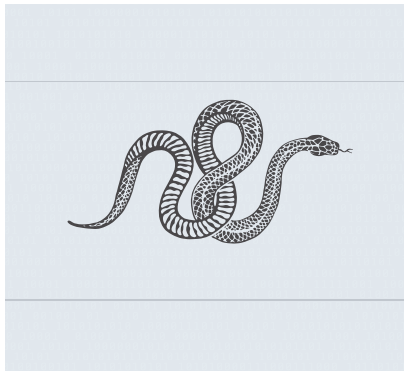
AEROREPORT 01|21
The aviation magazine of MTU Aero Engines I www.aeroreport.de

# Hydrogen is the future

*MTU Aero Engines has high hopes for hydrogen*

**COVER STORY**

## Hydrogen is the future

Whether for sustainable aviation fuels, for carbon-free combustion in the gas turbine, or for zero-emission conversion into electricity in the flying fuel cell to power electric motors—MTU Aero Engines has high hopes for hydrogen in the future.

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## A cunning approach to image analysis

The job of post-processing microscope images on the computer for materials development, quality inspection or failure analysis used to take metallographers days on end. Developed in-house, MTU's Natter software automates the process, reducing this time to a matter of minutes.

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## No idle hands here

Additional facilities, new engine types: MTU Aero Engines is expanding service and support to make its market offerings even better. The MRO sites in China and Poland are gearing up for maintenance of the PW1100G-JM, and a new repair shop is going up in Serbia.

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## Climate-friendly routes

In addition to further technical improvements to aircraft, operational measures such as climate-optimized flight routes and fuel-saving approach procedures will help shrink air travel's ecological footprint in the future.

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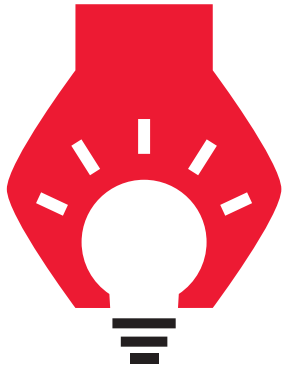

**PEOPLE**

## DIY in the prototype workshop

MakerSpace is a high-tech workshop in Munich for inventors and creatives. It's where MTU Aero Engines employees tinker with software, tools and machines to create prototypes of their product concepts in an environment conducive to new ideas and accomplishment.

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**GOOD TO KNOW**

## Overcoming crackling and interference

"Reduce to minimum." From a linguistic perspective, aviation is an industry of acronyms and abbreviations. Many of them are rooted in history; some have arisen to overcome the challenges posed by headphones and noise. Emergency communication, too, plays an important role.

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### PEOPLE



### GOOD TO KNOW



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**$H_2$ = Hydrogen ___**

*Hydrogen is a chemical element with the symbol H and atomic number 1. In the periodic table, it is in the first period and in the first IUPAC group. Hydrogen is the most abundant chemical element in the universe, but not in the Earth's crust. It is a component of water and most other organic compounds.*

# Hydrogen is the future

*Whether for sustainable aviation fuels, for carbon-free combustion in the gas turbine, or for the flying fuel cell– MTU Aero Engines has high hopes for hydrogen.*

**Text:** *Denis Dilba*


**Dornier 228** ____ *The twin-engine turboprop aircraft will be equipped with a hydrogen-powered fuel cell and used as a flying testbed.*

H2


**Fuel cells** ___ *When used as an energy source, fuel cells emit nothing but water, meaning they enable virtually climate-neutral and pollutant-free flight.*

Designed back in the 1980s and sporting an elongated nose and two propeller-driven turboprop engines, the Dornier 228 certainly does not look like the future of aviation. However, if everything goes to plan and the aircraft takes off from the DLR German Aerospace Center's Oberpfaffenhofen research airport in 2026, it will have a technical revolution on its wing: a fuel cell powertrain specially developed for aviation applications. "As things stand today, the fuel cell in conjunction with sustainably produced hydrogen offers the greatest long-term potential for realizing emissions-free aviation. That's our vision for the future," says MTU's Chief Operating Officer Lars Wagner. "We believe that a fuel cell system of this kind could in future provide sufficient power and range to be used as the primary propulsion system for regional, short- and medium-haul aircraft."

It was only logical for MTU Aero Engines to become a development partner in the ambitious fuel cell project. In August 2020, Wagner and Professor Rolf Henke, Executive Board Member for Aeronautics Research and Technology at the German Aerospace Center (DLR), signed a memorandum of understanding to develop the powertrain for a hydrogen fuel cell. Their objective is to equip the Dornier 228 with a high-performance fuel cell and an electrical, single-sided propeller engine with over 500 kW shaft output, and then put it through its paces in flight tests. Except for water and steam, the powertrain will be completely emissions-free. Up to 80 experts are lined up to work on this pioneering project. "The experience and data acquired in our collaboration, including in the fields of aviation regulation and certification, will prove vitally important to ongoing product development," Wagner says.

## Improving fuel cell performance is a must for aircraft applications

Barnaby Law, Chief Engineer Flying Fuel Cell at MTU, is confident that it's possible to keep the highly ambitious development schedule on track. As fuel cell technology has matured, driven primarily by the automotive industry, the power-to-weight ratio has improved steadily over the past ten years; at the same time, wider supplier chains have been established. "Overall, that's a great basis to start further developing the technology for aerospace applications," he says. Because fuel cells need to be made even more powerful if they are to become the primary propulsion system for aircraft carrying a larger number of passengers and flying over a certain range. Law believes there is no need to fear insurmountable obstacles: "Given that weight reduction is inher-

*"As things stand today, the fuel cell in conjunction with sustainably produced hydrogen offers the greatest long-term potential for realizing emissions-free aviation. That's our vision for the future."*

**Lars Wagner**
*Member of the Executive Board, Chief Operating Officer of MTU Aero Engines*

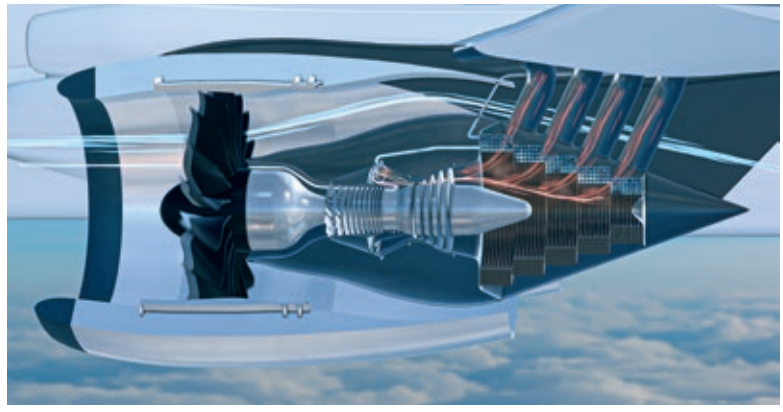
ently more important in aviation than in the automotive industry, we already know some viable approaches to start optimizing fuel cells," the fuel cell specialist says.

Using lighter high-tech materials such as titanium, which is widely used in aviation, helps save weight for instance. It would also be feasible to use the expensive but performance-enhancing catalyst material platinum, even if this would slightly increase the load. But even with the additional costs this involves, the fuel cell is still relatively inexpensive compared to other climate-friendly solutions, and the huge advantage of this technology is that it really is emissions-free, Law explains. However, additional technologies are required to enable passenger aircraft powered by fuel cells to fly–first and foremost, the fueling system. Because hydrogen gas occupies such a large volume, even when stored in pressure tanks, aviation applications will use liquid hydrogen cooled to minus 253 degrees Celsius. "You can imagine the tank like a large vacuum flask," Law says.

## Other green, hydrogen-based technologies are available

However, this concept works only because aircraft use large amounts of hydrogen and flights follow a regular, planned schedule, Law explains. "If you put a liquid hydrogen tank in a car, drove to the airport and returned two weeks later, the tank would be more or less empty." Aircraft, on the other hand, use the hydrogen before it has a chance to heat up and become gaseous. But there is a catch to the solution, as Law explains: "Looking at it from a purely physical perspective, liquid hydrogen has a volume four times that of kerosene for the same energy content." In practice, however, this factor is slightly smaller and lies somewhere between three and four. In other words, the longer the route the aircraft flies, the larger the hydrogen tank required. "For distances of up to about 3,500 nautical miles, or just under 6,500 kilometers, it still makes sense to accommodate the tank, with modifications, in the current aircraft configuration. For longer routes, other solutions are better," the fuel cell expert explains.

"Potential options are to burn hydrogen directly in the gas turbines or to use sustainable aviation fuels (SAFs), which are produced using the power-to-liquid or sun-to-liquid process," says Dr. Stefan Weber, Senior Vice President Engineering and Technology at MTU. In theory, it would be possible to make the switch now to burning hydrogen directly, he explains, because the necessary modifications to the geared turbofan (GTF) would be relatively easy to make. However, green hydrogen is not yet available in sufficient quantities. Alternatively, SAFs are attractive because they are "drop-in" fuels, as Weber explains: "Virtually no modifications need to be made in the engines, aircraft or other infrastructure to accommodate them." These two technologies alone would offer some big advantages: burning hydrogen directly does not produce any $CO_2$ emissions and also prevents particulate emissions. As for SAFs, they close the carbon cycle, thus immediately helping to achieve climate-neutral flight. As combustion of SAFs is cleaner, they also have the potential to generate fewer contrails.

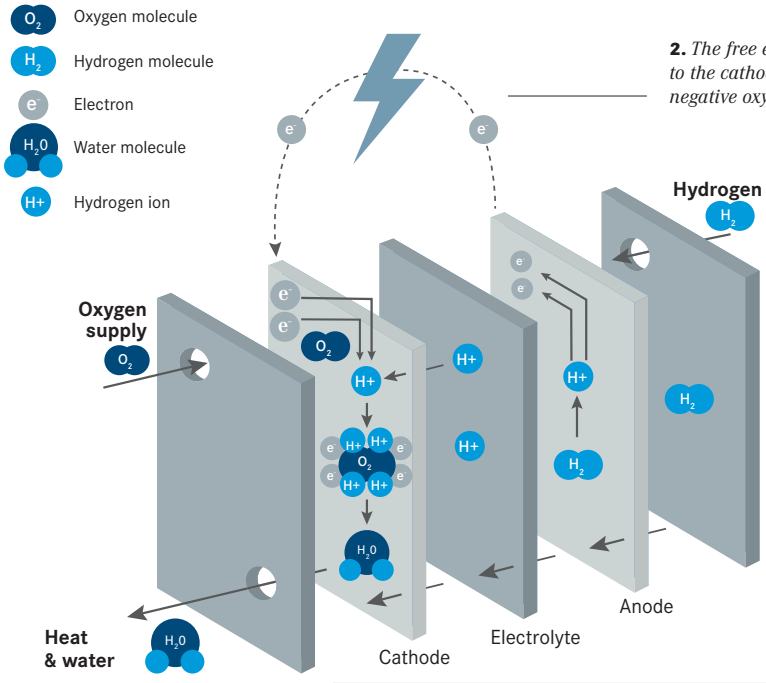


**Water-Enhanced Turbofan (WET)** ____ *This concept evaporates water in a heat exchanger in the engine and injects it into the combustor. The aim is to use the energy in the exhaust to increase power output while reducing emissions through steam injection.*

## Faster pace of development required for climate-friendly technologies

In a study published in June 2020, Clean Sky, the largest European research program, estimates that direct-burn hydrogen systems can reduce the global warming effect of flying by between 50 and 75 percent, and SAFs can reduce it by between 30 and 60 percent. The study's authors believe that the fuel cell has the potential to reduce climate impact by 75 to 90 percent. "Essen-

**HOW A FUEL CELL WORKS**




**2.** *The free electrons flow as usable electricity via a conductor to the cathode, where they join with oxygen atoms to form negative oxygen ions ($O_2$-).*

**1.** *Each fuel cell contains two plate-shaped electrodes (anode and cathode) separated by an electrolyte. The electrolyte can conduct ions, but is impermeable to gases. Located on the electrodes, the catalyst materials ensure that the gases channeled into the cell release charge carriers (ions). Hydrogen molecules ($H_2$) on the anode split into hydrogen atoms, which in turn release electrons to become positively charged hydrogen ions ($H^+$).*

**3.** *The hydrogen ions travel through the electrolyte to the cathode, where they join with the oxygen ions to form water, releasing heat in the process.*

tially, we need all three technologies," Weber says. While SAFs are the only option for operating the existing aircraft fleet in a more climate-friendly way, he explains, it is illogical to simply rely on a single solution if even better technologies are available in the long term. The same principle applies to the further development of the GTF. For example, if the water-enhanced turbofan (WET engine) concept is used in conjunction with SAFs, it would offer the potential to drastically cut emissions, even for long-haul aircraft. With this concept, water is evaporated in a heat exchanger in the engine and injected into the combustor. The exhaust heat is used to evaporate the water, which can significantly improve the propulsion system's efficiency. Moreover, wet combustion prevents $NO_x$ emissions almost entirely.

So the evolutionary refinement of the GTF is not over yet either, Weber says, adding that there are still an extra few percent of fuel savings left to achieve. "If you take the Paris Agreement goals seriously and want to keep global warming below two degrees, you come to the conclusion that we need to develop all these greener technologies faster and more aggressively than before—and that's exactly what we're doing," Weber says. "To play its role in this scenario, the flying fuel cell needs to be ready for large-scale deployment by 2040 at the latest." Fuel cell expert Law firmly believes that this is possible: "Then we'll be able to fly away on vacation in an A320-category aircraft with a fuel cell powertrain."

Do you have any questions, requests or suggestions?
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More on this topic: **www.aeroreport.de**

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**Denis Dilba** holds a degree in mechatronics, is a graduate of the German School of Journalism, and founded the "Substanz" digital science magazine. He writes articles about a wide variety of technical and business themes.

# The component puzzle

*Developing and optimizing fuel cells and hydrogen tanks is a challenge. But identifying the best way to integrate those components into the aircraft is just as tough.*

**Text:** *Denis Dilba*

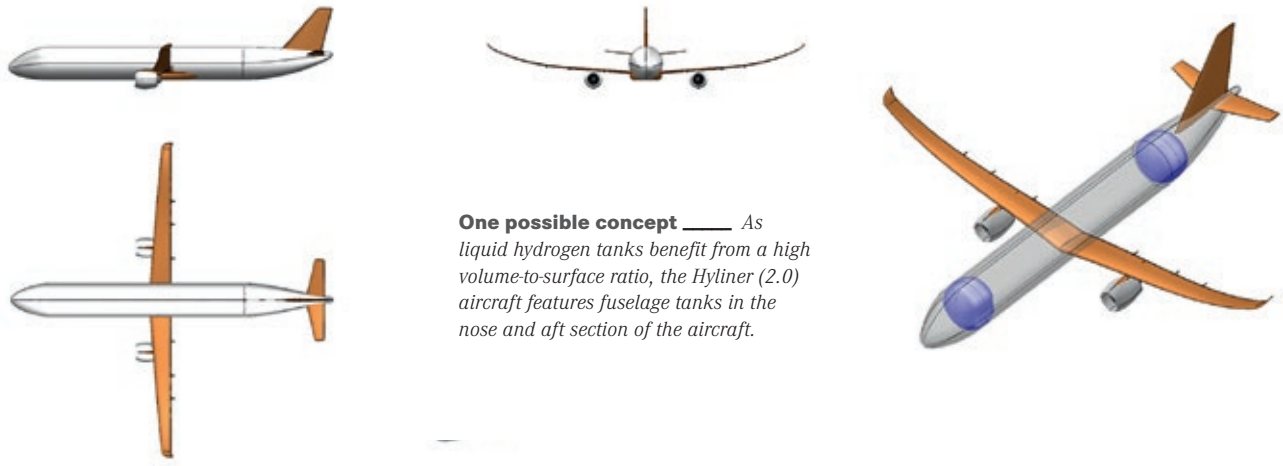
MTU Chief Engineer Flying Fuel Cell Barnaby Law is confident that passenger aircraft will be hydrogen-powered in the future—and he is not alone. Just seven short weeks after MTU and the German Aerospace Center (DLR) signed a memorandum of understanding to join forces in developing a fuel cell powertrain in early August 2020, Airbus published its definitive plans for making aviation more environmentally friendly. Airbus envisions a hydrogen-powered turbofan concept for medium- and long-haul flights. Modified engines would burn the volatile gas directly. Airbus thinks this aircraft could enter service in 2035. One aspect of this design isn't obvious at first glance: the $H_2$ aircraft has no windows at the rear pressure bulkhead, which is where the hydrogen tank is located. "There has to be a compromise somewhere if you want aircraft to be powered by hydrogen," Law says.

This is because, even at minus 253 degrees Celsius, supercooled liquid hydrogen has a volume four times that of conventional kerosene for the same energy content. "That means there simply isn't enough space to store hydrogen in the wings, where the kerosene tanks are currently integrated," fuel cell expert Law explains. This


**Turbofan design** _____ *The aircraft for 120 to 200 passengers has a range of more than 2,000 nautical miles.*


**Turboprop design** _____ *The aircraft for up to 100 passengers has a range of more than 1,000 nautical miles.*

**HYLINER (2.0) AIRCRAFT**



**One possible concept** ____ *As liquid hydrogen tanks benefit from a high volume-to-surface ratio, the Hyliner (2.0) aircraft features fuselage tanks in the nose and aft section of the aircraft.*

restriction also applies to hydrogen-based propulsion systems that rely on fuel cells. Moreover, apart from the larger footprint, a liquid hydrogen tank must be spherical or cylindrical in shape to withstand the higher pressures compared to kerosene tanks. "If you don't want to mount the tank on the outside of the aircraft—not advisable, as it would have a major impact on the aerodynamics—the fuselage is your only option," Law says. This is also where he sees the $H_2$ tank being positioned. To be able to transport a similar number of passengers, hydrogen-powered aircraft will therefore need to be either greater in length or wider in fuselage diameter.

### An $H_2$ tank is too large and too heavy for long-haul and ultra-long-haul flights

Law presents other possible scenarios, such as distributing the fuel among several small tanks or combining a larger, comparatively low-pressure $H_2$ storage tank with a smaller high-pressure tank. The latter solution is worth considering for hydrogen direct combustion, since the engines require hydrogen pressures of 60 bar for this. "As a rule, however, several small hydrogen tanks will always be heavier than one or a few large tanks." For this reason, he expects the second option to become the future standard. However, when it comes to long-haul and ultra-long-haul flights, he points out that just a single tank—even one made as usual of lightweight aluminum—would be so large and heavy that liquid hydrogen is no longer economically viable. "To put it bluntly, the tank would take up all the space, with none left for passengers," Law says. That's why MTU believes that long-haul aircraft will be powered by drop-in sustainable aviation fuels (SAFs).

*"The fuel cells can be placed either in the fuselage, as close as possible to the hydrogen, or in the nacelle, as close as possible to the electric motor."*

**Jochen Kaiser**
*Head of Visionary Aircraft Concepts at Bauhaus Luftfahrt*

Apart from the challenge of integrating the liquid hydrogen tanks, designing aircraft with fuel cells as the primary propulsion system begs the question as to the best location for the cells. "There are two alternatives," says Jochen Kaiser, Head of Visionary Aircraft Concepts at the Munich aviation research institution, Bauhaus Luftfahrt. "The fuel cells can be placed either in the fuselage, as close as possible to the hydrogen, or in the nacelle, as close as possible to the electric motor," he says. Locating them in the fuselage offers the advantage of short hydrogen pipelines to the fuel cells. The downside: longer cables have to be laid to the electric motors. These advantages and disadvantages are reversed in the nacelle, with shorter electric cables and longer $H_2$

pipelines. In Kaiser's view, the latest research indicates that placing them near the electric motors offers additional benefits. First, it is easier to dissipate the waste heat from the fuel cell stacks if they are in the nacelle; second, conventional cable technology would be sufficient.

### Placing the fuel cells near the electric motors is the best solution

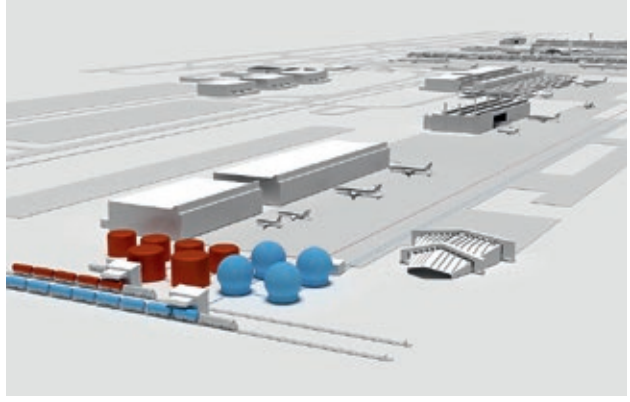
"The situation is different when the fuel cells are in the fuselage," says the Bauhaus Luftfahrt scientist. Because the voltage has to be kept lower in the aircraft for safety reasons, it takes considerably thicker and heavier cables to conduct the same electrical current. "One possible solution to this problem would be high-temperature superconducting cables–they are much lighter and can conduct a great deal more electricity," Kaiser says. However, this technology is still in its infancy. Which is why, in Law's opinion, integrating the fuel cells into the nacelle is the only way to go. "Our philosophy at MTU says no experiments, except in research and development. When implementing technologies, we favor tried-and-true technologies that are part of our expertise. After all, aviation has the most stringent safety requirements."

*"When implementing technologies, we favor tried-and-true technologies that are part of our expertise. After all, aviation has the most stringent safety requirements."*

**Barnaby Law**
*Chief Engineer Flying Fuel Cell at MTU*

However, he adds, MTU is extremely confident that hydrogen propulsion will be a reality within the next 15 to 20 years. "This presupposes that the majority of airports around the world have implemented the necessary hydrogen infrastructure by then," Law says. "It can be done," says the MTU expert. But how is another matter entirely.

**Propulsive fuselage** ____ *The enlarged fuselage surface of a hydrogen aircraft results in synergetic savings potential when using a propulsive fuselage.*



**Infrastructure** ____ *The infrastructure at airports must be adapted for the logistics of liquid hydrogen alongside conventional kerosene.*

Do you have any questions, requests or suggestions?
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# Augmenting reality

*In its Inno Lab, MTU is using augmented reality (AR) to simplify the steps to take when working on an engine.*

**Text:** *Thorsten Rienth*

**Remote support from far away** —— *Augmented reality (AR) technologies are opening up a world of new opportunities in the engine business. MTU is using AR to simplify work steps.*

Some things don't quite fit together as you might expect. On the one hand, the Inno Lab at MTU Aero Engines has a real start-up feel about it with its tall windows and bright, interconnecting rooms. It has social areas and large flat screens, a "pitching" area, a test environment for camera-computer systems and a 3D printer. But then you find a Lego® model in another room, and it's almost like you've stepped back in time.

Looks can be deceiving. In fact, the thrust nozzle of an EJ200 engine built out of Lego® bricks is the proverbial gateway to a new world of augmented reality (AR). A world where AR applications could one day provide valuable support for the many work steps involved in the engine business–from component assembly to inspection and quality analysis.

### Proof of concept—and how Lego® bricks fit in

Laying the groundwork for this approach is Thomas Staak, who heads MTU's Technical Documentation department. He reaches for a tablet and holds it in front of the thrust nozzle model with the camera turned on. A tool appears on the display and a shade opens. Then another tool flashes up. In a stylized movement, it shows how to detach and replace a segment of the thrust nozzle.

The idea is for an engine mechanic to follow these on-screen, augmented reality instructions to execute the work step on a real engine. "At the same time, the system could provide automatic access to the corresponding process in the maintenance documentation, for example, to show the mechanic any open repair tasks," Staak says. And if necessary, a specialist engineer could support the engine mechanic remotely via the tablet's camera.

As part of a development project with a specialist Hamburg start-up, Staak and his colleagues have completed the first stage of a long journey. They have a proof of concept–the technical term for the brief demonstration with the camera and model to show that the idea is feasible. Their first task was to test the principle behind this application of AR. The Lego® model of the thrust nozzle let them greatly simplify depiction of the "real" component and build the software based on simple structures. A further advantage of the plastic models is that they are easy to build on—one brick at a time. Every change and every new level of detail is a learning process for the software and engineers alike. "Our colleagues over at the start-up in Hamburg have the same model, which makes it quick and easy for us to jointly tweak and optimize individual functions of the AR application as and when we need," Staak says.

There is sound, strategic logic behind this approach. “We want to learn how augmented reality works and how we can best apply it to our requirements,” Staak explains. What hardware is useful and what isn’t? How can we integrate artificial intelligence (AI) software, for example to run automated failure analyses?

## Test program for first AR application already underway

Anyone who wants to see what Staak means by all this will need to look beyond his section in the Inno Lab. A few buildings further along, in the shop where MTU assembles the PW1100G-JM engine that powers the Airbus A320neo, one of the first tablet-based AR applications has already been tested. Here, too, the development steps were supported by a Lego® model–this time of a Geared Turbofan™, which is considerably larger and more complex than the thrust nozzle. In this application of AR, assistive animations and computer-aided checks are used to verify that small brackets for oil lines on the engine are installed in the right places and are correctly aligned. Thanks to the Lego® model, the engineers can test the bracket mounting process without having to assemble or disassemble real, complex modules. The brackets were 3D printed in plastic especially for the purpose.

The artificial test environment offers another huge advantage. In the assembly shop, day-to-day operations run on a very tight schedule, which leaves no time for any kind of tests or trials. With the Lego® model, engineers can now check and test the theory for mounting the brackets from the comfort of their office.

However, the test in the PW1100G-JM assembly shop also shows that using AR on such complex components is not always straightforward. “Sometimes an edge reflects, sometimes the light incidence changes and casts a shadow. But we’re getting to grips with that now,” Staak says. And if it’s still not right? “Then we adjust it.” He pauses for effect before continuing: “And that just means we’ve become a little bit smarter, a little bit better.”

**First AR application in testing** —— *This application verifies that brackets are installed in the right places and correctly aligned. This lets engineers test the bracket mounting process without having to assemble or disassemble real modules.*


**Virtual reality (VR)** enables users to experience a virtual world in 360 degrees, to view it from every angle, to move around within it and to interact with it. Users feel removed from their actual environment, as if they have been transported into the virtual world.

**Augmented reality (AR)** meanwhile, simply enriches the real world with virtual content, which means users need to be present where the action is taking place. AR then overlays their perceptions of their real-world environment with real-time information in the form of text and graphics. This means, in contrast to VR, that AR users remain grounded in physical reality.

Do you have any questions, requests or suggestions?
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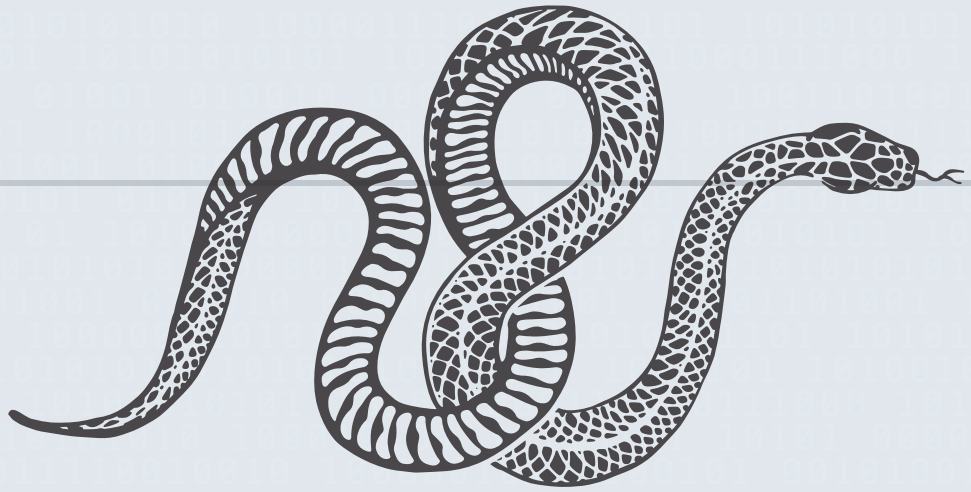
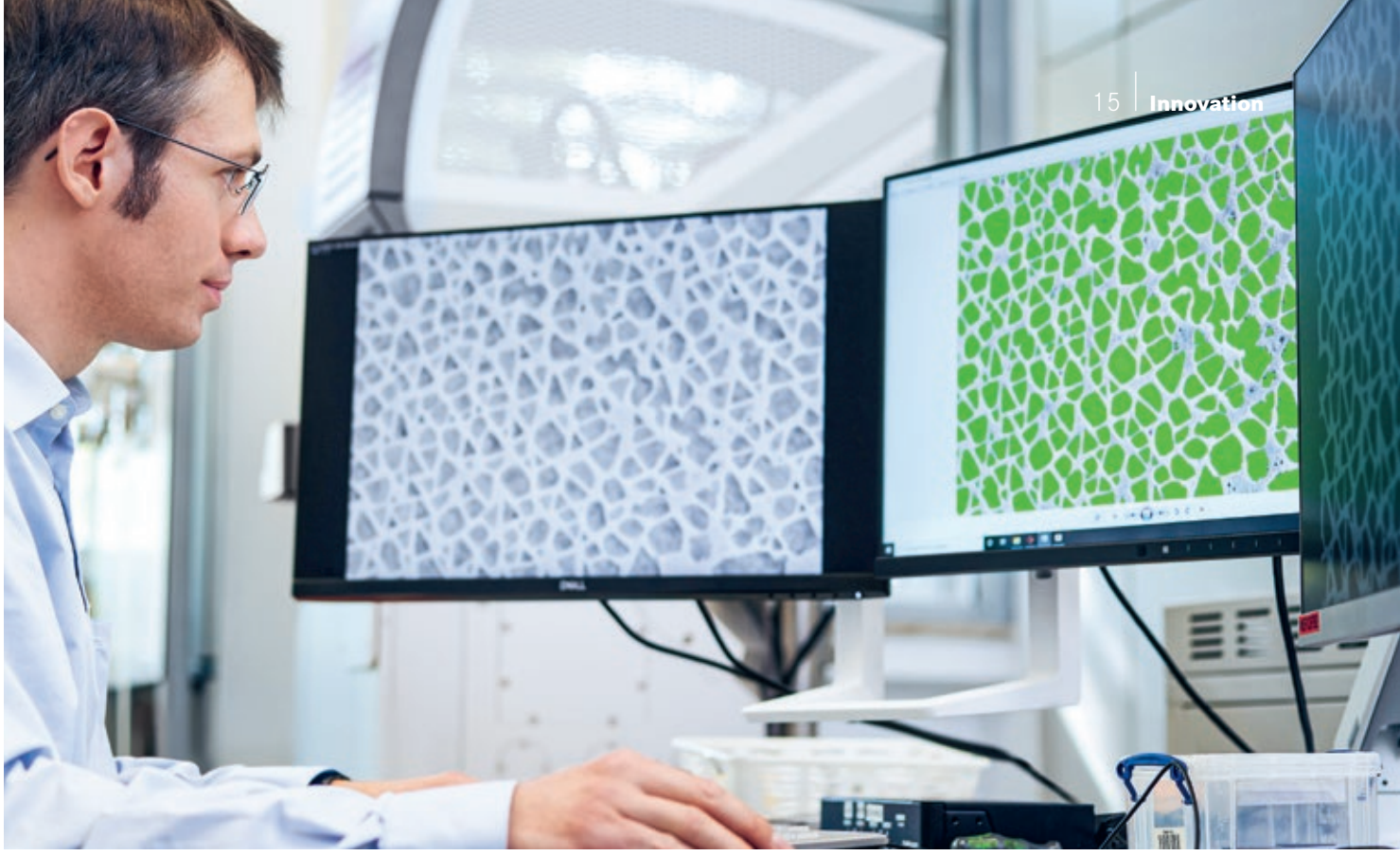


# A cunning approach to image analysis

*The job of post-processing microscope images on the computer for materials development or quality inspection often used to take metallographers days on end. MTU's Natter software reduces this time to a matter of minutes.*

**Text:** *Denis Dilba*



**Automated image analysis** ____ *Natter adds color to one phase of the material. This serves to classify material properties to assess factors such as overheating of the material during flight.*

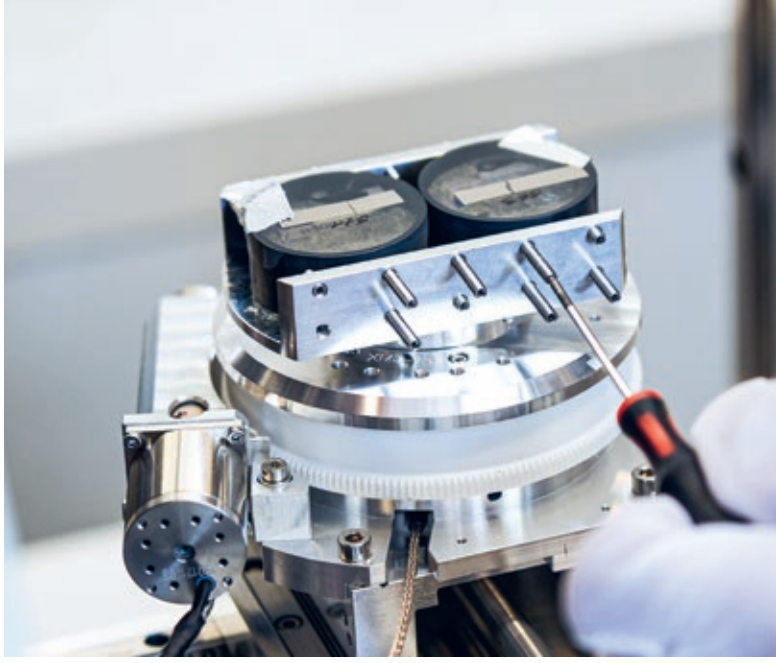
If you casually overheard a work meeting between Julian von Lautz and Dr. Hendrik Kramer, you might well get the idea that the two engineers were planning a trip to a reptile zoo. You might hear them mention python and anaconda, and repeatedly talk about the world's largest snake family, colubrids or Natter in German. The Natter, they say, is very fast indeed. People in IT will know that the first two are actually references to the programming language Python and its toolkit Anaconda–not real snakes. But what about Natter? "It stands for 'Neuronal Analysis Tool To Evaluate Rapid' and describes new deep learning software that takes image analysis in metallography to a completely new level for materials development, quality inspection and failure analysis," explains materials expert Dr. Hendrik Kramer. He works in the Materials Analysis/Metallography team at MTU Aero Engines in Munich and image analysis falls under his area of responsibility. Kramer teamed up with Julian von Lautz, then Senior Manager Failure Analysis, and other colleagues to put the idea into practice. "Admittedly, we came up with the name Natter first and only then a description to fit it," he says.

The acronym and its definition hit the nail on the head: similar to the way that colubrids use their lightning-fast bite to snatch their prey, the MTU software uses artificial intelligence (AI) to classify microscope images of metals at an unprecedented speed. This really comes into its own in materials development, quality control and failure analysis. Natter is already in use for nickel-based alloys, where the percentage of γ' phase in the metal is decisive for the quality of the material properties at high temperatures. The challenge was that analysis of these microscope images had to be performed manually in some cases, which is a very laborious task. In the first step, a computer program classifies each pixel as light or dark based on its grey value and calculates the area of each pixel.

## A long time coming: automated image analysis

"Depending on the material, a few special rules apply, such as counting adjoining light or dark areas only if they reach a certain size and shape or depending on how far away other areas occur," Kramer explains. The old software produces an image

**Efficient approach** ____ *The new software saves the metallographers valuable time in their work. Previously, it took them 30 minutes to analyze each image; Natter can do the same job in three minutes.*



**Precision** ____ *To prepare them for examination under the scanning electron microscope, the damaged parts of the components are set in plastic, ground and polished.*

**Natter** ____ *stands for 'Neuronal Analysis Tool To Evaluate Rapid' and describes MTU's new deep learning software used in metallography to analyze images for quality assurance and failure analysis.*

| | |
|---|---|
| Segmentation time per image: | **5 sec.** |
| Congruence of the analysis results with those by human testers: | **96%** |

with a rough pre-selection of light and dark areas, which a metallographer then has to check and improve. To do this, the experts have to click to add, remove or even trace individual areas by hand, a process that can take half an hour or so. "Given that a full analysis job can comprise 60 images, our highly trained metallographers sometimes sat clicking away at the computer for almost a week," Kramer says. The idea to automate this process using AI came about years ago and had been an aspiration for just as long. However, for most of that time, the machine learning algorithms required for this use case just weren't powerful enough.

It was only when von Lautz and Kramer came across a special, newly developed deep learning method around three years ago that automated image analysis became a potentially viable option. They immediately designed a research project for a master's student as a swift way to clarify if the approach could actually solve their problem. "Following about two months of programming activities, it was already clear that the new method would work," von Lautz recalls. It took the two engineers a good year to get all the proper documentation in place, optimize the program code and prepare the training data so that Natter was ready to use, they explain. "You shouldn't underestimate the work involved in preparing the data for such methods. It takes a huge amount of effort," Kramer says. To train their deep learning software, they used 2,400 pairs of images for which they already had the right solutions for the respective tasks. Around 2,000 of these were to train the software and the remaining 400 were to check the progress of the training.

## Natter improves image analysis performance by at least 90 percent

According to Kramer, picking out the image pairs was only one part of the job. Getting the data into a standard format took just as long, if not longer. "The images come from different microscopes, vary in the way they are exposed and cropped and have different resolutions," he says. It took several months before it was possible to start training Natter on a uniform dataset. But all the effort more than paid off. Automated image analysis using AI takes just five seconds per image. The results of the automated analyses correspond to those of human testers with just over 96 percent accuracy. "So Natter's processing time is next to nothing," Kramer says. Nevertheless, the MTU engineers are erring on the side of caution and expect that an expert will still

**A closer look** ____ *Before the software is used to analyze the integrity of the metal, the component is inspected for damage.*

**Looking ahead** ____ *Julian von Lautz believes that in the medium to long term, such AI methods will take the form of virtual assistants for aerospace engineers.*

have to visually inspect every automatically evaluated image and perhaps check every tenth image again by hand.

"But even then, it will take only three minutes per picture using Natter rather than half an hour," von Lautz says. "That boosts performance by at least 90 percent." And it massively reduces the metallographers' workload, who now need only two to three hours for a job that used to take a week. This frees them up to focus on other tasks, such as the development of new materials. According to von Lautz, MTU is ahead of the game in its implementation of this automated image analysis software. "In the future, we'll work on making Natter suitable for analyzing even more materials in addition to nickel-based alloys," he says. But both the MTU engineers are already thinking even further ahead. "In principle, the method offers a good solution for all image processing work—especially when the problem can't be described mathematically but a lot of training data is available," Kramer says. And its use isn't necessarily restricted to metallography. Von Lautz believes that in the medium to long term, such AI methods will take the form of virtual assistants for aerospace engineers.

"In the same way that modern AI diagnostics programs assist doctors by automatically indicating any metastases on an X-ray of the lungs, these devices will help us engineers to focus our attention on the relevant areas during analyses and tests," von Lautz says. This will allow engineers to perform more tests in less time to the same level of quality as before, if not higher, he explains. "In the aviation industry, where safety comes above everything else, the future belongs to such AI solutions."

## DEEP LEARNING

*Deep learning is part of a broader family of machine learning methods that fall under the umbrella of artificial intelligence. The algorithms they use are based on artificial neural networks, loosely inspired by way the human brain processes information. The adjective "deep" comes from the use of multiple layers in the artificial neural networks that form a deep structure. Following appropriate training with suitable data, deep learning systems can very successfully recognize patterns in large, unstructured sets of data. Such methods are therefore used in speech assistants, for autonomous driving—and now, with specific adjustments, to test the quality of materials using image data.*

Do you have any questions, requests or suggestions?
Contact the editors here: **aeroreport@mtu.de**

More on this topic: **www.aeroreport.de**

Text:
**Denis Dilba** holds a degree in mechatronics, is a graduate of the German School of Journalism, and founded the "Substanz" digital science magazine. He writes articles about a wide variety of technical and business themes.

# Protecting aircraft from frost

*Icy wings interfere with aerodynamics and pose a threat to safety. In the future, a new laser technique could make deicing aircraft faster and more efficient.*

**Text:** *Denis Dilba*

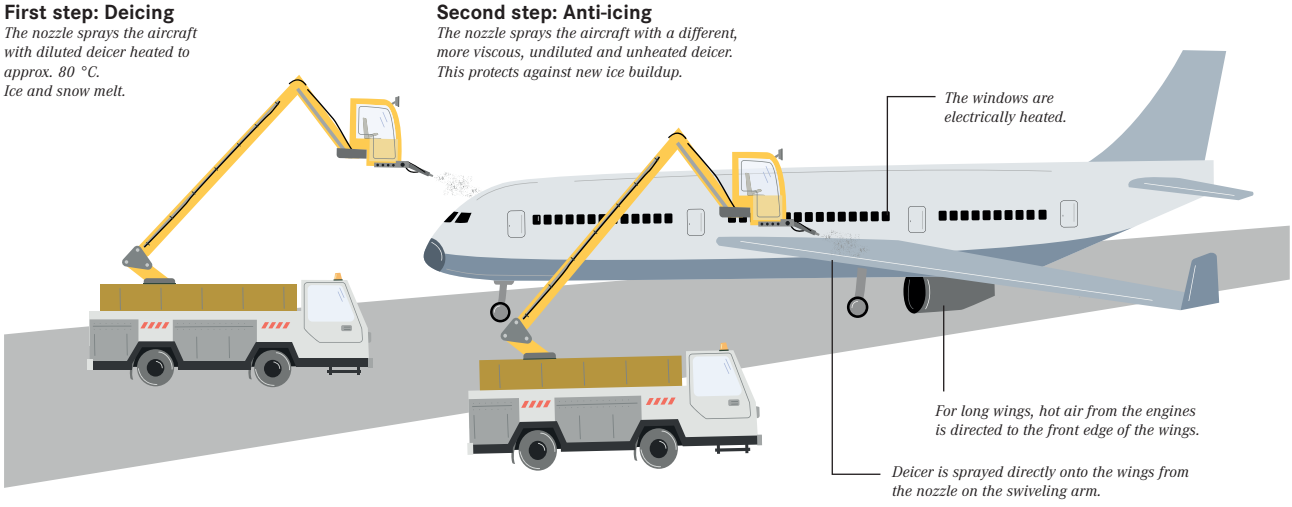
## Ice buildup on the ground

> Frost buildup, e.g. overnight on aircraft surfaces and propellors
> Ice formation on aircraft due to sleet

On cold fall and winter days, aircraft sometimes need the same thing people do: a hot shower. The difference is that passenger aircraft get a shower of water mixed with glycol if the wings are covered in ice and snow, if not before, because that has a negative impact on aerodynamics. Even if the layer of frost on the wings is just a few millimeters thick, it can significantly increase air resistance, which in turn decreases lift. If the wings—and especially the leading edges—become severely iced up, the aircraft may even stall and thus get into serious difficulty. Then there's the weight issue: a five-millimeter layer of frost covering the wings of an Airbus A320 can weigh up to 375 kilograms, which also significantly increases fuel consumption. It follows that passenger aircraft scheduled to fly in cold conditions are deiced prior to takeoff as a matter of course.

During the last deicing season from October 2019 to April 2020, this procedure was performed 5,291 times at Munich Airport alone. From the point of view of the deicer manufacturers, that constituted a bad winter: the year before, that figure was 10,572—almost exactly twice as high. But even if future winters were to become still milder and aircraft remained frost-free on the ground, the problem remains of how to deice the wings during flight. This is generally done during descent, when aircraft leave their cruising altitude—at which air temperatures can be as low as minus 50 degrees Celsius, even in summer—and dip into more humid layers of air. On the ice-cold outer shell of an aircraft, water droplets freeze solid incredibly fast. Developing protective systems capable of removing such ice deposits while also inhibiting the buildup of ice during flight has therefore been

**CONVENTIONAL DEICING OF AIRCRAFT**




*Source: Shutterstock*

## Ice buildup in flight

> Supercooled liquid cloud droplets land on and then freeze to cold aircraft when flying through cloud
> Larger water droplets freeze to cold aircraft when flying through fog, rain or drizzle
> Solid particles such as snowflakes or ice crystals freeze to aircraft when flying through sleet and snow
> Frost builds up on cold aircraft surfaces caused by deposition when entering warmer, more humid layers of air
> Ice builds up due to adiabatic expansion of humid air in the carburetors of piston engines when flying through humid air masses

a top priority for aviation researchers for a long time. Since the 1930s, various technologies have been developed to protect propellors, rotors, engine inlets, wings and tail assemblies from ice.

### New anti-ice technologies must meet exacting requirements

Many smaller propellor aircraft are equipped with inflatable rubber boots, for instance on the wing leading edges. As the boots expand, the ice breaks off. Large passenger aircraft tend to employ hot air bled from their engines and carried via tubes to the leading edges of the wings. Although very effective, this method reduces engine performance. Individual electric wing heaters are more efficient, but these require batteries that make the aircraft heavier. This means that there is great demand for optimized technical solutions that can reduce–or ideally entirely prevent–the buildup of ice during flight while consuming less power than the options available today. And there is no shortage of ideas, including water- and ice-repelling microstructures that can be worked into films stuck onto the wing surface or integrated directly into the wings themselves. Work also continues into mechatronic systems designed to dislodge ice using high-frequency vibrations.

However, none of these ideas has yet become a commercial application for passenger aircraft. “The requirements are exacting: any solution must be able to withstand mechanical strain such as erosion caused by sand, insects and other contaminants, vast fluctuations in temperature and especially high-energy UV radiation,” says Tim Kunze, Group Manager Surface Functionalization at the Fraunhofer Institute for Material and Beam Technology IWS in Dresden. In collaboration with Airbus and TU Dresden, his team has developed a promising laser treatment for surfaces, which

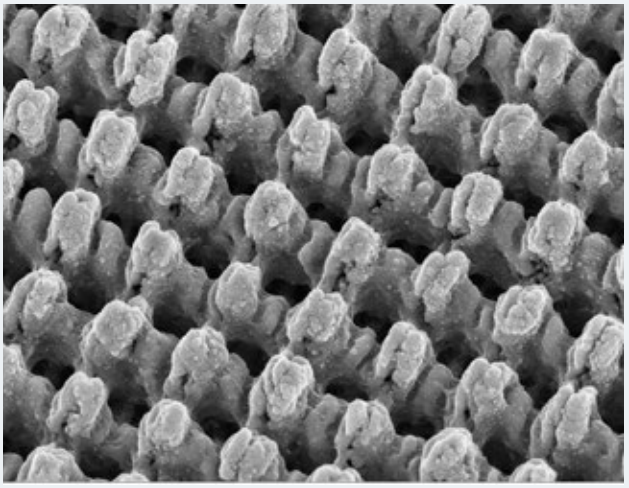
**CHANGE IN LIFT CAUSED BY ICE BUILDUP**


**Ice formation on aircraft** ____ *Ice impairs aerodynamics, especially through reduced lift, while also increasing air resistance and the weight of the aircraft. Ice buildup describes the deposits of ice or frost on aircraft that can happen both in flight and on the ground.*

ANTI-ICING TECHNOLOGIES

**Previous anti-icing systems for passenger aircraft have mainly been based on bleeding hot air from the engines. The following are a selection of more efficient solutions that are in the pipeline**

**Ice-repelling films** ____ *Just as water rolls off a lotus leaf, ice cannot build up on films with certain microstructures. The Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB is using plasma processes to add such ice-repelling surfaces to polyurethane films. One of the challenges is to find a durable adhesive capable of attaching these films to aircraft wings for years at a time.*



**Direct microstructuring** ____ *Another method of making ice-repelling surfaces–here, the microstructures are built directly into the wing material. The Fraunhofer Institute for Material and Beam Technology IWS uses a process known as direct laser interference patterning (DLIP). According to Fraunhofer IWS researchers, DLIP is a cost-effective way of producing particularly complex microstructures, and flight tests have already yielded positive results.*


**Electrically heated paint** ____ *Villinger GmbH, an Austrian company specializing in anti-ice technology, is developing paints equipped with semi-conductive polymers to make them heatable. These are already being used on small aircraft. The Fraunhofer Institute for Manufacturing Engineering and Automation IPA is pursuing a similar idea: heating layers of carbon nanotubes located beneath protective paint to prevent ice from building up on the surface.*

**High-frequency vibration** ____ *Engineers at the German Aerospace Center (DLR) want to literally shake off the ice problem. To do this, they are using actuators to subject icy wings to targeted high-frequency vibrations. The ice then breaks loose and falls off. This technology is said to be more efficient than the bleed-air systems commonly used in passenger aircraft, and several business jets already rely on it to deice their tail assemblies.*

**ICE ISN'T JUST ICE**

**Clear ice**
*In meteorology, clear ice–also known as black ice–refers to the weather-related ice deposit that forms as completely transparent, glassy ice whenever rain, mist and similar precipitation freezes.*

**Hard rime**
*Hard rime, or white frost, is a solid precipitation that forms from supercooled fog water droplets on surfaces, especially at high wind speeds and an air temperature of typically –2 to –10 °C.*

reaching two goals at once: It creates a micro-nano structure that is more resistant to the build-up of ice and causes the ice to fall off on its own once it reaches a certain thickness. And using such structures in combination with electric heating systems makes deicing more energy-efficient.

## Lasered microstructures offer great deicing potential

"Direct laser interference patterning (DLIP) has the potential to reduce the use of environmentally harmful deicing agents on the ground, lower fuel consumption and shorten the time passengers have to wait while aircraft are being deiced," Kunze says. He also points out that flying weight would also drop because aircraft could be equipped with smaller electric heating devices. "This is bound to interest an aviation industry striving to become more electric," Kunze says. At the beginning of October 2020, the journal Advanced Materials Interfaces published details of comparison tests on miniature wings. The tests showed that ice disappears up to 90 percent faster from DLIP surfaces than from untreated surfaces equipped with the same heating capacity. Kunze says that untreated surfaces would need five times more heating capacity to achieve the same result. Project partner Elmar Bonaccurso, materials scientist at Airbus, is satisfied with the lab test results: "Now we have to show that DLIP surfaces perform under real conditions."

To achieve this goal, flight tests using an Airbus A350 equipped with DLIP surfaces have been underway for two years. "The microstructure remained stable," Bonaccurso says. He hails this as a major, if only partial, success: "We're looking for an additional chemical coating for the DLIP structure that will make it even more effective," Bonaccurso explains, adding that only then will the technology be ready for use. Meanwhile, Kunze and his team are optimizing the commercial viability of the DLIP process in collaboration with laser manufacturers. Neither researcher is willing to speculate about when DLIP surfaces could enter production. "We're still in the predevelopment stage and will first have to see that through before we can reliably predict any kind of timeframe," Bonaccurso says. "But in the spirit of reducing the environmental impact, we're naturally working as quickly as possible."

*"Direct laser interference patterning (DLIP) has the potential to reduce the use of environmentally harmful deicing agents on the ground, lower fuel consumption and shorten the time passengers have to wait while aircraft are being deiced."*

**Tim Kunze**
*Group Manager Surface Functionalization at the Fraunhofer Institute for Material and Beam Technology IWS in Dresden*

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**MTU LOCATIONS WORLDWIDE:**

*01 __ MTU Maintenance Canada*
*02 __ MTU Maintenance Dallas*
*03 __ Vericor Power Systems*
*04 __ MTU Aero Engines North America*
*05 __ MTU Maintenance do Brasil*
*06 __ Ceramic Coating Center*
*07 __ MTU Maintenance Lease Services*
*SMBC Aero Engine Lease*
*08 __ MTU Maintenance Hannover*
*09 __ MTU Maintenance Berlin-Brandenburg*
*Pratt & Whitney Canada*
*Customer Service Centre Europe*
*10 __ MTU Aero Engines, headquarters*
*Aerospace Embedded Solutions*
*11 __ EME Aero*
*MTU Aero Engines Polska*
*12 __ MTU Maintenance Serbia*
*13 __ MTU Maintenance Zhuhai*
*14 __ Airfoil Services*


# No idle hands here

*MTU is stepping on the gas to further expand its MRO capacity. Three sites report on their activities.*

**Text:** *Nicole Geffert*

One thing is certain: the MRO specialists at MTU Aero Engines don't know the meaning of idle hands. To better serve their customers and cement their reputation as maintenance experts, the teams are expanding their range of services and support—as recent developments at the MTU sites in China, Poland and Serbia show.

In the Chinese Year of the Buffalo, MTU Maintenance Zhuhai will be celebrating its 20th anniversary. You might be tempted to say: "Wow, look how you've grown!", and you would be perfectly justified. Since operations began, growth has been an unwavering focus of the successful joint venture between MTU and China Southern Airlines. The shop has recently been expanded and repaired its 3,000th engine, and a second location is now in the pipeline. At the moment, the team is busy preparing to welcome a newcomer to the shop: the PW1100G-JM.

The latest generation of Pratt & