboration between the Planetary Sensor Systems section at the DLR Institute of Planetary Research and the Institute of Geology and Mineralogy at the University of Cologne. The aim of this project was to investigate the potential for acquiring oxygen through thermal decomposition or pyrolysis of lunar rock – in this case chondrules, spherules in meteorites, which were formed in the solar protoplanetary nebula. The experiment showed that this material could be melted using concentrated solar energy.

Once the capabilities of the solar furnace had been successfully demonstrated in a smaller vacuum chamber, a significantly larger chamber – more than one metre in diameter – was procured and improved, giving way to more space experiments.

### Tests for the BepiColombo mission to Mercury

The chondrule oxygen experiment was followed by the most extensive series of tests to date – for multiple components of BepiColombo. This spacecraft is scheduled to fly to Mercury in 2015, where it will investigate the planet's geological, magnetic and atmospheric conditions. All previous ESA interplanetary missions have been sent far from the Sun, so the technology has always been exposed to very low temperatures. And this is the specific challenge – BepiColombo is the first ESA mission to deliver a spacecraft into a very hot region. Once in Mercury orbit, the side of the satellite turned towards the Sun will be extremely hot, while the opposite side will be extremely cold. The external components of the spacecraft must be able to withstand around

## Research with solar energy

A total of some 180 experiments have been carried out in the solar furnace since it was commissioned in 1994. The focus has been on solar chemistry and materials research. Decomposition of waste sulphuric acid, recycling of aluminium, solar production of hydrogen and knowledge of the ageing process of automotive paint are typical applications for the research conducted outside the area of renewable energy.

Solar cell for BepiColombo during an endurance test. It is exposed to a high thermal load in vacuum using a special infrared light source.



## Test facility for extreme conditions

DLR researchers are using the high-flux solar furnace and the xenon high-flux solar simulator to test new technologies. For this, they are working with concentrated sunlight and artificial light, enabling radiation strengths of up to five megawatts per square metre and temperatures of up to 2000 degrees Celsius. Researchers and application specialists from academia and industry have a wide range of options for developing and qualifying processes in which concentrated solar radiation is used. This particularly involves the chemical storage of solar energy and its application in high-temperature chemical and metallurgical processes.

10 solar constants, that is, 10 times the solar radiation in Earth orbit. Such high thermal loads can be particularly well reproduced in a solar furnace. Although the spectrum is not quite the same as at Mercury, due to the influence of Earth's atmosphere, it simulates space conditions much more realistically than the artificial light sources previously used in the aerospace industry for tests of this kind.

Also appreciated by the aerospace industry is the advantageous size of the solar furnace for testing individual spacecraft components. Hiring a vacuum chamber and the associated services for testing individual components when an entire satellite will fit into it – as is the case with the Large Space Simulator (LSS) at the ESA ESTEC Test Centre in Noordwijk, the Netherlands – entails considerable expense. As the largest vacuum chamber in Europe, with a diameter of 10 metres and an installation depth of 15 metres, the LSS is simply too big to conduct long-term stability tests for individual solar cells only a few tens of centimetres across.

The first task in the development of the BepiColombo mission was to carry out thermal tests on two different samples of the solar cell structures that will be used on the spacecraft. The cells, measuring 20 by 20 centimetres, had to be uniformly

## The xenon high-flux solar simulator

A high-intensity artificial light source based on elliptical reflectors and short-arc xenon lamps enhances the solar furnace during the winter, when there is insufficient solar radiation, and for long-term experiments. The shortwave radiation emitted by the source, which has an output of around 25 kilowatts, is delivered as concentrated energy at a distance of three metres, over a target area of 100 square centimetres and with a power density of up to 4.1 megawatts per square metre.

