A FUTURE WITHOUT CONTRAILs?

HOW TARGETED FLIGHT ROUTE PLANNING CAN REDUCE THE CLIMATE IMPACT OF AVIATION

More topics

- DIVERSITY IN THE TANK
  FAQs on Sustainable Aviation Fuels (SAF)

- NEW IMPETUS FOR RAIL
  High-tech railbus gives disused routes a new lease of life
WHAT IS NEW?

Every two years, the global aerospace community gathers at the International Aerospace Exhibition (ILA) at Berlin Brandenburg Airport. From 5 to 9 June 2024, the time will come again. DLR is one of the largest non-commercial IALA exhibitors. We will be showcasing our current research highlights – including the ALICIA project – in our DLR stand. ALICIA stands for ‘Aviation Life Cycle and Impact Assessment’. The aim of this project is to digitally assess the climate impact, energy demand and added value of an aircraft from production through to decommissioning. A major aspect of ALICIA is the development of flight deck designs that consider new air traffic management concepts. An exhibit at the DLR stand will explain why this is so important.

Spaceflight will also be represented, with experts on Germany’s contribution to the new European heavy-lift launcher Ariane 6, among others. DLR will contribute to numerous exhibits for the neighbouring Space Pavilion in Hall 4 as well. In addition, experts will be available to provide insights into space missions in which Germany is involved. Part of DLR’s research aircraft fleet will be on display on the airport apron, including the new UpLift research aircraft (D-CUPL) that will be exhibited for the first time. The aircraft will be used to further develop environment-compatible aviation technologies.

We look forward to seeing you there!

Dear reader,

Did you know that nearly half of the climate impact of aviation consists of non-carbon-dioxide effects? These include contrails – the only effect that can be observed in the sky with the naked eye. Most contrails have a warming effect on the climate. Their formation could be reduced by clever flight route planning – leading to an immediate effect on the carbon footprint of aviation.

However, more flexible route planning has a number of consequences. Air traffic controllers must be able to quickly react to changing conditions. New, improved assistance systems, which are being developed at DLR and allow flight route adjustments to be made in real time, can provide support here.

The systems need to be fed with data to enable reliable modelling, for example on weather and climate development. DLR researchers are working on new modelling tools. DLR measurement technology has also been installed in commercial aircraft for 30 years now and provides valuable data on the composition of the atmosphere.

But to significantly reduce the climate impact of air traffic, we need to do more. This is why DLR experts are also focusing on alternatives to fossil fuels. They are researching Sustainable Aviation Fuels (SAFs), that could reduce both carbon dioxide emissions and the formation of contrails. Find out why and how the amount of SAF already produced today could be beneficial and what the market ramp-up of these fuels could look like in the future in our magazine article.

Sustainable fuels are also becoming increasingly important in spaceflight. The fuels developed by the DLR spin-off InSpace Propulsion Technologies are less harmful and easier to handle than the current standard. InSpacePropulsion Technologies is just one of many examples of how DLR is bringing basic research to the market via technology transfer.

Happy reading!

Your editorial team

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

About DLR

DLR is the Federal Republic of Germany’s research centre for aeronautics and space. We conduct research and development activities in the fields of aeronautics, space, energy, transport, security and digitalisation. The German Space Agency at DLR plans and implements the national space programme on behalf of the federal government. Two DLR project management agencies oversee funding programmes and support knowledge transfer.

Climate, mobility and technology are changing globally. DLR uses the expertise of its 54 research institutes and facilities to develop solutions to these challenges. Our 10,000 employees share a mission – to explore Earth and space and develop technologies for a sustainable future. In doing so, DLR contributes to strengthening Germany’s position as a prime location for research and industry.

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Targeted flight route planning for climate-friendly aviation

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The DLR team has worked together with the rail vehicle manufacturer Alstom. In spring, they presented the initial results of a special measuring system for recording low flight speeds, which is fitted with instruments on the main and tail rotor blades, has a rotor head equipped with instruments, and, in future, will have a detachable nose boom. During its time at DLR, it has been used for numerous projects, including research into optimised approach and take-off procedures, testing assistance systems for pilots and autonomous precision landings of paraglider systems.

Using the measurement data from the flights, DLR researchers have been able to continuously expand and improve their computer simulation programs. It also serves as a demonstrator for flight characteristics and performance tests to familiarise young scientists with the special features of helicopter flight tests. The BO105 is stationed at the DLR site in Braunschweig.

CONCENTRATED SOLAR ENERGY

For 30 years, DLR scientists in Cologne have been using a solar furnace to explore how and where concentrated solar power can be used. The large-scale facility consists of a heliostat that aligns itself with the Sun. Harnessing the Sun’s rays, the heliostat concentrates the sunlight into a concentrator consisting of 159 hexagonal mirrors. The concentrator further condenses the radiation by a factor of approximately 5000 and directs it to a focal point within the laboratory building. Within seconds, temperatures of over 2000 degrees Celsius are achieved, with a power density of five megawatts per square metre. This energy is utilised for a variety of experimental applications. The current focus of the experiments is on the storage of solar-generated energy using chemical energy carriers such as hydrogen and sulphur. The stored solar energy can then serve as a sustainable fuel source. Fuels produced using solar energy hold promise for applications in both the transport and heating sectors, offering a means to mitigate carbon dioxide consumption throughout production.

The solar furnace is located at the DLR site in Cologne.

LUNAR CONTROL CENTRE TO BE ESTABLISHED IN OBERPFaffenHOFEN

DLR, the European Space Agency (ESA) and the Free State of Bavaria are planning to establish the Human Exploration Control Center (HECC) for future human spaceflight missions to the Moon in Oberpfaffenhofen, Germany. This involves the expansion of the Columbus Control Centre – from where the operation of the space laboratory is controlled – into a Moon Mission Control Centre. To this end, a new building will be constructed on site. The HECC will support future missions to the Moon and, above all, the operation of the Lunar Gateway from the European side. New operational and deployment concepts for lunar missions are also being developed. In the long term, it will also be possible for astronautical missions into the trans-lunar region, for which AI-based methods and deployment concepts for lunar missions are also being developed. In early 2024, DLR revised its aviation strategy for the European Green Deal, with a focus on non-carbon effects. This offers immense potential for reducing the climate impact of aviation comparatively quickly, especially by implementing appropriate flight routes. This requires a robust policy framework as well as increasing automation and standardisation in aircraft, air traffic management and flight guidance. The new DLR aviation strategy charts the path towards climate-friendly aviation by the middle of the century. To that end, DLR is conducting research across the entire spectrum, together with the aviation industry and research institutions in Germany and abroad – from aircraft concepts and components to low-emission propulsion solutions using sustainable energy sources, all the way through to climate-optimised flight routes and regulatory measures.

© NASA

IN BRIEF

COLOGNE: Twelve individuals will undertake a unique experiment, relinearising for 60 days with their heads tilted six degrees lower than their legs. Beginning in September, they will become ‘terrestrial astronauts’: The DLR Institute of Aerospace Medicine is conducting this new bed rest study to evaluate measures aimed at mitigating postural and movement difficulties after returning from a mission spent in microgravity.

HAMBURG: To ensure robust medical preparedness, the German government has established 61 Medical Task Forces (MTF) throughout Germany that can provide medical care to patients during emergencies. As part of the EUROMED project, the task forces practised their deployment procedures in a run-up to the European Championships. DLR supported the exercise with a camera system, traffic data and pilots.

LAMPOldSHAuSEN: The DLR team has achieved a significant milestone with the inaugural successful test of their in-house developed Liquid Upper Stage Demonstrator Engine (LUMEN). On the European Research and Technology Test Bench P8.3, the pump-fed liquid oxygen and methane engine enables the validation of technologies that can only be tested in a complete rocket engine.

MUNICH: DLR has been collaborating with the United Nations World Food Programme in fighting hunger since 2019. The partnership between these two organisations has recently been extended until 2029. With over two decades of expertise in the field, DLR offers technological assistance in various domains, including fleet management and autonomous vehicles, drones, geoinformation, preventing and forecasting hunger.
EUROPEAN RESEARCH FOR CLIMATE-FRIENDLY AVIATION

Over the past ten years, DLR, alongside numerous industry and research partners, has been conducting intensive research into climate-friendly air transport technologies in a wide range of projects as part of the European aviation research programme Clean Sky 2. The Clean Aviation Annual Forum in Brussels in March 2024 marked its conclusion (2013–2024) and its continuation under the title Clean Aviation. By the end of this year, the programme will have brought together almost 1000 companies from across Europe in high-tech projects, and delivered more than 100 demonstrators and over 1000 innovative technologies.

With its contributions to technology and demonstrator platforms in Clean Sky 2 and now in Clean Aviation, DLR is playing a key role in shaping climate-friendly air transport in Europe. It is particularly concerned with the evaluation and analysis of new aeronautics technologies and their potential. DLR has been involved in a total of 27 projects within the context of Clean Sky 2, including the Multifunctional Fuselage Demonstrator, the Rapid And Cost-Effective Rotorcraft (RACER) demonstrator, the H2FC-WIN project and flight tests with the DLR Falcon 2000LX ETAR.

GERMAN-US GRACE-C ENVIRONMENTAL MISSION EXTENDED

Life would not exist without water and that is why, alongside clean air, it is by far the most important resource on Earth. But groundwater levels around the world are constantly changing. On 17 March 2002, "toon" and "tire", the first two satellites in the Gravity Recovery and Climate Experiment (GRACE) mission were launched by NASA and DLR. Their data have transformed our understanding of how water moves and is stored around the planet.

Twenty-two years later, the German Space Agency at DLR and NASA have extended this mission for the second time with the Gravity Recovery and Climate Experiment-Continuity (GRACE-C), which succeeds GRACE Follow-On (GRACE-FO). Like its predecessors, the GRACE-C will precisely measure small distance changes between the satellites due to gravity variations.

Following the launch of the two satellites, which is expected to take place in 2028, they will be deployed at an altitude of approximately 500 kilometres. As they orbit the Earth, flying one behind the other at an average distance of just 220 kilometres, areas of slightly stronger gravity will affect their positions and hence the distance between them. The extremely precise microwave ranging system will detect these changes and enable the mapping of Earth's gravity field with unprecedented precision.

400 KILOGRAMS OF RESEARCH IN MICROGRAVITY

On 27 February 2024 at 8:27 CET the MAPHEUS 14 high-altitude research rocket, operated by DLR, successfully launched from the Esrange Space Center near Kiruna, Sweden. The high-altitude rocket reached an altitude of 265 kilometres, during which it provided approximately six and a half minutes of microgravity for its scientific payload – a total of 14 experiments which were all safely recovered following landing. The findings from these experiments will benefit future space missions, the development of technology and materials as well as people on Earth.

MAPHEUS 14 was launched using the new ‘Red Kite’ rocket motor – a collaborative effort between DLR and Bayern-Chemie. The second stage of the rocket employed an Improved Malemute, a military rocket motor repurposed for civilian research, also manufactured by Bayern-Chemie. The new Red Kite solid rocket motor serves as both the first and second stage for multi-stage high-altitude research rockets. It is particularly powerful and allows payloads of more than 400 kilograms. This marks a milestone, as this is the first time that the propulsion system of the high-altitude research rocket has been fully developed by Germany.

PICTURE PERFECT – 25,000 ORBITS AND COUNTING!

The European Space Agency (ESA) Mars Express spacecraft has been orbiting Earth’s planetary neighbour Mars, once every seven hours for more than two decades. During orbit number 25,000, the High Resolution Stereo Camera (HRSC), developed by DLR, acquired a rather special image that offers a sweeping view of one of the most geologically interesting areas on Mars: the Tharsis region. The image data was acquired from a distance of 10,500 kilometres and combined with a terrain model based on NASA’s MOLA laser measurements.

The Tharsis plateau is enormous – with an area of approximately 25 million square kilometres, it covers an area roughly the size of the North American continent. Four of the largest martian volcanoes rise into the sky there. The HRSC team – responsible for planning the acquisition of this wide-angle image – even managed to capture the martian moon Phobos passing in front of the Red Planet. Phobos, the largest of Mars’ two moons, is the target of the Japanese-European Martian Movers Exploration Mission (MMX) which is expected to set off for the martian system in 2026, place a rover on the moon in 2029 and bring samples back to Earth in 2031.

For 20 years, the twin GRACE satellites shown in this artist’s impression have been documenting changes in Earth’s gravitational field.

DLR Divisional Board Member for Aeronautics Markus Fischer presents results during the Clean Aviation Forum 2024.

The MAPHEUS 14 high-altitude research rocket lifts off from the Swedish Esrange Space Center on 27 February 2024.
A FUTURE WITHOUT CONTRAILS?

How targeted flight route planning can reduce the climate impact of aviation
by Stefanie Huland and Michael Müller

Air traffic and emissions are rising – and so is the demand to reduce the climate impact of flying. In short, aviation is heading for a massive upheaval. But real improvement has to be about more than alternative propulsion systems and greener fuels. Non-carbon-dioxide effects such as contrails and nitrogen oxide-induced ozone are also adding to change. Avoiding these contributions through clever route planning could be an effective way of reducing the climate impact of aviation.

In 2020, Manchester Metropolitan University published a study together with DLR. It found that aviation accounts for 3.5 percent of human-induced climate change, of which approximately 1.6 percent comes from the greenhouse gas that is probably the best-known driver of global warming: carbon dioxide produced by the combustion of kerosene. The remaining two percent is attributed to non-carbon-dioxide effects, including nitrogen oxides, aerosols, ozone and contrails. Contrails form when the water vapour contained in exhaust gas becomes saturated or supersaturated on contact with the cold ambient air. Water droplets then condense on the soot particles contained in the exhaust gas and freeze immediately in the cold air. If the environment remains sufficiently humid (oversaturated with ice), the contrails will linger for hours, affecting the climate. Contrails have a net global warming effect, especially in the evening or at night. Similarly, nitrogen oxides from aviation lead to the formation of ozone and the breaking down of methane – both greenhouse gases that affect the radiation balance and thus the climate. In some cases, these non-carbon-dioxide effects can last for days, weeks, months or even years, depending on the atmospheric conditions and the processes that they trigger. As such, they are directly related to the flight routes.

Together with air traffic controllers, researchers from the DLR Institute of Flight Guidance in Braunschweig used the ATOMS radar simulator to investigate which tools can support and relieve the workload.

D-KULT
DEMONSTRATOR FOR CLIMATE- AND ENVIRONMENT-FRIENDLY AIR TRANSPORT

D-KULT is testing processes to reduce the climate impact of air traffic. It looks at how we can keep carbon dioxide and non-carbon-dioxide effects, noise and operational costs as low as possible. One key aim is to avoid contrails and reducing non-carbon-dioxide effects at the same time through targeted planning of flight routes – both in simulation and on the basis of real flights. DLR is coordinating the project, with input from the DLR institutes of Atmospheric Physics (coordinating institute), Flight Systems, Air Transport, Flight Guidance and Aerospace Medicine. A number of other organisations and companies are also involved: Germany’s DFS air traffic control agency and DWD weather service, software company Jeppesen, aerospace engineering and information technology company PACE, Deutsche Lufthansa and Lufthansa Systems. Airbus Operations, DHL’s European Air Transport Leipzig subsidiary, the Federal Association of the German Air Transport Industry (BDL) and cross-border air navigation services agency EUROCONTROL. MUAC are associated partners.
How weather conditions affect the climate impact of aviation

Airlines plan routes for their scheduled aircraft and submit them to the responsible control centre for approval. Low kerosene consumption and the shortest possible flight routes are given priority in these plans. At present, parameters such as the environmental sustainability of air traffic are not given the same consideration. The climate impact of these non-carbon-dioxide effects varies greatly depending on the prevailing weather and the 3-dimensional location of the flight trajectory. For instance, long-lasting contrails only form in ice-supersaturated regions. In other words, the route with the lowest kerosene consumption may not necessarily be the most climate friendly. This is where the D-KULT research project comes in (see info box). This LuFo project aims to develop methods and tools to reduce the non-carbon-dioxide effects of aviation.

The role of air traffic controllers after take-off

Airline flight routes are approved by air traffic control and communicated to pilots shortly before take-off. This takes account of fuel consumption and the weather conditions. Nevertheless, last-minute changes are often made at short notice after take-off. Flight paths might be changed owing to unforeseeable weather events or on-board emergencies which require an unscheduled landing. Sometimes, the flight paths of two aircraft might come too close and pose a safety risk, leading air traffic controllers to specify a course correction for one or both aircraft. These corrections can affect flight altitude, direction or speed. The DIAL research project (see info box) focuses on ways in which flight route planning and optimisation can be implemented at the same time in future, taking into account weather phenomena and climate aspects, and how those responsible can be supported. The DLR experts involved are analysing all the key factors influencing route planning in civil aviation and developing algorithms and assistance systems for this purpose.

Reducing climate impact by preventing contrails

In the future, it should be possible to plan flight routes in such a way that aircraft can avoid areas where atmospheric conditions are likely to result in long-lasting, strongly warming contrails. At the same time, the ‘cost’ of these detours should remain within an acceptable range and flights should dioxide not be more harmful to the climate due to increased carbon emissions. This means finding the optimum balance between cost, low kerosene consumption and the most climate-compatible route. Researchers have the challenge of predicting as reliably as possible whether contrails will actually form in a certain area at a specific time. To this end, numerical weather forecasting models are being further developed and compared with observations. Observation data from airliners cannot only be used to evaluate scientific models, they are also required to keep the weather simulated in the models close to reality. This makes it possible for the initial atmospheric state of the numerical simulation – ‘yesterday’s weather’ – to be described more realistically.

Pushing modelling to the limit

The challenge now is to extend these numerical weather prediction models so that they can estimate non-carbon-dioxide climate effects as accurately as possible. For this purpose, findings from climate modelling relating to contrails are among the main non-carbon-dioxide climate effects of aviation. They are the only effect that can be seen in the sky with the naked eye. Depending on where they originate, they may have a cooling or a warming effect, while the warming effect predominates on a global scale. In order to gain experience with the implementation of climate-optimised flight routes, we have decided to identify flight routes that avoid the formation of contrails. Satellite images reveal whether our alternative route planning has been successful. Ultimately climate-optimised flight paths have immense potential for reducing the climate impact of aviation, as they could be flown with today’s fleet of aircraft.

In 2020, you wanted to investigate the feasibility of operational measures to reduce non-carbon-dioxide effects. How are things looking today?

Back then, we were a long way from flying such climate-optimised routes. Today we are immersed in testing tactical and strategic operational measures. We really are trying to avoid areas with high non-carbon-dioxide effects in real airspace. Aviation companies and policy makers have also recognised the potential, so there’s a real spirit of optimism at the moment.

What do you think of the current sentiment?

In D-KULT, we are currently in the process of testing strategies for climate-optimised flight routes in real operations through various demo experiments. On the one hand, German air traffic control is helping us to avoid air traffic crossing sectors where working towards avoiding. At the same time, real systems for strategic flight route planning are also being expanded so that climate-optimised flight can be suggested to airlines on a daily basis. We embarked on this journey together back in 2010. But we need to continue. In making flying more climate-friendly, one of our key aims is to understand the processes in the atmosphere more precisely and to provide reliable assessments of the climate effects. We remain focused on this aim and are moving towards it step by step.

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DIAL INDIVIDUAL AND AUTOMATED AIR TRAFFIC

DIAL aims to deliver technology and concepts that increase airspace capacity while ensuring safety. It endeavours to connect novel meteorological services for safety and climate with assistance systems to support air traffic controllers. This frees up time for the controllers, which they can use to provide pilots with climate-friendly routes. In doing so, the DLR experts are looking at all influencing key factors for route planning in civil aviation, ranging from general flight guidance concepts to space weather, the effect of operating conditions on engine emissions and the development of cutting-edge calculation methods for creating flight routes. The project is being led by the DLR Institute of Flight Guidance. The DLR Institutes of Atmospheric Physics, Combustion Technology, Aerospace Medicine, Air Transport and Communications and Navigation are also involved in DIAL.

The impact of emissions are incorporated into weather forecasting models. The effect of aircraft emissions on the atmosphere is highly complex and heavily dependent on the prevailing meteorological situation, so as to yet predicting the climate impact of non-carbon-dioxide effects is challenging. It is important to identify and quantify the different sources of uncertainty. Ultimately, it is essential to know the climate effects with sufficient accuracy to be able to make a robust decision when choosing an alternative, more climate friendly route. D-KULT examines how well such predictions work and how significantly new route calculations affect the climate impact of air traffic. Weather services, air traffic controllers, airlines and the scientific community must work closely together to refine route planning systems with the aim of identifying routes with a lower overall climate impact, all while taking this uncertainty into account.

Rigid airspace structure makes planning more complex

Ideally, leveraging the full climate potential of flight route optimisation would mean having the capacity to be able to fly wherever you want. But the sky is full, and it is getting even more crowded as time goes on. According to predictions, the number of passenger flights is set to triple by 2050. To prevent accidents, the airspace is divided according to a rigid structure that can be imagined as a high-rise building, where aircraft are only allowed to fly on a specific ‘floor’. Over the Atlantic, for instance, the general rule is that you fly out at one altitude and back at another. If you wanted to fly lower due to weather phenomena, you would have to go two ‘floors’ down. As the change in altitude costs fuel and usually also time, the most economical thing to do is to simply fly straight on through, despite the expected formation of contrails. The additional kerosene consumption might exceed the benefit of avoiding contrails.

100 Flights programme ready to launch

New developments are afoot for aviation in Europe. The 100 Flights programme by the Climate-Friendly Aviation working group will launch on 5 June, just in time for the ILA Berlin international air show. The programme focuses on avoiding contrails in actual flight operations. The D-KULT project is responsible for analysing these flight tests. DIAL is also approaching the home straight in its four-year funding period. The next step will be validation on a larger scale, again in the form of simulation. This work is intended to show that all components are working together and that ongoing optimisation is taking place. A climate response model will be used to estimate the respective climate effect. Days of real air traffic before and after the start of the coronavirus pandemic serve as input for the upcoming simulation. The central question is about the actual benefit of connecting all route information for optimisation – or, more precisely: How much fuel could have been saved compared to flying without optimisation? How much less carbon dioxide would have been emitted? And how much global warming could have been avoided by flying around sensitive areas?

“Assistance systems will increasingly create more freedom to implement custom, climate-optimised routes.”

Maik Friedrich
Human Factors Department and Head of DIAL

Maik Friedrich tested tools for automating air traffic management together with project participants. Shown here is an eye-tracking measuring system.

How could a pilot’s job change in the future?

1. Assistance systems will increasingly find their way into everyday work, as a way of relieving the burden on pilots. This will free them up to implement custom, climate-optimised routes. In our efforts to further automate airspace control, DIAL is investigating two different concepts: single controller operations and sectorless air traffic management (ATM). In the former, only one controller is deployed per sector, supported by assistance systems. These essentially take on the tasks of route planning. In the time gained, climate aspects can be taken into account when planning the route. During our most recent DIAL tests, we examined eight DLR assistance systems developed in our simulators together with air traffic controllers. Two of them proved particularly promising.

What are the potential climate benefits of sectorless ATM?

1. It is a new approach. Instead of dividing the airspace into sectors, there is only one large airspace. The air traffic controllers are then responsible for a certain number of aircraft from departure to landing, instead of just for a fixed sector. They can guide aircraft on more direct routes between departure and arrival airports, especially in large cross-border airspaces. As a result, we would achieve a higher airspace capacity. And this would help to protect the climate, as the additional capacity can be used to carry out as many ‘climate-optimised’ flights as possible. The larger the sectorless airspace, the greater the environmental benefits. Concepts such as direct routes or increased automation can also significantly increase the positive impact of the sectorless concept.

How do flight route planning and airspace structure come together?

1. Another focus of the DIAL project is joining up current climate goals in aviation with their biggest impact factors. The various factors influencing the climate are depicted in realistic simulations and their impact analysed. These simulations can be improved by incorporating novel meteorological services that detect and identify weather risks and disruptive events along flight routes and calculate the climate impact of the route. The simulations can be particularly effective in systematically varying flight route planning and airspace structures and in examining the effects on air traffic and climate impact as realistically as possible. This enables us to provide better support to decision-makers in aviation today.

The airspace over Europe is one of the busiest. According to EUROCONTROL, there are an average of around 28,000 flights per day in 2023.

The shortest route is not always the one with the least impact on the climate. The DLR researchers determine the best option, taking into account various factors such as the weather forecast or route length. Due to the chosen map projection (Mercator), the routes close to the pole routes appear significantly longer than in reality.

The air traffic is on the rise, but how could it get even more crowded? According to EUROCONTROL, there were an average of around 28,000 flights per day in 2023.
DIVERSITY IN THE TANK
Sustainable Aviation Fuels (SAFs) – an alternative to fossil aviation fuels
by Anja Tröster

What do waste oil, green plants, hydrogen and sewage sludge all have in common? All of these materials can be used to produce sustainable fuels to power the aircraft of the future. Sustainable Aviation Fuels (SAFs) have become increasingly important in air transport over recent years. But what are they, exactly? What sets SAFs apart from conventional kerosene? What role do sustainable fuels play in the decarbonisation of air transport? What is the state of the current research? And what advantages do these potential successors to conventional kerosene offer? This article answers key questions about SAFs.

What are SAFs?
SAFs encompass a variety of sustainable fuels made from very different raw materials. They all have two things in common – they are chemically almost identical to kerosene, but are not based on fossil raw materials, and they have a significantly lower carbon dioxide footprint than kerosene over their entire life cycle (from source to combustion). SAFs are intended to replace fossil fuels in medium and long-haul air transport – areas that are difficult to electrify. The first semi-synthetic SAF, from South African company Sasol, was approved in 1998.

How are SAFs produced today?
At present, there are eight approved manufacturing processes. By far, the largest amount is currently produced using the HEFA (Hydroprocessed Esters and Fatty Acids) process, where the starting materials are (used) vegetable and animal oils and fats, such as the fat from deep fryers. These fats and oils are first hydrogenated. Similar to crude oil, the result can be refined into kerosene. However, this process is not indefinitely scalable, so scientists are working on alternatives. Methanol appears particularly promising.

The multitude of acronyms and scientific terms can be confusing. Which ones are worth bearing in mind for the future?

The term ‘Sustainable Aviation Fuels’ is decades old – it was coined when people first started the search for alternatives to kerosene. There are now so many non-fossil fuels that there are three generations in their development. The first generation was fuels made from biomass. The second generation uses waste materials of biological origin. HEFA fuels belong to this group. According to current thinking, only synthetic or electricity-based fuels, known as e-fuels, can be scaled sustainably. For that reason, DLR is concentrating on researching, testing and optimising these chemical energy sources. The sun-to-liquid process is being researched in the solar thermal experimental power plant in Jülich. At the Leuna Chemical Park, DLR is setting up a production process for Power-to-Liquid (PtL) fuels on a semi-industrial scale, which is intended to accelerate the market ramp-up of electricity-based fuels.

Why are SAFs and, above all, synthetic fuels more climate-friendly alternatives to kerosene?
During the combustion process, fossil fuels release the carbon that they sequestered over a long period of time while they were being created. This means that they add to the accumulation of carbon dioxide in the atmosphere and contribute to global warming. In the case of sustainable aviation fuels, the carbon dioxide that could potentially be released upon combustion has been removed from the cycle at an earlier stage due to the use of sustainable resources, thus significantly reducing net carbon dioxide emissions. This is evident from analysis of their life cycle. In addition, many of these new fuels can be designed in such a way that they produce virtually no soot and therefore cause fewer contrails. The production of synthetic, or electricity-based, fuels uses less water and land than the production of biogenic fuels, which are obtained from organic substances. When produced using renewable energy and carbon dioxide from the atmosphere, they can be almost completely carbon neutral, but there is still a long way to go before this can be achieved. The biggest hurdle is energy consumption during production, which remains very high. The necessary capacities have yet to be created.

What other innovations are being worked on?
Austrian oil and gas company OMV has developed the ReOil method, a patented process for extracting crude oil from end-of-life plastic waste. A SAF can be refined from the end product in a second processing step. British start-up Firefly is looking to use the most unusual raw material of all – human excrement. According to Firefly founder James Hygate’s calculations, each person produces enough excrement per year to generate four to five litres of SAF. If the UK were to use the entire quantity at its disposal, it could cover at least five percent of its national fuel requirement.
Can SAFs be mixed with conventional kerosene?

At the moment, SAFs can only be used in applications for commercial aviation when mixed with kerosene. A maximum admixture of 50 percent is currently permitted. However, the proportion of actual admixture is less than one percent due to the fact that only small quantities are currently available on the market. From 2025, an initial admixture of two percent SAFs will be required by law for all flights departing from Europe. This admixture will rise to five percent in 2030. The aim is to increase this proportion to 63 percent by 2050 – an important step towards achieving climate-neutral aviation.

What is the greatest advantage of SAFs?

SAFs can be specifically designed in the laboratory to ensure low-emission combustion, so that little to no soot particles are produced in the aircraft engines. DLR studies show that when pure SAFs are used, up to 80 percent less soot is released into the atmosphere than with kerosene. This results in fewer contrails. As such, these fuels can make a far greater contribution towards reducing the climate impact than simply cutting carbon dioxide emissions.

Can the amount of SAFs that are being produced today have a positive effect on the climate?

It is not necessary to wait for widespread availability; the benefits from SAFs can be achieved now. DLR researchers have shown that the targeted use of SAFs in regions with a lot of contrail formation has a significantly greater effect than introducing them for all flights. This is because contrails do not appear to the same extent everywhere; there are specific hotspots. These include some of the busiest regions over Europe. To that end, DLR researchers are working on concepts for the ‘smart use’ of SAFs – for example, specifically in these hot spots. It should be noted, however, that this will require changes to infrastructure on the ground.

Do SAFs only generate less soot during flights, or does this also apply at airports?

Local air quality would also improve at airports if kerosene were gradually replaced by SAFs. This is evident from the initial findings of measurements carried out at Copenhagen Airport as part of an EU research project that measured the emissions from an aircraft fuelled with a mixture containing 35 percent SAFs over a period of several weeks. The data showed a 30 percent reduction in the level of particles.

If the energy transition succeeds in this area, who will benefit?

A world in which climate-friendly flight is a reality requires different infrastructure on the ground. There are several reasons for this. For one thing, there are so many different ways to produce non-fossil fuels that there are bound to be regional differences in solutions. At present, the oil and gas industry is concentrated in 22 countries, which supply 90 percent of all fossil feedstocks. Half of the produced amount comes from just five countries. According to estimates from the DEPA2050 study, 5000 to 7000 refineries worldwide will be required to produce the necessary quantities of SAFs. In future, this will give rise to regionally diverse production, rather than monopolies. This could result in the creation of 14 million jobs in and around production – not just in Europe, but worldwide.

At present, SAF’s market share is less than one percent. How is the market set to ramp up?

Advances are already underway, triggered by two major policy decisions. In 2021, the USA launched the ‘SAF Grand Challenge’, a funding programme for the domestic production of biogenic SAFs. The goal is to produce more than 11 billion litres per year by 2030. For its part, the EU chose a different path and set quotas in spring 2023. Both measures have given producers planning security. It is clear that both start-ups and large corporations are now starting to invest in the development of a new industry.

What is meant by the terms drop-in and non-drop-in?

Drop-in fuels are those that can be used immediately across the entire fleet without the need for any modifications to the aircraft. These fuels are therefore compatible with all engines commonly used today, including the engines of older aircraft. Non-drop-in fuels require certain modifications – for example to seals in the fuel system. They have not yet been approved.

Anja Tröster is responsible for public relations at the DLR Institute of Combustion Technology.
As the latest addition to DLR’s research fleet soars above the Bavarian town of Bad Tölz, only the aircraft’s livery hints at its future mission. By the end of 2025, the Dornier 328 turboprop passenger aircraft will have been converted into an UpLift flight test platform for environmentally friendly technologies. The aim of the UpLift project is to support the development of all technologies that will help to make aviation more sustainable. In this context, the aircraft will be made available as an open test platform. Among other things, the turbines are being adapted to be able to operate with fully formulated synthetic aviation fuels (SAFs).

For the first time, researchers will be able to analyse the air chemistry and contrail formation of a turboprop aircraft that runs 100 percent on aromatic-free SAFs in real-life operations. Aromatics – cyclic hydrocarbons – are an essential component of conventional aircraft fuels, for one thing, they cause the polymer seals of tanks to swell, preventing fuel leaks. However, they are largely responsible for the formation of soot during fuel combustion in engines. Aromatic-free SAFs, by contrast, reduce soot formation and thus also the formation of contrails. UpLift will be presented for the first time at the ILA International Air Show in Berlin from 5 to 9 June 2024.

The main target group for the UpLift flight test vehicle, registered as D-CUPL, is the German aviation industry – especially small and medium-sized enterprises that do not have their own research aircraft. DLR is cooperating with Deutsche Aircraft GmbH on the current conversion and expansion of D-CUPL into a flying test bed. D-CUPL will be stationed at DLR’s Flight Experiments facility in Braunschweig.
Future air transport is subject to major requirements, resulting in considerable challenges for research. The European Union has stipulated a target of reducing aircraft noise by 65 percent by 2050. At the same time, aviation needs to be made more climate friendly. Is it possible to reconcile the two? Michael Mößner is a noise researcher at the DLR Institute of Aerodynamics and Flow Technology in Braunschweig. He is currently addressing these challenges together with his colleagues.

How many people are actually affected by aircraft noise?

1. In Germany, approximately one percent of the population lives in the immediate vicinity of an airport, so we are talking about 820,000 people who are exposed to noise levels of more than 55 decibels every day. They need rapid relief. If we want to achieve the level recommended by the World Health Organization (WHO), we must reduce overall noise pollution, a special value is calculated based on a specific period of time. This is called the equivalent continuous sound level (LAeq) and is measured in dB(A). In its Night Noise Guidelines (NNGL), the WHO recommends a guideline value for external noise of 40 dB(A). If the value is over 33 dB(A), the likelihood of waking up increases.

2. A study by the DLR Institute of Aerospace Medicine showed that sleep disorders can occur at levels as low as 35 dB(A) indoors.

What can be done to make aircraft quieter?

In our SIAM project, we tested a number of options – different flight routes, higher altitudes and changes to the aircraft itself, to name but a few. On an aircraft, the engines are among the loudest elements during many phases of flight. At present, the trend is towards larger engines. This increases fuel consumption. This is a major challenge in our research – identifying the optimal combination of technologies, aircraft configurations and flight procedures while meeting policy requirements.

The focus is rightly on climate compatibility, which does not allow for uncompromising quiet aircraft like ours. New development and market acceptance can take decades. For a quick and cost-effective solution, we focus on modifications such as covering various landing gear elements on existing aircraft. This is why, in addition to the futuristic aircraft designs in SIAM, we also carried out wind tunnel tests with an Airbus A320 half-model, with added noise reduction measures from the previous Low Noise ATRA (UNATRA) project.

A few years ago, we carried out flight tests involving conversions on an A320, with very good, practicable results. All of this is now being incorporated into our follow-up project, LU(FT)² 2030. Since tests that involve additions to real aircraft are extremely expensive and time-consuming, we are applying the findings from UNATRA to a virtual environment. By conducting additional wind tunnel experiments and flight simulator tests, we are aiming to make our numerical methods more reliable and improve noise reduction measures on conventional and future aircraft.

Looking in your crystal ball, will we be able to meet the EU’s requirements by 2050?

Yes, that is true. As part of SIAM, we have virtually designed a quiet, cutting-edge aircraft that fulfils the above-mentioned and other noise reduction aspects. It manages to strike a balance between feasibility and maximum noise reduction. We have also carried out extensive aerodynamic and structural analyses, which allow us to make reliable statements about as many aspects as possible. However, new approaches to solutions often come at the expense of efficiency and climate compatibility.

So, creating a low-noise yet climate-friendly aircraft is not so easy. Why is that?

To give one example, the T-tail, which is necessary for safety reasons, is heavy. It increases the surface area, causes greater drag and ultimately increases fuel consumption. That sounds like a real dilemma. How are you applying your findings?

Actually, the opposite is true. While the thrust remains the same, air flows more slowly through the engine, making it quieter. By using liners, a kind of damping mat with small holes, we can also absorb sound within the engine itself. However, for people living near an airport, the most effective way of reducing noise is to place the engines above the wings. This means that the sound cannot radiate downwards unhindered, and the residents are essentially in the acoustic shadow of the engine.

I imagine that kind of aircraft would look a bit unusual.

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The point at which a sound is deemed to be ‘noise’ depends on many factors. Above all, duration and volume are decisive factors. Aircraft noise is not a constant sound, but it is usually perceived as more irritating than sounds that remain at a constant level. To realistically assess and compare overall noise pollution, a special value is calculated based on a specific period of time. This is called the equivalent continuous sound level (LAeq) and is measured in dB(A). In its Night Noise Guidelines (NNGL), the WHO recommends a guideline value for external noise of 40 dB(A). If the value is over 33 dB(A), the likelihood of waking up increases.

The interview was conducted by Vera Koopmann, who works in public relations at the DLR Institute of Aerodynamics and Flow Technology.
The aircraft of the future must be both climate-compatible and affordable. What these aircraft might look like and what technologies will power them is what the DLR Institute of System Architectures in Aeronautics, based in Hamburg, is exploring.

The scientists are investigating new technologies and aircraft. To do this, they have to evaluate all possible options and choose optimal solutions. This process is complex because new designs bring new interactions that must be understood and exploited. As part of the EXACT (Exploration of Electric Aircraft Concepts and Technologies) project, 20 DLR institutes are jointly developing aircraft concepts for a projected market entry in 2040. These combine, among other things, the advantages of gas turbine and electric propulsion, such as the plug-in hybrid configuration shown on the left.

The scientists are assessing the entire lifecycle of an aircraft, including its components and energy carriers. To assess the impact of aviation technologies, DLR researchers have developed ALICIA (Aviation Life Cycle and Impact Assessment), a digital assessment platform that can be used to model and evaluate aviation as a whole system. DLR is working alongside numerous research organisations and industry towards achieving the goal of climate-friendly aviation.

**CABIN**

The aircraft can accommodate 250 passengers, a very large number for hybrid-electric drive architectures. This increases the aircraft’s market appeal. In each row, three people sit on either side of the central aisle.

**FUEL TANK**

Kerosene for the gas turbine is used to extend the range and as an emergency power reserve. The plug-in hybrid turboprop concept can also fly on synthetic jet fuel.

**BATTERIES**

The electric motor has an output of 4.25 megawatts and drives the six-metre diameter propeller. The batteries are housed in the engine nacelles. They have a capacity of 10.6 megawatt hours and weigh a total of 26.5 tonnes. To avoid losing time at the airport, the batteries must be recharged within 20 to 30 minutes.

**PLUG-IN HYBRID**

Range: 2800 kilometres, or 500 kilometres electric only
Cruising speed: 750 kilometres per hour
Climate impact reduction potential: 85-95 percent (compared with current aircraft in the same passenger class)
Energy consumption: 9 kilowatt-hours per person per 100 kilometres (electric) or 13 kilowatt-hours per person per 100 kilometres
Operating cost reduction: 5-15 percent

**NEW AIRCRAFT CONCEPTS FOR CLIMATE-NEUTRAL AVIATION**

This aircraft may appear conventional on the outside, but it is equipped with some of the most innovative technical solutions. Its turboshaft engine, equipped with large rotors, boasts exceptional energy efficiency at just slightly reduced flight speed. DLR is also looking into how propellers should be designed to reduce noise both on the ground and in the cabin. Hydrogen propulsion is an important option across various configurations.

**TURBOPROP CONFIGURATION**

**TRUSS-BRACED WING**

Very long wing spans reduce drag and thus energy consumption. Supporting struts would give them the strength of conventional wings without an excessive increase in weight, though the interaction between struts and wings must be studied carefully. Because space at airports is limited, researchers are also exploring the feasibility of folding wings.

**GAS TURBINE**

One large gas turbine is more efficient than two smaller ones. It is fuelled by kerosene and maintenance costs are lower due to the need for fewer maintenance cycles.

**ELECTRIC DRIVE**

The electric motor has an output of 4.25 megawatts and drives the six-metre diameter propeller.

**BLENDED WING BODY**

The blended wing body configuration seamlessly integrates the fuselage and wing to reduce surface area and drag, thus lowering energy consumption. DLR is actively exploring ways to design a pressurised cabin for passengers without adding mass, as well as techniques for maintaining controllability without increasing drag.
Rail transport is one of the great hopes in the mobility transition. Unlike other motorised means of transport, rail is already relatively climate-friendly and energy-efficient, as well as one of the safest means of transport. Rail is making a major comeback: the German government wants to double passenger transport capacity by 2030 and make travel by rail more affordable. This means integrating innovative power supply systems, lightweight construction, sustainable materials, running gear design, air conditioning, automation and control, and regulation all feed into the project. “The NGT TAXI is about more than just the vehicle – that is, the train; it is also a novel operating concept and the train control and safety technology is part of the infrastructure,” explains Jens König from the DLR Institute of Vehicle Concepts, from where he coordinates all activities of the NGT TAXI vehicle.

Reviving routes with a new approach

Since the 1950s, around 30 percent of the German rail network has gradually been shut down, but it still holds potential. Reactivating these routes is often possible and, most importantly, considerably less costly than building new ones. The Association of German Transport Companies (VDV) and the advocacy group, Allianz Pro Schiene, are proposing the reactivating of almost 300 routes over a total length of more than 4500 kilometres. This would mean that over 300 cities and communities, and thus 3.4 million people, would be reconnected to the rail network.

“Reactivating must also be economically viable and needs to fit into existing transport modes,” says König. “We need some new ideas. What we are developing is similar to the railbuses that train enthusiasts will know from the 1950s and 60s. The NGT TAXI is a state-of-the-art variant of this and brings this approach right to the future.” The DLR researchers do not envisage large, long, heavy trains, as this would mean fully expanding the routes again and extensively equipping them with control and safety technology. Instead, they are opting for modular, small, light, automated trains with alternative drive systems. The design is intended to be barrier-free and provide plenty of space to accommodate luggage, bicycles and pushchairs.

Lightweight, modular and alternatively powered

In terms of the design of the car body, crash behaviour and control and safety technology, the NGT TAXI is considering approaches from the tram sector, their existing specifications and approval processes. The car body consists of a floor, a roof and end sections. In order to make these lightweight, the researchers calculate an optimal load-bearing structure using topology optimisation. Stiffer and heavier material is only used where the static and dynamic loads acting on the car body require it.

The futuristic rail bus is powered by climate-friendly and locally emission-free batteries or fuel cells. After all, secondary routes and disused lines usually have no overhead catenary, and batteries could provide a range of up to around 100 kilometres. For longer distances, DLR is focusing on fuel cells in combination with smaller batteries, which provide the power needed for accelerating and store the energy recovered during braking. Standardised power packs will be designed for the power supply concept. Depending on the vehicle size, route profile and range, one or more of these drive units will be installed in the train.

Another feature of the NGT TAXI is the modular vehicle structure and drive concept, which can be flexibly adapted to the circumstances. The shortest version of the train is almost 10 metres long, with 12 seats; the longest is 17.5 metres long and has 54 seats. This is made possible by modular carriages in different length derivatives, which can be produced in larger quantities and therefore more cost-effectively.

Automation on the rails

Automation is a key feature of the NGT TAXI. The systems, sensors and cameras required for this must be largely integrated into the vehicle, so that they are as independent as possible from the respective rail infrastructure.

Accessible and offering plenty of storage space: the interior of the NGT TAXI is designed to meet the requirements of regional transport users.

Thanks to its modular design, both the length and capacity of the NGT TAXI can be flexibly adapted to the requirements.
Deutsche Bahn is currently recruiting for more than 1000 train drivers. If more traffic is to be shifted back towards rail, it will exacerbate this labour shortage. During periods when trains are run at low capacity, drivers may be a significant cost factor. Automated driving offers new opportunities for the railways in both respects.

Underground trains have been running automatically on closed net-works for some time now, while further examples exist in the freight train sector. However, there are as yet no automated trains running as mixed services – in other words, sharing lines with conventionally driven vehicles. Automated trains must be able to interact comprehensively and independently with other trains, the infrastructure, the surrounding environment and the passengers. Camera and driver assistance systems already exist, but there is nothing that would enable safe, fully automated operation at the moment. “We will need a remote train operator workstation in a control centre,” says Michael Meyer zu Höste from the DLR Institute of Transportation Systems, who oversees the work packages for the operation of the NGT TAXI. This includes automation and control and safety technology. “In exceptional situations, trained personnel can intervene if the automation does not know what to do. But this is a completely new field of work that needs to be developed and tested first.”

Flexible and on-demand use

Economic viability is a prerequisite for the recommissioning of railway lines. Linking the trains up to existing transport modes in general and the railway network in particular requires careful intermodal transport management. Although feasibility studies have come to a positive conclusion in 75 percent of cases, less than 10 kilometres of track have been reactivated in the last two years according to an evaluation by the Pro-Rail Alliance and the VDV. New operating concepts like the NGT TAXI can help speed up the process. Indeed, the technology could enable the development of new routes that are currently deemed unprofitable to operate based on the current evaluation process.

So far, trains have been running according to a fixed timetable. “We are developing different operating concepts for the NGT TAXI, including for regular operation at certain times of day or on-demand operation that depends on the given number of passengers,” says König. “As it is for regular operation at certain times of day or on-demand operation, the NGT TAXI will only be successful if it enjoys a high level of acceptance among operators and users. Prototypes offer the opportunity to touch the vehicle, try it out and come along for a ride and understand its operational specifics.”

The prototype: a major step

For the first time as part of its NGT research projects, DLR is planning to build a drivable prototype and demonstrate its feasibility through test subject operation. Such real-scale demonstrators are rare in institutional railway research. “From our experience in the automotive sector, we know how important prototypes are for research, industry and public acceptance,” says Tjark Siefkes, Director of the DLR Institute of Vehicle Concepts. “After all, a concept like the NGT TAXI will only be successful if it enjoys a high level of acceptance among operators and users. Prototypes offer the opportunity to touch the vehicle, try it out and come along for a ride and understand its operational specifics.”

“MEET THE NGT FAMILY”

Under its flagship Next Generation Train (NGT) concept, DLR is developing a vision of future rail transport as an essential part of mobility geared towards sustainability and greater capacity. A whole family of trains has been created. The NGT HST (High-Speed Train) is a double-decker, high-speed multiple-unit train that can travel at up to 400 kilometres per hour. The NGT LINK is a double-decker, inter-regional commuter train designed to connect cities with each other and with metropolitan areas. The NGT CARGO is a fast, quiet, automatic freight train that can be assembled from individual cars and powered end-cars as required. This allows goods to be transported flexibly, quickly, reliably and without expending excessive resources. The NGT flagship concept is continuing to grow, with concepts for future-forward train stations and logistics terminals, plus the current work on the NGT TAXI.

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“In projects like this, we benefit from DLR’s strengths: our interdisciplinary expertise in engineering, our broad range of expertise and our focus on practical application.”

Tjark Siefkes
Director of the DLR Institute of Vehicle Concepts

Concepts such as the NGT TAXI are ideal and relatively manageable due to the size, weight and costs, especially in view of the usual dimensions in the railway sector. For example, an ICE 4 of the kind that Deutsche Bahn has been using for several years’ costs more than 30 million euros, is approximately 375 metres long and has an empty weight of about 740 tonnes. “The insights that we gain from building and testing this sort of prototype are immense,” says Siefkes. “Bringing technologies and developments together in this vehicle and executing operational tests on them is completely different from working on individual components or simulating them on the computer: in projects like this, we benefit from DLR’s strengths: our interdisciplinary expertise in engineering, our broad range of expertise and our focus on practical application.”

The DLR team intends to create the shortest version of the NGT TAXI, with a length of just under 10 metres and an empty weight of between 15 and 20 tonnes. The first version of the NGT TAXI will also serve as a test vehicle on which components can be installed or replaced to assist later scientific projects during the transfer into practical applications. Researchers from nine DLR institutes are working closely to make this happen. DLR is gaining further expertise and feedback from its collaboration with 21 project partners from research and industry as part of the Europe’s Rail Project FP6-Future. Some manufacturing companies have signalled early interest in advancing with the construction of the prototype and some operating companies declared early interest in executing test subject operation, both in close partnership with DLR. “Our aim is to conduct research over the long term,” says Siefkes.

Denise Näsele is a Media Relations editor at DLR’s Corporate Communications department.

A piece of the future in his hands: Jens König with a model of the NGT TAXI.
Did you know that women face a significantly higher risk of injury than men in traffic accidents of similar severity? And that they tend to express greater dissatisfaction with public transport than their male counterparts in various countries? Findings such as these, documented in scientific literature, prompted researchers Laura Gebhardt and Sophie Nägele of the DLR Institute of Transport Research and Mascha Brost of the DLR Institute of Vehicle Concepts to investigate further.

The disparity between men and women, known as the gender gap, manifests itself in various aspects of daily life. Perhaps the most recognised instance is the gender pay gap – a well-documented phenomenon indicating that women still earn less on average than men in comparable professional positions. Such gaps can be identified and measured thanks to scientific studies and observations. In their study ‘Please Mind the Gap’, DLR researchers Laura Gebhardt, Sophie Nägele and Mascha Brost reveal that a gender gap also exists in the design of modes of transport.

Different tasks, different needs

Whilst most men work full-time and commute to work in the morning and return home in the evening, women are statistically more likely to work part-time and undertake additional care responsibilities. As a result, their journeys tend to be shorter but more complex, simply due to the combination of professional work and caregiving duties. These distinct roles lead to different demands in terms of the modes of transport used. For example, the lack of space for pushchairs and wheelchairs or sufficient storage space for bags and luggage on buses and trains primarily affects female passengers. For many women, the lack of such elements renders utilising public transport more difficult or even impossible.

“Data and studies have shown that public transport is used more often by women. They are also less likely than men to have access to a car and are more willing to forego driving,” says Gebhardt. She adds: “To target this main user group, the needs and requirements of women must be taken into account when designing mobility services. Merely applying the ‘shrink it and pink it’ approach – essentially, just painting it pink and make it smaller – simply isn’t enough.”

Comparable research in the field of software design shows that usability improves for everyone when the needs of women are taken into account. “The same almost certainly applies to the design of modes of transport,” says Sophie Nägele. The impact is clear: initiatives aimed at facilitating boarding for women with pushchairs also enhance overall accessibility of buses for everyone. Similarly, everyone feels safer in well-lit underpasses.

Safe for everyone?

In Europe, crash restraint systems such as airbags are tested almost exclusively with crash test dummies based on the physical characteristics of men. Consequently, these systems are primarily evaluated for their efficacy in protecting male occupants during accidents. However, considering the physical differences between men and women, including differences in muscle and fat distribution, this approach poses a significant safety concern for women.

Local public transport also has considerable room for improvement, for example with regard to safety in the event of accidents and abrupt driving manoeuvres. A directive from the European Council mandates that vehicles carrying more than nine passengers must feature handrails positioned at a height between 80 to 190 centimetres. The average German woman is 1.65 metres tall and therefore cannot easily reach handholds placed at a height of 1.90 metres. As a result, many women use lower support options to support themselves, such as seat backrests or other lower objects that were not initially designed for this purpose. This makes them less stable on average and increases their risk of injury during braking or acceleration manoeuvres.

Disregarding gender differences can sometimes lead to unhealthy behaviour. According to a study conducted in 2011, 41 percent of surveyed women stated that they have avoided or reduced their liquid intake when travelling by train, even when thirsty. The reason for this was to avoid having to use the public toilets available, due to poor hygiene conditions.

DID YOU KNOW?

Women have different needs, and transport services need to account for these differences. The gender gap in transport design can lead to unsafe conditions for women, such as inadequate handhold heights in public transport. Initiatives to facilitate boarding for women with pushchairs can also improve overall accessibility for everyone. Attention to gender differences is critical for ensuring safe and accessible transport for all.
Synthetic nitrogen fertilisers are an integral part of modern agriculture: they increase crop yields and are relatively inexpensive to produce. The problem is that the extraction and subsequent processing of nitrogen are not exactly environmentally friendly. DLR researcher Lena Klaas of the Institute of Future Fuels wants to change all that. The doctor of physics is currently working on a new air separation process in the SESAM project.

Pure nitrogen is a crucial raw material in the chemical industry. One of its uses is to produce fertiliser. In the future, it could also have potential for the decarbonisation of shipping. How is nitrogen traditionally obtained?

Air is made up of 78 percent nitrogen, 21 percent oxygen and one percent other substances. When we remove oxygen from the air, nitrogen remains. This process is called air separation. At present, mainly cryogenic air separation is used: the air is liquefied and then slowly reheated. As each gas has a different boiling point, the gases can be separated from one another in this way.

In the SESAM project, you and your team have developed a thermochemical process for obtaining high-purity nitrogen. How does this work?

At the core of the SESAM project is the reactor that we have developed. This is where air separation takes place. Inside it is a reaction material that can absorb and release oxygen without changing its structure. When we heat this material, it releases oxygen, like a sponge drying out. When our ‘sponge’ is dry, we cool it down. We then feed air into the reactor, the oxygen collects in our material and what remains is nitrogen, which we remove from the reactor. We reheat the material, the oxygen is released and the process begins again.

That material sounds pretty special.

It really is! It comes from the perovskites family of materials. These are ceramics that share the same basic structure but are actually extremely diverse. To decide on one, we performed a pre-selection using computational methods. Besides having the right physical and chemical parameters, we wanted the material to be non-toxic and inexpensive.

As part of her doctoral thesis, Lena Klaas investigated perovskites with a wide variety of compositions. To the right: Close-up of the perovskite granules.

The team from the DLR Institute of Future Fuels designed and built the reactor for air separation.

We wanted to ensure that it had not been extracted under inhumane conditions, as is often the case with cobalt. I then tested the potential materials in the laboratory. We ultimately settled on perovskite granules made from calcium, strontium and manganese.

“One key advantage is that we can produce nitrogen on a smaller scale. In future, fertiliser could ideally be entirely produced on site where it is needed, from start to finish.”

Lena Klaas
Researcher at the DLR Institute of Future Fuels

Essentially, the SESAM team is introducing a new air separation process. What are the advantages of this?

One key advantage is that we can produce nitrogen on a smaller scale. In future, fertiliser could ideally be entirely produced on site where it is needed, from start to finish. This would eliminate the emissions and losses that currently occur during the transportation of ammonia or fertiliser. From a financial point of view, our thermochemical process is probably more expensive at the moment because it has not yet been established, and it currently requires a similar amount of energy to cryogenic air separation. Theoretically, it should be possible to use electricity produced from sustainable sources for cryogenic air separation, but this is not currently happening everywhere.

The process of converting nitrogen into ammonia and ultimately fertiliser is a very energy-intensive process. Could it be made greener?

The aim is to make the entire process of producing fertiliser carbon-neutral, which involves both air separation and the subsequent processes for producing ammonia and obtaining nitric acid. We started by looking at the beginning of the chain. Our process requires temperatures of up to 900 degrees Celsius. We can save several tonnes of carbon dioxide by generating this heat with solar energy.

Solar energy is limited in Germany. Do we have any alternatives?

Yes! We were the first to show that a thermochemical process of this kind can work on a small scale. Producing ammonia requires high-purity nitrogen with an air content of less than 10 ppm – 10 oxygen particles per million nitrogen particles. When we pre-cleaned the air and ran it through our reactor, it came out at 1 ppm – ten times better than our expectations.

What happens next?

We have just started our follow-up project. We will review our thermochemical process and expand our material screening. Maybe we will find a material that is even more suitable. We are working on this with DLR spin-off, ExoMatter. thyssenkrupp will also be involved. We have managed to get the company FGK on board, too. So far, we are working towards running the process in our little solar furnace. I am really looking forward to what lies ahead.

This interview was conducted by Julia Heil, Editor at the DLR Corporate Communications Department.
THE FALCON’S PRECIOUS PREY

The Hayabusa2 mission transported samples from the asteroid Ryugu to Earth
by Ulrich Köhler

25 August 2022. There is a palpable nervous tension in the laboratory wing of the DLR Institute of Planetary Research. They are expecting a delivery today, but there is nothing ordinary about it. The delivery – somewhat prosaically delivered via parcel post – will contain a speck of dust billions of years old. It arrives without security arrangements or any great fanfare. A signature later, and Giulia Alemano and Alessandro Maturilli cradle the nitrogen-filled sample container made of stainless steel and plexiglass in their hands. Since that day, the team has analysed ‘A0112’ in minute detail. Samples collected by spacecraft that are brought to Earth are extremely valuable for science because they tell stories about the origins of our planets and the Solar System.

This particular sample was ‘dropped off’ by the Japanese Hayabusa2 spacecraft, whose target was asteroid Ryugu. On 5 December 2020, the spacecraft brought samples from the asteroid to Earth. Hayabusa2 means ‘Peregrine Falcon’ in Japanese. The hermetically sealed sample container contained over five grams of material – much more than anyone had hoped for. Thanks to sophisticated analysis techniques available today, this seemingly small sample counts as a huge amount, and is of inestimable scientific value. The samples are over 4.5 billion years old, almost the same age as the Solar System.

‘Sample return’ – the pinnacle of space exploration

Being able to examine samples on Earth from another celestial body is hugely significant. Of course, the capabilities of today’s telescopic instruments are enormous, not least because they can be aimed at their target objects from a great distance. By examining high-resolution images of the surfaces of these bodies, scrutinising their material composition with various spectrographs and measuring an array of physical parameters, researchers get a comprehensive picture of the planets, moons and even small bodies in the Solar System. These findings are even more accurate if physical samples are obtained from celestial bodies in a targeted way – from locations that have already been carefully observed and have a known geological context – and are then taken to laboratories on Earth. There they can be analysed by hundreds of scientists using powerful equipment for months, years and even decades on end.

Even a four-and-a-half billion year old grain of dust needs a mundane delivery note for its journey from Japan to Berlin-Adlershof.

Over the course of almost seven decades of space exploration, the highly complex robotic extraction of samples from distant bodies and their return has become possible, having once been unimaginable. Almost 400 kilograms of Moon rock transported to Earth

This supreme discipline of space exploration began with the astronauts on the Apollo missions, collecting rocks on the Moon by hand, equipped with standard geology hammers. In total, they brought 2415 individual samples weighing 382 kilograms to Earth. Now, this is the Holy Grail of planetary research. Between 1970 and 1976, the Soviet space programme demonstrated that such samples could also be collected automatically – probes 16, 20 and 24 of the Luna series returned to Earth with a total of 321 grams of drilled lunar dust. China also brought samples to Earth in 2020, after the Chang’e 5 lander touched down near the relatively young volcano Mons Rümker and brought 1731 grams of samples to Earth, with the resulting Chinese study confirming that it was active less than two billion years ago. China has since announced another sample return mission to the Moon in 2024. This time, the landing is planned for the far side of the Moon. As yet, no samples have been taken from Mars or other planets in the Solar System, including their numerous satellites, as such a process remains too complicated and expensive. However, NASA’s Perseverance rover has been on the Red Planet since 2021, taking sample after sample from the surface of the planet.

HAYABUSA2 AND MASCOT

The Japanese space agency JAXA chose an asteroid as its target for the second time with its Hayabusa2 mission. Its predecessor, Hayabusa (2003–2010), brought samples from such a body to Earth for the first time in 2010. Hayabusa2 then lifted off on 3 December 2014, bound for the asteroid Ryugu. On 27 June 2018, the probe arrived at the asteroid, where it studied and mapped it from a distance of about 20 kilometres. Two micro-rovers were deployed on 21 September 2018, and on 3 October 2018, the MASCOT landing module developed by DLR and the French space agency CNES, separated from the probe and had its first contact with Ryugu six minutes later. MASCOT carried four experiments on board: a radiometer (DLR), a camera (DLR), a magnetometer (University of Braunschweig) and an infrared spectral microscope (University of Paris South). On 21 February 2019, Hayabusa2 extracted a sample from the surface of Ryugu, from an area that had been altered by external influences. On 11 July, it took a second sample from the bottom of an artificial crater that had previously been excavated by a small kinetic impactor on board, collecting material that had undergone no – or only slight – changes. The samples landed safely in Australia on 5 December 2020.
sample in the once water-filled Jezero Crater. Perseverance seals the samples and deposits them as it goes, and in about ten years the Mars Sample Return mission from NASA and ESA will collect these samples, head back into orbit and bring them to Earth.

As early as 2029, the Japanese Martian Moons eXploration (MMX) mission will land on the larger of Mars' two moons, Phobos, take samples and send them to Earth. Mars material is probably scattered on Phobos due to asteroids impacting the Red Planet, which is 6000 kilometres away. So, in a sense, Mars would also be contained in these samples. DLR is extensively involved in both of these projects, from the scientific research to the hardware.

In 2003, the first Hayabusa mission was also sent to an asteroid – (25143) Itokawa – which it reached in 2005, and then collected dust from its surface. It ran into some technical problems on the return flight, but with patience and great ingenuity JAXA managed to bring the capsule with the – unfortunately scarce – grains of dust down to Earth on 13 June 2010.

The analyses revealed a broad spectrum of minerals and substances on Ryugu that at first glance seemed almost Earth-like. Layered silicates make up around 20 percent of the mass of the samples, made up of minerals such as serpentine (‘snakestone’) and saponite (‘frogstone’), which have a crystalline structure consisting of silicon-oxygen tetrahedra that lie on top of each other in carpet-like layers. In between, with one another, shattered or crunched into the then young planets. The tens of thousands of craters on the Moon are testament to the turbulent first billion years of the Solar System.

With the exception of a few bodies that have grown into larger ‘almost planets’ – such as the dwarf planets Ceres and Pluto and the asteroid Vesta, which have a similar shell structure to the planets – these leftover small bodies are barely changed witnesses to the earliest period of the Solar System. As such, they relate the first stages of planet formation and development, especially in relation to Earth, Mercury, Venus and Mars. Interestingly, recent studies of some of the approximately 50,000 meteorites that have fallen to Earth and are now in special collections, and spectral observations with large telescopes on Earth and in space, have shown that asteroids contain water in the form of ice. The further away from the Sun they were formed, the more ice they contain. Thrillingly, their material also includes organic compounds.

**The complete programme**

Back to the DLR Institute of Planetary Research and Sample A0112. Researchers began by visually examining their granule from asteroid Ryugu, which weighs 5.1 milligrams and measures 3046 by 1823 micrometres. To protect the ‘Berlin Sample’ from contamination or oxidation, they made their initial measurements inside a sealed sample container. High-resolution 3D images were taken from different sides using a digital microscope, so as to describe the 3D shape. The grain is black with a surface as dark as charcoal and tiny, micrometre-sized lighter elements inlaid. The first infrared spectroscopy measurements were also carried out through a glass panel using near-, mid-, far-infrared wavelengths and visible light, to determine its minerals and lighter elements inlaid. The analyses revealed a broad spectrum of minerals and substances on Ryugu that at first glance seemed almost Earth-like. Layered silicates make up around 20 percent of the mass of the samples, made up of minerals such as serpentine (‘snakestone’) and saponite (‘frogstone’), which have a crystalline structure consisting of silicon-oxygen tetrahedra that lie on top of each other in carpet-like layers. In between,
there is space for hydroxyls – oxygen-hydrogen compounds – which indicate that water must have played a role in the formation and development of this type of asteroid.

One surprising and significant feature is the occurrence of the magnesium carbonate dolomite, known from the world-famous Dolomites in Italy, alongside other carbonates such as iron and sulphur, as well as more exotic minerals. The iron and magnesium-rich silicates olivine or pyroxene, which are typical of many other planetary bodies and found in many meteorites, were observed less frequently here. The sample grain examined had a density of about 1.3 grams per cubic centimetre which, allowing for measurement errors, fits well with the overall determination of Ryugu's density. It is thought that more than a third of the asteroid consists of cavities.

The various research teams soon noticed similarities to a very rare group of meteorites called the ‘CI class’. The ‘C’ stands for carbon and the ‘I’ stands for Ivuna – a class of meteorite named after the Ivuna meteorite, found in Tanzania in 1938. There are only nine CI specimens in collections on Earth. Although these meteorites are carbon-rich, they are not made up of tiny, fused globules known as chondrules, but rather of breccia – parent rock that has been shattered by collisions and is full of cracks, fractures and angular elements. The Ryugu samples are most similar to CI chondrite meteorites but are more chemically pristine. The chemical composition of the Ryugu samples is a closer match to the Sun’s photosphere than to the composition of any other natural samples studied in laboratories.

**Formed in the icy depths of the Solar System**

Analyses carried out at DLR’s Planetary Spectroscopy Laboratory, the Museum of Natural History in Berlin and specialist firm Bruker Nano Analytics, indicate that Ryugu must have formed at a great distance from the Sun as part of a much larger parent body. It is very cold there, minus 200 degrees Celsius or even colder, and there is far too little solar energy for changes and chemical reactions to take place. Water and carbon dioxide are only stable there in the form of ice. According to estimates by teams involved in evaluating the sample in Japan and Germany, this development probably occurred very shortly after the formation of the Solar System; perhaps only two or three million years later. The only heat that may have altered the asteroid, for a relatively short period of time, was generated by the decay of radioactive aluminium isotopes – so traces of these changes are rare in the samples.

Inconspicuous, but of inestimable scientific value; a first look in the laboratory in Sagamihara into one of the two five-centimetre-large Hayabusa2 sample containers.

ASTEROID (162173) RYUGU

The target of the Hayabusa2 mission was discovered on 10 May 1999 by the LINEAR project, run by the Massachusetts Institute of Technology’s Lincoln Laboratory for the systematic detection and tracking of near-Earth objects. It has a diameter of around 900 metres and a shape reminiscent of a rough diamond with eight faces – although, its northern and southern hemispheres are almost round. Ryugu is a carbon-rich (‘C’) type asteroid with a mass of about half a billion tonnes. With a density of 1.2 grams per cubic centimetre, Ryugu is very light and probably full of cavities. Asteroids of this size tend not to be made up of caked rock units, but are held together loosely due to gravity – a ‘rubble pile’. Ryugu orbits the Sun every 475 days, during which the asteroid interacts with Earth’s orbit twice. Ryugu does not pass dangerously close to Earth.

Could Ryugu have originated in the Kuiper Belt – sometimes also referred to as the Kuiper-Edgeworth Belt – beyond the orbits of Uranus and Neptune, home to the icy dwarf planets Pluto, Eris and Makemake, and hundreds of thousands of comets? This inevitably gives rise to two key questions. How did Ryugu, now orbiting so closely around the Sun, get to the inner Solar System? And is it actually an asteroid? Could it, in fact, be a comet that has shed its characteristic volatile substances over billions of years? After all, 33 different amino acids were identified in the samples, which are also found on comets. Ryugu’s journey to the inner Solar System could have been initiated by the fragmentation of its parent body and was perhaps accelerated by one of the large planets. But that would have happened when Ryugu was already travelling within the outer Solar System one billion years ago, already an old, dead lump of matter.

During the analysis of the Ryugu sample in the DLR laboratory, involving many measurements taken with a wide variety of devices, one particular observation with a microscope provided a special insight: the discovery of these ‘craters’ on the tiny speck of dust. Such depressions are caused by micrometeorites hitting into the asteroid at speeds of over ten kilometres per second. The angular rock fragments on the surface then weather into dust over the course of billions of years. The laboratory team at DLR in Berlin-Adlershof no longer show any signs of trepidation when it comes to dealing with this 4.5-billion-year-old slice of the Solar System. It is almost astonishing how routine such processes have become for them. No hands tremble at the importance of the task; on the contrary in fact, the Institute is looking forward to the arrival of three more grains of dust from Ryugu, probably again in one of those yellow delivery vans.

Ulrich Köhler is a planetary geologist and has been kept very busy looking at the Moon and Mars. Over the course of his 33 years at DLR, his interest in the small bodies of the Solar System has gone from ‘zero to 100’.

DLR planetary researcher Ulrich Köhler during the microscopic characterisation of the primordial matter sample from the asteroid Ryugu.
ThinkSystem SD650-N V2 server
4.7 petaflops
works in Site Communications for
Water cooling for GPUs and CPUs (Green IT)
Infiniband high data range (HDR) with 320
47 graphics processing unit (GPU) nodes, each
271 central processing unit (CPU) nodes, each
E
onto terrabyte.

Big Data in Earth Observation
A platform for high-performance data analysis
by Anja Philipp

Earth observation has changed significantly over the last two decades. Numerous government and private satellite providers, such as the European Union and commercial providers such as Amazon Web Services or Google Earth Engine, process vast amounts of data. These providers not only offer significant computing capacity but also incorporate Earth observation data from around the world into their cloud platforms. “However, these cloud systems do not provide the specific Earth observation data required for our specific applications,” says Stefan Diehl, Director of the DFD. “What is more, neither the data nor the algorithms we have developed for analysis are reliably protected from third-party access. Consequently, in the long term we would inevitably become dependent on proprietary, commercial systems. That was the motivation behind the development of terrabyte,” he adds.

“The high-performance platform has simplified working with Earth observation data,” says Jonas Eberle, Project Manager of terrabyte. “Instead of days or months, now we might only need hours for complex calculations.” The platform is specifically designed for analysing large Earth observation datasets. In addition, the latest software enables quick and easy transmission and execution of applications and programs. These services and tools are continually expanding to adapt terrabyte to new applications and improve the utilisation of computing resources.

The Earth observation data is also processed as analysis-ready data (ARD) and can be immediately used and combined without the need for additional pre-processing steps.

Direct access to the relevant data
DLR researchers analyse and process the data. For example, using the data they were able to demonstrate that air quality had improved globally during the coronavirus pandemic, when the concentration of tropospheric nitrogen dioxide in Europe and Southeast Asia dropped by more than 40 percent. This was attributed to lower economic activity and reduced traffic volume during lockdown. For this purpose, terrabyte evaluated 1.2 trillion individual measurements from the European satellite Sentinel-5P to reach this conclusion.

Using the high-performance platform, researchers have also been able to map the development of settlements globally with a resolution of up to ten metres for the first time. The DLR researchers evaluated data dating back over 40 years for this purpose. “The end result, the World Settlement Footprint, shows streets and buildings,” says Mattia Marconcini, a terrabyte Developer at the DFD. “It clearly shows how quickly the world’s urban centres are expanding and where settlement density is growing.”

TERRABYTE COMPUTING POWER

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<thead>
<tr>
<th>Platform</th>
<th>ThinkSystem SD650-N V2 server</th>
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<tr>
<td>GPU</td>
<td>47 graphics processing unit (GPU) nodes, each with four A100 NVIDIA accelerators</td>
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<td>Computing power</td>
<td>4.7 petaflops</td>
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<tr>
<td>Storage</td>
<td>50 petabyte distributed storage solution for IBM Spectrum Scale (DSS-G) storage from Lenovo</td>
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<td>Network</td>
<td>InfiniBand high data range (HDR) with 320 gigabytes</td>
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<td>Cooling</td>
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DLR researchers analysed 15,000 satellite images spanning 37 years to investigate how the snow lines in the Aosta Valley in northern Italy have changed. Yellow shows the snow deficit in 2022 compared to the long-term average.

“terabyte has simplified working with Earth observation data. Instead of days or months, now we might only need hours for complex calculations.”
Jonas Eberle
Project Manager terrabyte

The future of terrabyte
terabyte will be continuously developed in conjunction with the LRZ over the coming years. Software for workflows will be integrated and standardised services offered to simplify processing. The developers are also working on applications that can automatically make databases available.

“terrabyte is also part of the DLR project Visual Data Analysis Platform (ViPloRE). Its aim is to enable interactive applications to be executed by a web-based system on all three DLR HPC clusters in the future. Julian Zeidler from the DFD is confident: “Thanks to terrabyte, DLR is very well positioned to provide important information on social challenges and global change in light of the rapidly growing volume of Earth observation data.”

Anja Philipp works in Site Communications for the Eastern region.

Global change and its effects on people and the environment pose major challenges for scientific research. To find solutions, researchers need direct access to the relevant data. The terrabyte high-performance computer provides exactly that. Networked with the satellite data archive of the German Remote Sensing Data Center (Deutsches Fernerkundungsdatenzentrum; DFS), users from DLR and selected external research institutions can access a comprehensive, curated collection of Earth observation data with global coverage. In addition, DLR is continuously uploading data from other providers such as the European Space Agency (ESA) and the US space agency NASA onto terrabyte.

There are currently around 60 petabytes in the DFD archive – the amount of data acquired over the last 50 years. This is equivalent to approximately 15 million feature films. Additionally, more than 15 terabytes of new data are added every day, providing both historical and current information about the state of our planet, thus enabling detailed mapping of changes.

Secure data instead of cloud systems
Up until now, scientists have mostly used cloud systems from commercial providers such as Amazon Web Services or Google Earth Engine to process vast amounts of data. These providers not only offer significant computing capacity but also incorporate Earth observation data from Europe and the US into their cloud platforms. “However, these cloud systems do not provide the specific Earth observation data required for our specific applications,” says Stefan Diehl, Director of the DFD. “What is more, neither the data nor the algorithms we have developed for analysis are reliably protected from third-party access. Consequently, in the long term we would inevitably become dependent on proprietary, commercial systems. That was the motivation behind the development of terrabyte,” he adds.

“…”

High-performance computing cluster at DLR
terabyte is one of three DLR high-performance computing clusters (HPC clusters). CARA and CARO (Computers for Advanced Research in Aerospace) are powerful supercomputers that offer extremely high computing performance. They are used, for example, to simulate flows around aircraft wings and the behaviour of fuel in a rocket engine (see article in DLR-magazine 173).
Sometimes a person’s career path takes the most surprising twists and turns. That was certainly the case for Petra Georgi. In 2007, after studying at a technical college to become a state-accredited dietitian and earning a doctorate in chemistry, she began working at DLR in Oberpfaffenhofen in 2007, and went on to join the Project Management Support Department in Cologne in 2009. As head of this department, she acts as an interface between research and administration on the one hand and external project partners on the other. In our interview, she explains how her career took a decisive turn following a holiday on the Atlantic coast.

And how did you end up at DLR?

Petra Georgi: During a summer holiday on the Atlantic coast, I was browsing through job advertisements and saw one from DLR that seemed just made for me. They were looking for a department head for Contract Management in Oberpfaffenhofen. I applied and got the job!

“Our job is to identify possible hurdles and remove them.”

Petra Georgi
Head of the Project Management Support Department

What are your tasks in your current role in project management support in Cologne?

Petra Georgi: We assist our researchers and engineers with applying for complex projects. We take a close look at the grant, contract and general conditions. People who are not specialised in this often do not understand the finer details and are not aware of the ramifications of certain requirements. Our job is to identify possible hurdles and remove them.

What do you consider to be particularly important when negotiating contracts?

Petra Georgi: As a publicly financed institution, our ‘framework’ conditions differ from those of companies. I focus on ensuring that both contracting parties are happy with the outcome of the negotiations. After all, the collaborations should run as smoothly as possible over several years and in some cases even decades.

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A will be tested in space for the first time next year. reduction costs and replace toxic propellants currently used. If everything goes as planned, a propulsion system developed by them at the DLR Institute of Space Propulsion in Lampoldshausen since 2011. The new propellants have to be non-toxic, easier to handle than existing ones and less complicated to test. In the space industry, these are referred to as ‘green propellants’. Werling has developed the ‘HyNOx’ technology based on nitrous oxide and ethane, which has been tested and improved thousands of times at the DLR test stands in Lampoldshausen. ‘The fuel is especially well suited to smaller spacecraft, such as CubeSats,’ says Werling. These small satellites are often as small as a shoebox.

Lauck’s doctoral thesis is about a second new propellant ‘HIP_11’, which has been patented by DLR and is suitable for larger spacecraft such as capsules or landers. In HIP_11 hydrogen peroxide and a molten salt react with each other. The propellant ignites as soon as the substances come into contact with each other – a property of propellants described as ‘hypergolic’. HIP_11 stands for ‘Hypergolic Ionic Liquid Propellant developed at M11’. ‘My doctoral thesis is almost finished, so HIP_11 will soon be flying into space,’ says Lauck. ‘It’s a very special moment.’ The first test in space InSpacePropulsion Technologies still has to overcome the hurdle of getting into space for the first time. ‘Most customers require an in-orbit demonstration,’ says Werling. For this reason, the start-up got in touch with the Curtin University in Perth, Australia, which is planning missions with a CubeSat. Together, they get down to business. InSpacePropulsion Technologies will not only supply the HyNOx propellant to thrust the Australian CubeSat but also the 3D-printed engines, tanks, electronics, valves and interfaces. The CubeSat could launch as early as next year.

In 2023, InSpacePropulsion Technologies also won a flight on a small satellite as part of DLR’s Small Satellite Payload Competition. This provided the company with a free satellite platform and a flight on a European microlauncher. The flight is planned for 2025.

From research to reality How did the two scientists come to form their own company? ‘There’s a lot happening right now in the New Space sector, which is focused on the commercialisation of spaceflight,’ says Werling. ‘Our green propellants can play an important role here, and we offer the right thrusters, too. After years of research and development, we want to see our technology actually fly.’

Although it’s only been on the market for a few months, InSpacePropulsion Technologies has a decade of impressive DLR research behind it. Lukas Werling and Felix Lauck hope that their start-up will make spacecraft propulsion more sustainable, reduce costs and replace toxic propellants currently used. If everything goes as planned, a propulsion system developed by them will be tested in space for the first time next year.

The two founders: Felix Lauck (left) and Lukas Werling (right).
NEXT-GENERATION AIR DEFENCE

Analyzing and assessing future fighter aircraft designs

by Yvonne Buchwald

Global security has undergone radical changes in recent years, with ever-increasing calls for better air defence for Germany and Europe as a whole. So how effective is our air defence and how can we improve it in the face of new threats? To be able to assess the situation and develop new technologies, the Federal Ministry of Defence relies on the expertise of scientists. The Federal Government’s aim is for DLR researchers to safeguard and expand the German Armed Forces’ ability to analyse and evaluate military aircraft.

How fast, how high, how efficiently and how stealthily will the next generation of fighter aircraft have to fly? What payload will they have to carry? How agile will they have to be? Should they be crewed or unmanned? These are the kinds of questions and issues that Andreas Schütte of the DLR Institute of Aerodynamics and Flow Technology and many of his colleagues are addressing on a daily basis. They are well aware that air defence is set to become more complex than ever. As threat scenarios have changed, so too have mission types and requirements for military aircraft. “For us researchers, it is not about developing a single combat aircraft or a single technology,” says Schütte. “Instead, we want to further develop our scientific methods and processes so that the German Federal Ministry of Defence can use our expertise to evaluate and assess the potential of future aircraft.”

Virtual model of a fighter aircraft

The researchers’ toolbox is made up of methods and processes, ranging from developing computational methods and structural models to constructing a computing network, carrying out the calculations or an experiment and, last but not least, assessing the results. DLR has just completed the large interdisciplinary project Diabolo, where researchers designed the Future Fighter Demonstrator (FFD), a virtual fighter aircraft.

“We are working on the assumption that close air combat will become less critical, as modern weapons allow engagement at long ranges,” explains Schütte. “As a result, supersonic flight performance will become increasingly important, while agility remains key to improving survivability.” Aircraft should be able to reach the operational area quickly and leave again swiftly after completing the mission. Military aircraft must be able to fly at subsonic and supersonic speeds at altitudes between zero and 15 kilometres, while demonstrating extreme agility and achieving angles of attack up to 45 degrees.

Robust, agile, connected and invisible

The greater the speed and agility of a fighter aircraft, the more compact it has to be and the higher the load that the wings, for example, have to be able to withstand. The engines play a key role in this. Integrating them in military design is much more complex than in civilian design because they have to be able to operate over a much wider speed range. They are integrated into the airframe to minimise visibility of the rotating fans.

The payload also plays a role, and, very importantly, the aircraft should be detected by the enemy as late as possible. The Diabolo project has made great progress with this, examining radar, infrared and acoustic signatures. The researchers have also improved upon their simulation tools by comparing them with the results of wind tunnel experiments.

Networking, new information technologies, intelligent data processing and secure real-time communications will all play an essential role in the air defence systems of the future. The follow-up project WingMates, led by Andreas Schütte, is looking not only at individual systems, as in the Diabolo project, but also at aircraft acting as a team – that is a network of fighter aircraft. Schütte is well acquainted with the requirements of the German Armed Forces: “In future, air forces will rely on combinations of digitally connected, semi-autonomous, crewed and unmanned platforms. WingMates is investigating aircraft that meet these requirements.”

Combining crewed and unmanned systems

European air forces will have to renew or replace their aircraft fleets in the foreseeable future. The necessary changes range from the modernisation of existing weapon systems like the Eurofighter to the introduction of the Next Generation Weapon System (NGWS) under the German-French-Spanish Future Combat Air System (FCAS) programme, Europe’s most important multinational armaments project. The NGWS is aimed at finding solutions for a future air defence system that consists of a combination of different flying vehicles interacting optimally with each other within a defence system. It encompasses the research work of Andreas Schütte and his colleagues from ten DLR institutes, as well as industry partners.

The projects also involve collaboration with industry partners to improve understanding of the aerodynamic or structural interaction of individual components on the aircraft, their effects and flow physics, the prediction of signature properties, the development of flight controllers, as well as suitable materials and construction methods. “Our close collaboration with DLR has been an excellent opportunity to investigate phenomena such as the influence of complex vortices on aerodynamics, sloshing effects inside the aircraft tanks, options for reducing sources of noise on the aircraft to improve stealth, and to further develop our simulation tools. This is also our chance to compare the results of existing methods and processes with those of independently developed procedures,” says Wolfgang Pecher of Airbus Defence and Space, who were involved in Diabolo, adding: “We look forward to continuing our involvement in the WingMates project, which is proving to be a great success.”

The ever-improving scientific expertise in technologies related to military applications can be decisive in the event of a battle. Andreas Schütte is convinced: “Here, too, we as researchers are fulfilling our mission of ensuring the Ministry of Defence’s assessment capability, supporting the German Armed Forces and strengthening Germany as a prime location for industry in a tried-and-tested close exchange.”

Yvonne Buchwald works in public relations at the DLR Institute of Aerodynamics and Flow Technology.

Participants in the Diabolo project

From research:
- DLR Institute of Aerodynamics and Flow Technology (project coordination)
- DLR Institute of Aerelasticity
- DLR Institute of Propulsion Technology
- DLR Institute of Flight Systems
- DLR Institute of System Dynamics and Control
- DLR Remote Sensing Technology Institute
- DLR Institute for Software Technology
- DLR Institute of Lightweight Systems
- DLR Institute of System Architectures in Aeronautics
- DLR Systemshaus Technik
- German-Dutch Wind Tunnels (DWW)

From industry:
- Airbus Defence and Space
- MTU Aero Engines

Images: © DLR

Andreas Schütte, Project Manager of Diabolo and WingMates, DLR Institute of Aerodynamics and Flow Technology, Braunschweig.
FAREWELL ALUMINIUM!

New approaches in lightweight aircraft manufacturing
by Michael Müller and Lars Larsen

For decades now, aluminium was seen as the final word in raw materials for aircraft construction, offering the same strength as steel at roughly half the weight – until thermoplastics came on the scene, that is. Like thermosets, they belong to the group of carbon fibre-reinforced polymers (CFRPs) and are lighter than aluminium, but can be welded. For 20 years now, CFRPs have featured in aircraft construction, including in the Airbus A350, with a carbon fibre content of up to 50 percent. Researchers are working to increase this proportion. New production processes are needed to enable the entire fuselage to be manufactured from CFRP in the future. Researchers at the DLR site in Augsburg are working on this.

There is much materials testing to be done before an aircraft fuselage made entirely of CFRPs finds its way into series production. It is important to understand the practical implications of working with these materials in the factory. Researchers at the Institute of Structures and Design within the DLR Center for Lightweight-Production-Technology tested this process using a true-to-scale fuselage model with A320 geometry. A project, including in the Airbus A350, with a carbon fibre content of up to 50 percent. Researchers are working to increase this proportion. New production processes are needed to enable the entire fuselage to be manufactured from CFRP in the future. Researchers at the DLR site in Augsburg are working on this.

Drilling the holes for the rivets creates metal filings that could damage installations in the lower part, so the complete basic structure is manufactured first. Only then are the interior components fitted in the flight deck and the passenger and cargo areas. This is currently done manually due to restricted freedom of movement in the closed fuselage.

The big advantage of components made of carbon fibre-reinforced thermoplastics is the fact that they can be welded. No rivets mean no metal filings. As a result, the assembly order can be completely reversed: the lower part of the fuselage remains freely accessible until both parts are welded together lengthways. This working method promises a fundamental improvement in the assembly process, by using robots to lay cables, install the floor deck and the passenger and cargo areas. This is currently done manually due to restricted freedom of movement in the closed fuselage.

Working on an open fuselage

Today’s Airbus A320 is manufactured using what is known as the sectional construction method. First, the lower and upper shell segments are connected by a longitudinal seam to form a section, commonly referred to as a ‘biscuit’. Several of these sections are then joined together by circumferential seams to form the fuselage. In aluminium fuselages, these connections are made using drilling and riveting processes.

In addition to DLR, the supplier Premium Aerotec, the aircraft manufacturer Airbus and the company Aerinnova Aerospace were also involved in the Multi-functional Fuselage Demonstrator (MFFD).

How to build an aircraft fuselage from carbon fibre

1. **The Outer Skin**
   - First, thermoplastic tape is heated by a robot-operated laser to around 380 degrees Celsius and laid down with pinpoint accuracy. The tool handled by the robot resembles an oversized tape dispenser. With minimal material waste and low energy consumption, this creates a thermoplastic laminate layer by layer, which does not need to be hardened separately. This process, refined by DLR, is called ‘in-situ consolidation’.
   - Ensuring that both the deposition rate and the material quality are high requires close coordination between all disciplines, from mechanical engineering and materials science to control engineering and simulation.

2. **Longitudinal stiffening**
   - Forty-four longitudinal stringers are welded onto the aircraft skin. The process used for this is called robot-based continuous ultrasonic welding. In a world first, thermoplastic films called energy directors are placed between the two parts that are to be welded together. A robot stimulates the components at 20 kilohertz. They begin to rub against each other, generating temperatures of around 380 degrees Celsius within a fraction of a second and welding the components together. The process is significantly faster than the drilling and riveting commonly used in the aviation industry.

3. **Transverse stiffening**
   - Twenty-four press-formed frames are resistance-welded on the installation tool using a motor-driven bridge developed by DLR. First, a robot precisely positions the frames at the target position. Next, a welding element between the components – in this case the frame base and the fuselage skin – is heated to 380 degrees Celsius and cooled under pressure. Little by little, 14 bases per frame are added to the skin. This robust technology delivers the joining strengths required by the aviation industry.

4. **Connecting longitudinal and transverse stiffening elements**
   - Resistance welding is once again used to integrate cleats between the stringers and frames. A small, lightweight robot is used alongside a standard robot, enabling operation within the smallest of spaces. The ‘cobot’ automatically aligns itself with stringers and frames by scanning them, thus eliminating the customary measuring of components or small-scale manual positioning, as is the case in current industrial applications.

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by greater efficiency in the production process. In order to demonstrate that a complete switch from aluminium to thermoplastics can be profitable, the researchers have set ambitious objectives for the MFFD fuselage demonstrator – as the project progresses, they aim to show that 60 to 100 units can be produced per month and that compared with the current Airbus A320, weight can be reduced by 10 percent and ongoing production costs by 20 percent.

Michael Müller is an Editor in the DLR Corporate Communications. Lars Larsen works at the DLR Center for Lightweight-Production-Technology.

for Manufacturing Engineering and Advanced Materials in Stade. The demonstrator is currently located at the ZAL Center of Applied Aeronautical Research in Hamburg, where it can then be used for further research.

Demonstrating economic viability

The switch from aluminium to CFRPs must be worthwhile both for aircraft manufacturing companies and operators. Additional costs that arise because production systems have to be adjusted or because CFRPs are more expensive than aluminium must be offset by greater efficiency in the production process. In order to demonstrate that a complete switch from aluminium to thermoplastics can be profitable, the researchers have set ambitious objectives for the MFFD fuselage demonstrator – as the project progresses, they aim to show that 60 to 100 units can be produced per month and that compared with the current Airbus A320, weight can be reduced by 10 percent and ongoing production costs by 20 percent.

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Passenger aircraft like the Airbus A330 fly around the globe between the troposphere (the lowest layer of Earth’s atmosphere) and lower stratosphere (the next layer up). This altitude range is particularly important for scientific research, as the concentration of nitrogen oxides, water vapour, carbon dioxide, methane, ozone and aerosol particles are important drivers of climate change. For a long time, we did not have a clear picture of the composition of the atmosphere and how it changes at this altitude. This is where the In-service Aircraft for Global Observing System (IAGOS) research platform comes in. Ten Airbus A330 aircraft are equipped with instruments that are collecting data on every flight, which can be used to better estimate changes in the global climate.

Until the start of operations in 2022, DLR Projektträger managed the project on behalf of the German Federal Ministry of Education and Research (BMBF). By collaborating with many stakeholders from science and industry, a cost-effective method was developed to continuously observe the air at flight altitudes and measure its components. Constructing and operating a research aircraft would have been significantly more expensive. The atmospheric data acquired is made available to the global scientific community free of charge and for the long term.

Passenger aircraft at the service of scientific research

As part of IAGOS-CORE, measurements are carried out permanently with ten passenger aircraft. Housed in a special rack below the aircraft, flight decks are instrument packages that analyse the air, store the data and send it to the IAGOS and Copernicus databases. In this way, the information is available to researchers just a few hours after an aircraft lands. IAGOS is being used to carry out a long series of observations on the composition of the atmosphere. As part of IAGOS-CARIBIC, a large air freight container in the cargo hold of a passenger aircraft is being fitted with measuring instruments. A Lufthansa A350 is being converted for a new generation of the measurement container equipped with significantly more and more precise measuring instruments, which will further improve our understanding of the atmosphere.

An important addition to satellite-based measurements

“The data collected by the IAGOS aircraft is essential for climate research, given the scarcity of direct data from other routine measurements for this altitude region. There is a lot we do not know about the atmosphere above the oceans because measurements here are only possible to a limited extent. Even satellites are unable to provide sufficiently detailed altitude-resolved measurements of the atmospheric composition in these areas,” says Jochen Elberskirch, Project Manager at DLR Projektträger. “The first airborne measurements were carried out in the 1990s. Together with the current IAGOS data, they form the basis for more than 400 scientific articles, including in the scientific journals Nature and Science. This new data marks a real step forward in scientific research.”

Global collaboration

The international research project has been made possible thanks to the cooperation between many research institutions, airlines and the aircraft manufacturer Airbus. In Germany, Forschungszentrum Jülich is coordinating the fleet of ten passenger aircraft, whilst the Karlsruhe Institute of Technology is in charge of the measurement container project IAGOS-CARIBIC. The DLR Institute of Atmospheric Physics is coordinating the fleet of ten passenger aircraft, whilst the Karlsruhe Institute of Technology is in charge of the measurement container project IAGOS-CARIBIC. The DLR Institute of Atmospheric Physics is contributing by measuring nitrogen oxides. DLR Projektträger has made this project fly.

Over the past ten years, IAGOS has collected atmospheric data from almost 26,000 measurement flights. China Airlines and Hawaiian Airlines, which analyse the atmosphere over the Pacific with their flights, are particularly important for the project. This provides a comprehensive picture of the global atmosphere.

IAGOS flights (1 November 2012–30 June 2022)

View into the IAGOS-CARIBIC container with the measuring components
More than 50,000 documents are stored in the DLR Central Archive, with some real treasures buried amongst them. This series of articles searches for clues amid the wealth of images, documents, records and articles to unearth such gems. In this issue of the DLRmagazine, we continue to tell you about some of the unusual research carried out in wind tunnels after the First World War.

Ludwig Prandtl at the water channel of the TH Hanover. Water channels were among the first experimental facilities that were allowed to be used for research purposes. The British, for example, instructed select scientists from the Aerodynamics Research Institute (Aerodynamische Versuchsanstalt; AVA) to detail their research activities during World War II.

In the years immediately after the end of World War II, aeronautics research and the construction of aircraft in Germany were banned by Allied Control Council Law No. 25. As in the wake of World War I, researchers at DLR’s predecessor organisations had to think up creative ways to continue their work in the field of applied natural sciences despite the restrictions and find sources of income to finance their activities.

After World War II, the three main predecessor organisations of DLR – the German Research Institute for Aviation (Deutsche Versuchsanstalt für Luftfahrt; DVL) in Berlin-Adlershof, the Hermann Gröning Research Institute (Deutsche Lufthafenforschungsanstalt; LFA) in Braunschweig and the Aerosdynamics Research Institute (Aerodynamische Versuchsanstalt; AVA) in Göttingen – came under the control of the victorious powers, which controlled their research facilities and employees for their own purposes. The British, for example, instructed select scientists from the LFA and the AVA to detail their research activities during World War II in writing. At the same time, the wind tunnels and test facilities at the three institutions were gradually dismantled or destroyed in accordance with the Potsdam Agreement. The research institutions gradually ceased operations.

Aerodynamic research for agriculture

While some of the AVA staff were able to transfer to the Kaiser Wilhelm Institute (KWI) for Fluid Mechanics in Göttingen following completion of their work for the British, LFA employees had no choice but to look for new employment. The director of the LFA, Hermann Blank (1901–1995), initially took up a role at the Federal Research Institute for Agriculture (Bundesforschungsanstalt für Landwirtschaft; FAL), which was established on the LFA site. As an aerodynamicist, he possessed a superb understanding of fluid dynamics processes and was therefore entrusted with two research tasks at the FAL: determining how seeds could be cleaned and sifted using wind and investigating the transport of grain, hay and straw via ‘pneumatic conveyance’, that is, through a series of pipelines pushed by a stream of air or gas. A number of AVA employees followed similar trajectories when their institute was taken over by the Kaiser Wilhelm Institute for Fluid Dynamics. Their knowledge of aerodynamics meant that they were assigned to the task of developing a floating sorting process for peas on behalf of a Hamburg company.

Several scientists who had worked at the AVA Institute of Cold Research during World War II – where they investigated ice formation on aircraft wings and tailplanes at high altitudes – were given the opportunity of moving to the KWI. After the war, they helped the Göttingen slaughterhouse upgrade its refrigeration system and developed a quick-freezing process for food.

These research activities were not only authorised by the British but actively encouraged as civilian-focused tasks that contributed to the rebuilding of public life within the British zone of occupation. There was also time for private research, as long as it did not violate Law No. 25.

The British, for example, instructed select scientists from the Aerodynamics Research Institute (Aerodynamische Versuchsanstalt; AVA) to detail their research activities during World War II.

Albert Betz (1885–1968), former head of the AVA and from 1947 director of the KWI for Fluid Mechanics and later the Max Planck Institute for Fluid Mechanics, developed a new type of clothes hanger which he successfully patented in 1949. As he did not have the time to market it himself, he hoped that his nephew would take on the project. Although the nephew was keen to find a buyer, he was also very busy working as a lawyer, so negotiations with interested companies took a long time. To make matters worse, Betz had very exacting expectations of the quality of the clothes hanger. He was adamant that it should be made of high-quality material that would ensure it could be used for as long as possible. Yet the interested companies did not have such high standards. As far as they were concerned, such an item did not have to last a lifetime, and they were more than happy to boost the manufacturing companies’ margins by opting for alternatives. Ultimately, the companies refused to use the appropriate materials in production. This marked the collision of two worlds – science and commerce. Unsurprisingly, this particular clothes hanger did not find its way into series production, so it did not end up appearing in wardrobes.

As the examples outlined here illustrate, in the late 1940s and early 1950s researchers had to transfer their skills and scientific strengths to areas that lay outside their core area of scientific expertise. This was far from easy, but it gave them a point of entry into new areas of work and ways of thinking, from which they benefited in the long term.

Jessika Wichner is in charge of the DLR Central Archive in Göttingen.

Albert Betz is in 1953 in the workshop of the MPI for Fluid Dynamics.

Albert Betz in 1933 at the high-speed wind tunnel in the AVA.

The dismantling of the AVA high-speed wind tunnel in 1946.

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The dismantling of the AVA high-speed wind tunnel in 1946.
At the NEMO Science Museum

by Claudia Sciarma

Large, turquoise-green building with a curved structure that gives the impression of a ship’s hull emerges from the water in the Oosterdok in Amsterdam. The NEMO Science Museum boasts an unmistakable architectural style that casts a spell from afar. Inside, visitors can experience science up close.

NEMO has its roots in the Labour Museum, founded in 1923 by painter Herman Heijenbrock, who wanted to share his collection of paintings and objects, and his enthusiasm for technology. The museum’s history is closely intertwined with the development of science and technology in the Netherlands, evolving over the last 100 years.

Today, the NEMO Science Museum is a modern institution that presents science and technology in a relaxed, interactive and accessible environment. The museum boasts around 20,000 artefacts categorised into four core collections: Lighting, Electrical Engineering, Energy Generation and Storage and Technology at Home.

The ‘Fenomena’ exhibition on the first floor immerses you into the NEMO universe. Many interactive exhibits await visitors here: a plasma and Storage and Technology at Home.

The ‘Fenomena’ exhibition on the first floor immerses you into the NEMO universe. Many interactive exhibits await visitors here: a plasma ball that can be used to generate sparks, a variety of colour filters that can be used to create impressive photographic effects, and much more.

At NEMO, science permeates all areas – be it on in information boards, on the flooring or in the seating areas: a label on the armrest of a chair provides information about the fact that thousands of pieces of space debris are in Earth orbit. Even as visitors use the staircase, a white and blue sign informs them that taking a single step requires the use of up to 200 muscles. On to the third floor, guests step into an exhibition about the building blocks of the cosmos.

Unveiling the Universe

In ‘Elementa’, visitors come across an extraterrestrial artifact: a 4.6 billion-year-old meteorite from Nantan, China, consisting largely of iron. This ancient space rock is a relic from bygone times. Visitors can witness and even touch this particular specimen. The sign above eloquently declares ‘It is probably the oldest thing that you will ever touch!’ On this floor, visitors can transition from meteors found on Earth to exploring the Universe through videos and interactive activities. Space trivia and extraterrestrial life are just two of the numerous topics covered here. The exhibit includes historical telescopes and features an interactive game projected onto a wall, providing an opportunity to defend Earth from all sorts of space hazards. Visitors can even embark on an imaginative journey through space, even choosing a pet or human companion to accompany them.

Who are you?

Following ‘Elementa’ is ‘Humania’ on the fourth floor. A tunnel leads to a colossal 8.5-metre sculpture by Dutch artist Florentijn Hofman – a human figure standing on its hands in a skeleton suit. As visitors interact with this impressive sculpture, it encourages reflection not just on their individual existence but also on the cosmic influences shaping humankind.

A panel at the entrance asks, ‘Who are you? Who were you?’ inviting visitors to explore their origins, identity, aging process, as well as the influences shaping them. Humania provides insights into the multifaceted human experience that stimulate curiosity in health, memory, and happiness. The exhibition segments delve into themes of the human experience, exploring diverse cultural perspectives on death and pushing the boundaries of our body’s movements.

On top of Amsterdam

NEMO’s rooftop is home to ‘Energetica’, an open-air exhibition with a variety of interactive sculptures and installations. They bring the topic of renewable energy to life. A water cascade offers a water play area suitable for children, a rainbow machine illustrates the interplay of light and water, and 12 fountains are installed on the roof, which are powered by various devices such as a wind turbine on the ‘wind island’. Here, visitors can test their strength against the elements. On the ‘solar island’, they can relax on chairs equipped with solar cells that produce energy in the sunlight. But of course one can also simply enjoy the view.

Whether intrigued by meteorites or energised by renewable sources, a visit to NEMO is an intense experience that will leave you in awe. In July of this year, the ‘Technium’, NEMO’s newest exhibition area, will open after six months of renovation work. Here, everything will revolve around engineering and technology – a fitting occasion for a visit to this futuristic ‘ship’ in the heart of Amsterdam.

Claudia Sciarma is an editor at EJR-Quartz.

NEMO SCIENCE MUSEUM

Oosterdok 2, 1011 VX Amsterdam

Opening times:
Monday to Sunday. 10:00–17:30

Admission:
17.50 euros, free for children under 4 years of age

All visitors must purchase or reserve a ticket with a start time in advance.

nemosciencemuseum.nl

Entrance to NEMO’s Humania exhibition
THE MOON BETWEEN VISION, UTOPIA AND REALITY

Joseph Silk is certain that humans will increasingly colonise the Moon. They will build permanent infrastructures, extract and utilise raw materials and conduct science on a large scale. After all, the Moon will someday be a holiday destination, and soon also a stepping stone to Mars.

Silk is a professor of physics and astrophysics at Johns Hopkins University and a really great ‘translator’ of stodgy topics. Back to the Moon – The Next Giant Leap for Humankind is also an excellent read. It is a precise description of the many technical, organisational and scientific framework conditions and the goals that can be derived from them. And yet it is only a vision, a utopia that it is hard – no, actually impossible – to imagine could one day become reality. The fact that he passionately advocates using the Moon as a platform for research and as a refuelling station for rocket fuel for the long journey to Mars in the next 50 years; of course! But the thesis that the Moon can provide for dwindling resources on Earth: no way!

Every terrestrial mine with its crude technology refutes this plan. Or the Moon as a place of refuge if we do manage to destroy the Earth? Come on! Perhaps it is the currently very intense earthly issues and conflicts that prompt us to react with the greatest scepticism to such utopian images on the horizon. It is not already unthinkable enough that Earth’s nations will succeed in reviving the 1967 Outer Space Treaty, which regulates ownership and activities?

Ulrich Köhler

CALL OF SIRENS ON MARS

Deep valleys and huge mountains, a very thin atmosphere and no global magnetic field. Mars, with its harsh environment, is extremely fascinating. Close to the outer edge of the Solar System’s habitable zone, the Red Planet is a great place to search for traces of extraterrestrial life – and its history is related to our own. In The Sirens of Mars, planetary scientist Sarah Stewart Johnson presents the history of the exploration of our planetary neighbour and the search for life there.

From the observations made with the earliest telescopes to the more recent space missions, Johnson gives the reader a wide view of Mars and the search for life. But not only Mars – while reading, we travel across the Earth, through our history, and discover more and more places somehow related to martian research.

But it’s not all about planets… the main characters are people, whose tales well represent human curiosity. We meet world-renowned astronomers Giovanini Schiaparelli, Carl Sagan and many others. But the story is also entangled with Johnson’s personal and professional journey, as a female scientist and a mother.

The more you read, the more you can discover. What does Antarctica have to do with Mars? Why is the ancient Yilgarn Craton in Australia interesting for planetary researchers? Do you know what Izvee Coot is named after? The Sirens of Mars will deepen your curiosity.

Claudia Schirma

3 BODY PROBLEM

Italian physicist Enrico Fermi designed the world’s first nuclear reactor and rode a tank through the Trinity A-bomb’s fireball, but it is most famous today for one deceptively casual question he once asked his Manhattan Project colleagues: Where is everybody?

This ‘Fermi Paradox’ concerning the apparently deserted nature of outer space has inspired countless theories, debates and late-night rambles. Now it has become the subject of a high-budget Netflix drama: The 3-Body Problem, based on the renowned trilogy of novels by Chinese science fiction author Liu Chixen. Without seeking to spoil the eight-episode first season, the story revolves around an uninitiated first contact with an alien civilization that turns out to have occurred decades in the past, with surprising consequences for our present.

This is the new project from the team that produced the smash hit ‘Game of Thrones’ for TV. Controversially for some they have westernised the sprawling narrative by centering it around a group of UK-based friends from university – some of whom turned out to be scientifically brilliant and a couple who haven’t. They make it accessible albeit, but the characters themselves are a weak spot, a bit too reminiscent at times of the gang from TV’s Friends. As with those 1990s icons, you might end up wondering: why are this bunch still hanging out together anyway?

But it isn’t the characters that keep viewers glued to this compulsive show, but the many and varied ideas that they end up grappling with – and the application of the scientific method to try and resolve them. We begin at a point where, somehow, science doesn’t seem to be working anymore, a development that appears to be connected to mysterious deliveries being made to top researchers. From there a lot happens, so much in fact that it strains credibility a bit every day life seems to go on as normal in the background, whereas you’d expect human civilization to start having a collective nervous breakdown!

Viewers will recognise several familiar faces from ‘Game of Thrones’, and like its predecessor, 3 Body Problem, in the end, a story about power. A development that appears to be connected to mysterious deliveries being made to top researchers. From there a lot happens, so much in fact that it strains credibility a bit everyday life seems to go on as normal in the background, whereas you’d expect human civilization to start having a collective nervous breakdown!

Ulrich Köhler

MYSTERY SCIENCE

Mystery Science wants to inspire children to love science and become lifelong learners. Their YouTube channel is full of mini-lessons that will encourage viewers to explore the world around them. But this isn’t all! On their website, MysteryScience.com, there is even more exciting content, including full units, seasonal collection and teacher resources.

PLANESpotterS

www.jetphotos.com

Are you an aviation enthusiast? Are you an avid airplane photographer? Then this is the place for you! Founded in November 2002, JetPhotos has developed into the largest aviation photography website on the internet. From their extensive photo database to their aircraft/airliner database, the active, friendly and informative aviation discussion forums, JetPhotos is truly a standout in the internet aviation community.

A MARTIAN ADVENTURE

accessmars.withgoogle.com

How would you like to go to the Red Planet from the comfort of your own home? In Access Mars you can explore the real surface of Mars exactly as it was photographed by NASA’s Curiosity Rover. By combining and analysing these images, NASA JPIL scientists created a 3D model used to study our planetary neighbour and future missions. And now… it’s also there for you to explore in your browser using WebVR.

RECOMMENDED LINKS

DR BECKY

youtube.com/DrBecky

How much science is there in the series ‘Dr Who’ or in the film ‘The Martian’? Dr Rebecca Smith, an astrophysicist at the University of Oxford, answers these questions on her YouTube channel ‘Dr Becky’. In addition to her reactions to films and series, you can find answers to astrophysics topics such as ‘How do we know how old the Milky Way is?’. You will also get an insight into her day-to-day work.

DLR at a glance

s.DLR.de/DLRtrailer

More than 10,000 people work and conduct research at DLR in more than 50 institutes and facilities. This presentation film gives an overview of the broad range of research topics and the numerous opportunities offered by DLR.

MYSTERY SCIENCE

youtube.com/MyMysterySci

Mystery Science wants to inspire children to love science and become lifelong learners. Their YouTube channel is full of mini-lessons that will encourage viewers to explore the world around them. But this isn’t all! On their website, MysteryScience.com, there is even more exciting content, including full units, seasonal collection and teacher resources.

WE WANT YOU!

DLR.de/careers

Any ambitious organisation needs great personnel. DLR offers a unique work environment and a pioneering spirit at every turn so that we can achieve great things together. We also offer an attractive programme for your personal development and work-life balance. Whether you want to start an apprenticeship or are in the middle of your studies, whether you are fresh out of university or already have professional experience – as part of our team, we will be your valued and supported right from the start. In our new careers page you will find out all there is to know about working at DLR. Check it out!
The consequences of climate change require us to act. New technologies should also ensure global mobility in the future. One element of this is individualised route planning in air transport. DLR is carrying out research into both how to avoid highly warming contrails through targeted route planning and into sustainable fuels that play a role in this context. This image shows the DLR research aircraft Falcon during a jet engine emission measuring campaign.