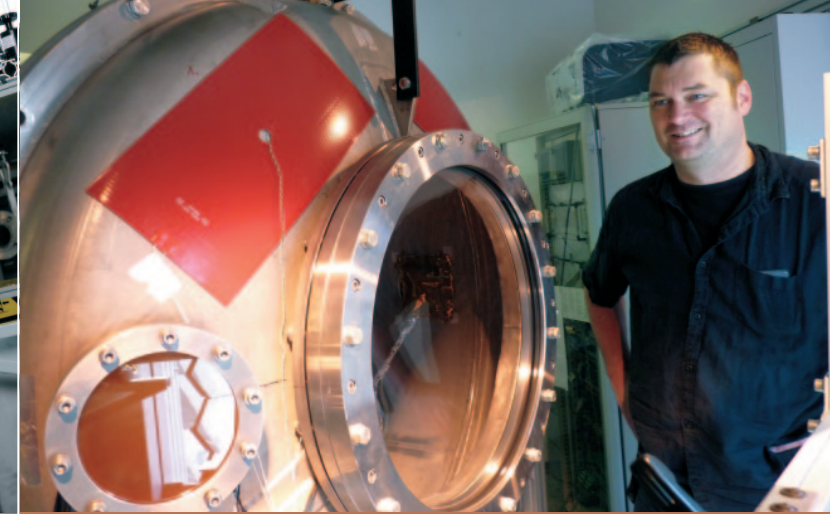
irradiated at an intensity of up to 10 solar constants (about 14 kilowatts per square metre), matching the conditions in Mercury orbit. Both endurance and thermal shock tests were carried out. During the course of this series of tests, systems to help replicate the conditions to be encountered as realistically as possible were developed and built by the solar furnace team. A cooling system to simulate the extreme temperature difference between the forward facing and rear sides was needed, so the DLR engineers at the solar furnace developed a system that could be used to simulate the actual temperatures – down to minus 150 degrees Celsius – to which the BepiColombo solar cells will be exposed.

### Long-term irradiation of solar cells simulates conditions near the Sun

For specific experimental requirements, the test environment is frequently not suitable for directly simulating the actual conditions required. So, during the 18 years that the solar furnace has been operating, there has been continuous improvisation, conversion, repair and, especially, new construction. For the solar cell tests, the engineers developed an experimental setup in which two cooled hollow chambers are symmetrically opened to slowly expose the enclosed solar array to the radiation. The



Engineer Christian Willsch, solar furnace operations, in front of a test set-up for radiation flux measurement devices.



Christian Raeder beside the large vacuum chamber. Radiation enters through the circular quartz glass window.

unit has a system of channels that can be fed with liquid nitrogen. Sensors on the pump ensure a constant level of nitrogen within the cooling unit.

To make the tests as comprehensive and reliable as possible, the loads on the solar cells for BepiColombo have to be examined at the optical boundary of the visible spectrum. The solar furnace system also provides artificial light sources for this if specific parts of the spectrum cannot be adequately filtered out. The artificial light sources are also an important prerequisite for long-term tests.

Prolonged thermal or infrared loads on the solar cells were investigated for the BepiColombo project. To achieve this, harsher conditions than those expected for the actual mission were established. This is intended to ensure that this extremely important component has sufficient 'stability reserves'. To achieve this, the test cells were irradiated with an infrared high-flux light source under vacuum conditions for 1000 hours, or 42 days, non-stop. The researchers set the target temperature at 250 degrees Celsius, which was increased by another 50 degrees over the final 10 hours. In addition, the surface temperature distribution during the heating phase was observed with an infrared camera.

En route to Mercury, the solar array will also be exposed to ultraviolet light. There is a particular threat of damage to the solar cells from radiation at this wavelength, which could possibly lead to a complete failure of the power supply. It must be ensured in advance that this assembly can survive heavy loads for extended periods without being damaged. In the initial test phase, the arrays were irradiated with concentrated ultraviolet light to determine the maximum operating temperature.

In the second test phase, six solar cell modules were irradiated with 2000 esh (equivalent sun hours). 'esh' is the annual energy input divided by the maximum radiant flux. This means that, with double the irradiation than that on Earth's surface, the exposure time for the solar cells is halved for the same energy output. Six to 10 times the radiation load can be expected for the trip to Mercury, leading to a 2000 esh performance requirement for the solar array, or an exposure time of six days non-stop. Hence, this experiment was not carried out using the solar furnace, but using a special high-pressure ultraviolet lamp delivering 460 watts in UV A and 50 watts in UV B via a parabolic reflector. The harshness of this radiation was clear as the reflective layer on the paraboloid began to disintegrate towards the end of the test. But the irradiated solar cells had to remain undamaged.

### Most recent test shows radiation resistance of aluminium and titanium

The most recent space test in the solar furnace ended in the summer of 2012, following six months of irradiation. In the tests under the optical space component (CSO) programme's 'Solar Irradiation Test for the CSO MLI Blankets and Coatings', run by the Centre National d'Etudes Spatiales (CNES) in Toulouse, various materials such as aluminium, titanium and multi-layer insulation with special coatings were tested for their resistance to concentrated radiation. In doing so, not only were flux densities that occur in space simulated, but also the absence of convection cooling of the samples in the vacuum of space. The substantial challenge here consisted of precisely maintaining the specified test parameters such as the duration and intensity of the radiation. Power densities of 17 to 230 kilowatts per square metre were applied. The effect of very high power densities on the samples could be seen after the experiment – their colour and structure had changed, or they had become brittle.

The aim of the test campaign was principally to determine precisely how much material evaporates from such coatings. To do this, 'witness plates' were placed in the vacuum chamber. These are highly polished metal discs that are cooled and so adsorb the outgassing products coming from the irradiated sample. This deposit can be qualitatively and quantitatively identified using spectroscopic techniques. To achieve the highest possible accuracy, an 'empty test' had to be conducted first, to determine the level of contamination due to the chamber itself. Furthermore, the contamination of the chamber was minimised by means of an extensive cleaning process, including a three-day bake-out phase.

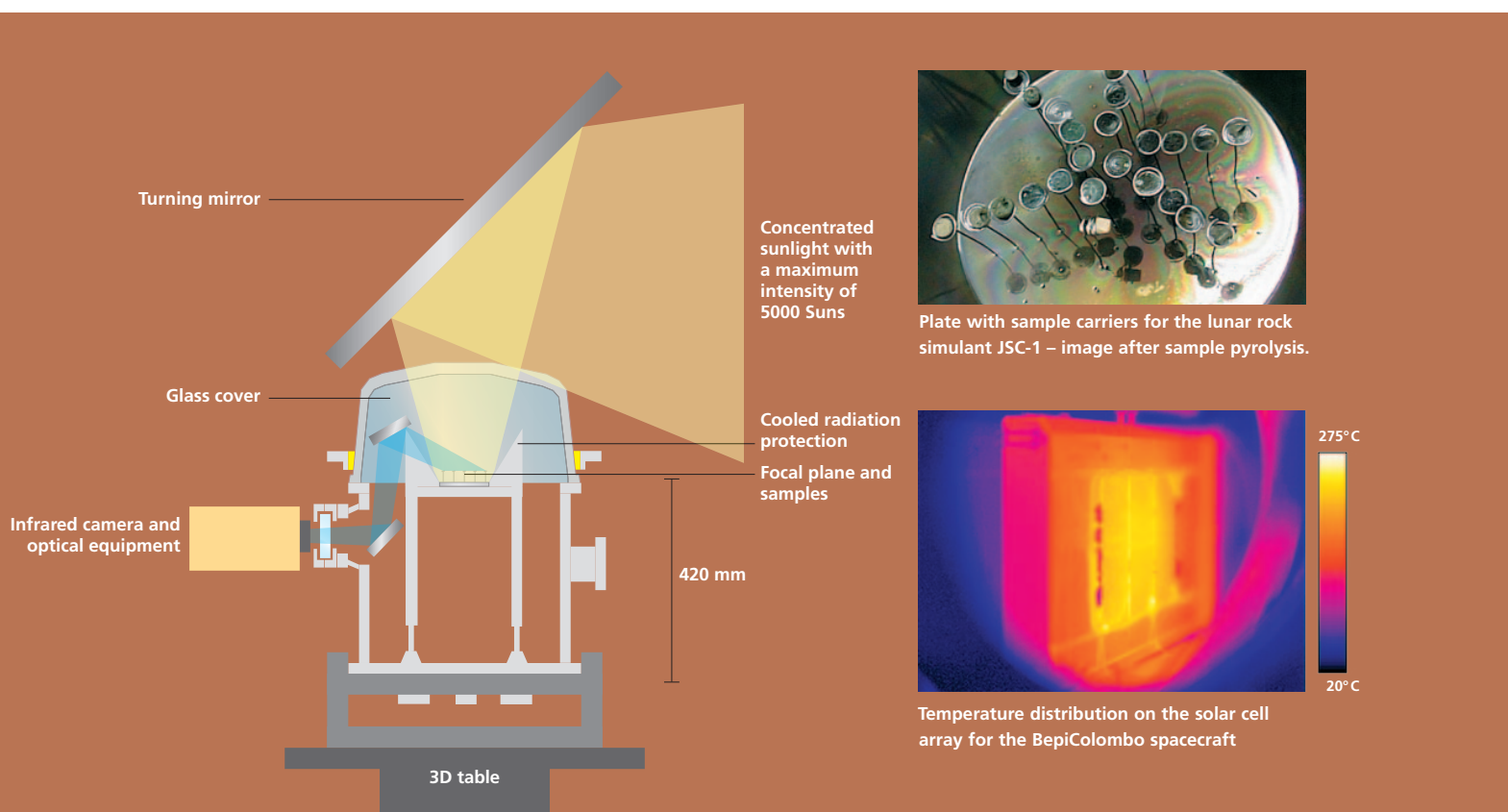
The flux density measurement technology developed by DLR's engineers is a worldwide leader. The especially high requirements of customers in the aerospace industry with regard to the precision of these measurements also led to improvements in the solar furnace systems. These are now, in turn, benefitting experimenters from the original core area of renewable energy sources. ●

### About the author:

Gerd Dibowski is a mechanical engineer with an education as an electrical craftsman who has contributed to the construction of the solar furnace and the high-flux solar simulator. Following a number of years in experimental operation, he has been head of the large solar furnace facility since 2006.



**More information:**  
<http://s.DLR.de/3p60>





# A curious collection

The Natural History Museum (Museum für Naturkunde) in Berlin was founded on the Unter den Linden in 1810. By 1880, the collection filled up two thirds of the Berlin University Building – it was bursting at the seams. Kaiser Wilhelm II personally opened the new museum building on the Invalidenstraße. Since then, the Natural History Museum has been successfully pursuing two main goals – collecting and researching. Over 30 million objects are showcased in the public exhibit area or slumber in collections that can only be accessed by researchers: 10 million invertebrates, 15 million insects, 130,000 fish, 180,000 mammals, 120,000 audio recordings in the animal noise archive – and the list goes on. Amazingly, throughout its 200 years of existence, the institution has succeeded in maintaining the atmosphere of a time in which museums educated and amazed the public.

## A stroll through the Natural History Museum in Berlin

By Manuela Braun

Ambatoarinite from Abi-Kambana, Madagascar; phos-genite from Monteponi, Sardinia; shimmering green malachite from the Shaba province in the Democratic Republic of Congo; or simply iron from Bühl near Kassel in Hessen. These wonderful names bear witness to things near and far. The mineralogical-petrographic collection at the Berlin Museum of Natural History holds 312,000 samples. Although one would expect the room to smell of history, dust and times gone by, the current cleaning staff will not allow this.

Still, the awe-inspiring cabinets filled with carefully labelled displayed items transport visitors back to the nineteenth century. Small knobs adorn the wooden cabinet frames, behind the panes of which the various minerals are presented. Some documents or exhibits are stored on pull-out shelves. Very special exhibits, such as a giant, violet amethyst from Brazil, are enthroned on dark wooden pedestals. Every cough and sneeze, however small, echoes loudly through the tall room.

### Close to the bone

But the largest exhibit in the Natural History Museum will not fit on a wooden pedestal. The head of a Brachiosaurus skeleton, towering 13.27 metres in height, looks tiny above the dinosaur's mighty torso. It is only by bending your head back and looking upwards along the thin, skeletal neck that you can see where the brain of this ancient animal once was. A 400-kilogram heart once beat in its chest. This remarkable specimen, the largest complete dinosaur skeleton in the world, was discovered during an expedition to Mount Tendaguru in today's southeast Tanzania, between 1909 and 1913, after which 250 tons of fossilised dinosaur bones were brought back to Berlin. An official certificate states that this Brachiosaurus has been awarded a Guinness World Record. The giant bones of the herbivore, which take up nearly the entire length of the main hall's opaque glass ceiling, look like polished wood.

The Museum avoids overwhelming people with vast numbers of facts. The label for the Brachiosaurus explains the dinosaur's immense dimensions – as tall as a four-storey building and as heavy as 10 adult elephants. At the time of its death, the creature would have weighed around 50 tons. This vivid comparison of the dinosaur with elements that visitors are familiar with gives a clear sense of the scale of the animal.

The Museum of Natural History also skilfully manages to bridge the gap between old exhibits and modern requirements. Besides avoiding tedious facts, the Museum has marshalled technology to convey information. An excellent example is the 'Jurascope', a pair of binoculars that, when pointed towards a skeleton in the hall, identifies which dinosaur you are looking at. Then, an animation begins in which the dinosaur is virtually covered in flesh, from joint to joint. Finally, the visitor can see the complete animal walking and grazing through a simulated landscape.

Another example of the use of modern techniques can be seen at the display of the relief-like fossil of the primitive bird *Archaeopteryx lithographica*. By alternating the direction of the light – sometimes from the left, and sometimes from the right – the primitive bird looks more vivid and almost lifelike. Not bad for the 150-million-year-old link between birds and dinosaurs.

### Journey into space

The Museum even introduces its visitors to the wonders of the Universe – using a very unique method. Space enthusiasts can lie down on a large, round bench in a darkened room while an image of space is projected onto the dome above. A comforting voice narrates how the Universe formed and what the various planets are made of. The light stays dim throughout – the illuminated planets on pedestals and the light from the space film become the only points of reference in the room. This provides the perfect atmosphere to lie back, relax and take in the images and facts, as well as giving the visitor an opportunity to rest during the museum visit. Afterwards, one can marvel at the bits of meteorites – pieces from space – in small illuminated cases.

### The illuminated 'wall of life'

Each gallery has a different atmosphere – after travelling through the Universe, the multi-metre high 'Biodiversity Wall' rises before the visitor. This mosaic of colourful animals, ranging from fish, starfish and crocodiles to snakes, birds and butterflies offers a tantalising glimpse of nature's enormous diversity of species. The size of the exhibit makes it hard to see everything at a glance, which is why the Museum has provided a small version so that you can take a closer look at the animals that you are interested in on a table with a magnifying glass.



The Museum is particularly well known for its 13-metre-tall dinosaur skeleton, which has made it into the Guinness Book of World Records.

Images: Museum für Naturkunde





Whether it is crocodiles or corals, the Biodiversity Wall gathers all that creeps or flies.



Gems, such as the enormous amethyst from Brazil, can be seen in the Mineral Collection.



Awe-inspiring cabinets display the collections – dust free.

Visitors find themselves standing in front of Tasmanian tigers, zebras and the now extinct quagga. Standing eye to eye with a life-sized kangaroo makes you realise that these animals are not so much cute as they are impressive. Turtles, penguins and seals float as if swimming through the air – the outer skin can be seen from one side of the display cabinet; from the other, the skeleton is revealed. Body parts that look almost identical from the outside turn out to be completely different. The fin of a sea turtle displays the bone structure of a reptilian leg, a seal has the cursorial legs of a mammal, and a penguin has the wings of a bird. Clearly, one fin is not the same as another.

Moving on, brief inscriptions explain that the two-spot ladybird continues to be a two-spot ladybird even if it has more spots or is black instead of red. It is more down to the temperature of the region the ladybird inhabits than the range of species. You can see how similar humans and apes are by looking at the skeletons of both on high pedestals at the end of the hall. Ape on the left, human on the right, and into the next hall.

**From the inside out**

Next comes the ‘Preparation Techniques’ exhibit – though not as aesthetically pleasing, truly fascinating. The beautiful animals on the Biodiversity Wall used to be alive before they were prepared for display in the Museum. Passing a skinned squirrel – you are forced to quickly accept the unsettling sight of a squirrel, with its fur next to it – and then move on to see a dead bird and preserved fish. Not a pleasant sight, but a window to the activities that take place in a museum of Natural History.

Those who have ‘survived’ the small, skinned animals go on to see Alfred Keller’s insect models. Never did a female mosquito look more threatening in flight than as a model the size of a small dog. Even more impressive is the treehopper, with odd, spiny appendages on its head that make it look like something out of a science fiction film. Just six millimetres long in nature, but here enlarged by a factor of 100, the 1950s plastic model shows the bizarre beauty of the *Bocydium globulare*.

**Inhabitants of a cabinet of horrors**

Towards the end of the tour we encounter 81,880 litres of alcohol poured into 276,000 glass containers – the ‘Wet Collection’. At a room temperature of 15 to 18 degrees Celsius, shelves upon shelves of containers reach up to five metres in height. The overhead light is reflected in the elongated glass walls containing a cabinet of horrors: goggle-eyed fish pickled in alcohol, squinting at onlookers; a hammerhead shark, looking sceptically through the glass; dumbfounded stingrays and reptiles. Once again, you feel like you have been transported back to the nineteenth century. However, this part of the research collection belongs to the new wing of the building, which was completed in September 2010.

The Museum has not let 200 years of history gather dust; the collections of Johann Centurius Graf von Hoffmannsegg and Siberian explorer Peter Simon Pallas, of the Baron of Schlotheim, Leopold von Buchs, and of Alexander von Humboldt still hold their own. And it is not incongruous that the exhibits of the Gazelle expedition, the Valdivia deep sea expedition and the Tendaguru expedition to Tanzania rub shoulders with space exploration or the multimedia globe in the ‘System Earth’ exhibition. Humboldt would surely have been surprised at today’s technology – but the Berlin Museum of Natural History of 2013 would certainly have gained his approval. ●



Reptiles and fish are preserved for eternity in the Museum’s ‘Wet Collection’



The Museum holds 200 years of history. Thirty million objects make up the collection that is housed in this venerable building on Invalidenstraße in Berlin.

**Museum für Naturkunde**  
Invalidenstraße 43  
10115 Berlin  
[www.naturkundemuseum-berlin.de/en](http://www.naturkundemuseum-berlin.de/en)



**Opening hours**  
Tue to Fri: 09:30 - 18:00  
Sat, Sun & holidays: 10:00 - 18:00  
Mon: closed

**Admission**  
Adults: 5 Euro, Children: 3 Euro

**Contact**  
Telephone +49 (0)30 2093-8591  
E-mail: [info@mfn-berlin.de](mailto:info@mfn-berlin.de)  
Guided tours: +49 (0)30 2093-8550



From jar to jar - amazing creatures, one after the other.



# Reviews

## The Universe – ours to discover

In honour of its fiftieth anniversary, the European Southern Observatory (ESO) has issued **Europe to the Stars**, a wonderful volume that provides a unique insight into ESO's quest to explore the heavens. The dream of an advanced observatory in the southern hemisphere that would re-establish Europe's leading role in space exploration was first advanced by Walter Badde and Jan Oort in the fifties. It was realised in 1962 with the signing of the ESO convention by its founding members: Belgium, France, Germany, the Netherlands and Sweden.

Having established their headquarters in Germany (first in Hamburg, then in Garching, near Munich), the search began for the perfect location for the new observatory. After extensive scouting, La Silla in Chile was chosen as the prime location, where, in 1969, ESO was officially inaugurated. Since then the observatory, expanded to include the Very Large Telescope (VLT) at Cerro Paranal and the Atacama Large Millimeter/submillimeter Array (ALMA), has been instrumental in the huge technological and scientific discoveries that have so significantly advanced our understanding of the Universe.

The book and accompanying DVD take the readers and viewers on a comprehensive guided tour of ESO's history, technological advances, and visions for the future visual exploration of space. The amazing photographs, including a number of impressive fold-out pictures, convey an acute sense of the vastness of the skies and the harsh and desolate landscape from which scientists unveil the mysteries of our Universe – one step at a time.

Merel Groentjes

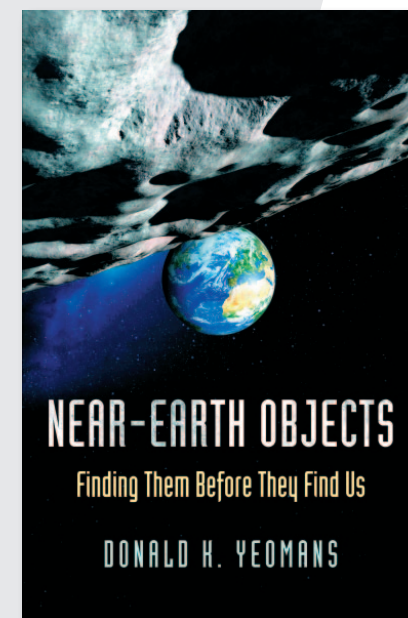


## Extrasolar planets

Scientists are on the lookout for extrasolar planets every day. To date, 869 have been found and confirmed, and no two are alike. Some are small, Earth-like planets, while others are roughly 30 times the size of our largest planetary neighbour, Jupiter. How are these planets found? The **Exoplanet app** is an excellent tool for learning about exoplanets, near and far. From background information on discovery methods to a comprehensive catalogue of all the exoplanets found – confirmed and yet to be confirmed.

Fly into the Milky Way and zoom into a planetary system. You will see animations of the planets as they move around their star. Choose a planet and see its size compared to our own planetary neighbours. This app gives you all the known parameters of the planet, which are updated on a daily basis. An added feature is a Correlation Diagrams option, where the user can create personalised charts according to the parameters chosen, and even export it as a file that can be printed out and shown. Last but not least, an Exoplanet News section provides links to scientific papers and articles discussing the latest discoveries. It's educational, free, informative and a great reference source for anyone interested in the search for planets around other stars.

Karin Ranero Celius



## Tracking down rocks in space

We live on a dynamic Earth, where we are subjected to volcanic eruptions, tropical storms, earthquakes and more. But of all the natural disasters that can affect us, only an impact by a large comet or asteroid – a Near-Earth Object (NEO) – has the potential to change all of civilisation forever. **Near-Earth Objects: Finding Them Before They Find Us** introduces readers to NEOs, the potentially hazardous objects that could provide an insight into the origin of the Solar System and also serve as stepping stones for space exploration.

Our Solar System is populated by millions of comets and asteroids. Many of these pass close to Earth in the course of their journey around the Sun. This book provides a reader-friendly and up-to-date guide for understanding the threats posed by NEOs. But just as they can destroy all around them, collisions during Earth's early history also delivered ingredients that might have led to the origin of life. The impacts also boosted evolution, ensuring that only the fittest survived.

The reality of what an impact may mean for us for centuries to come motivates scientists to track these objects down. This book takes the reader behind the scenes of today's efforts to find, track, and study NEOs. Donald K. Yeomans is keen to explain the potential benefits and resources we can get from these dangerous objects – such as obtaining water and oxygen, and using them as fuelling stations for expeditions to Mars and the outermost reaches of the Solar System. With this in mind, it's time to find Near-Earth Objects – before they find us.

Peter Clissold

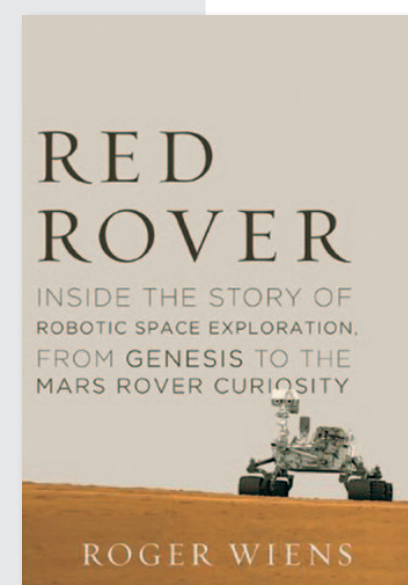
## Exploring Mars

Is there life elsewhere in the Universe? **Red Rover: Inside the Story of Robotic Space Exploration, from Genesis to the Mars Rover Curiosity** explores this long-standing open question. Mars, our closest planetary neighbour, has always inspired great curiosity, and has been one of the prime targets for exploration in our Solar System – both to evaluate it as a destination for mankind and to investigate the possibility that it could harbour life as we know it. To answer questions, researchers have sent various types of probes – from observation satellites through to rovers.

While studies of the suitability of the Martian surface for manned exploration continue, researchers recently successfully landed their latest explorer – Curiosity – a Jeep-sized space laboratory. In Red Rover, Roger Wiens, the Principal Investigator for the ChemCam laser instrument on Curiosity and a veteran of numerous robotic NASA missions, tells the story of how he contributed to the development of various robotic probes that made it to space. The reality of space exploration – tight deadlines, slim budgets and the threat of a shutdown – makes creative engineering and human ingenuity a must. All the hard work pays off as those involved in the missions live the critical moments of launch, voyage through space and entry into 'unknown' territory. Wiens' detailed description of the events taking place during Curiosity's arrival and descent to Mars will keep you on the edge of your seat.

From Genesis to Curiosity, this book gives an enthralling account of the behind-the-scenes of human achievements in space – past, present and future.

Karin Ranero Celius





## About DLR

DLR, the German Aerospace Center, is Germany's national research centre for aeronautics and space. Its extensive research and development work in aeronautics, space, energy, transport and security is integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space programme. DLR is also the umbrella organisation for the nation's largest project execution organisation.

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

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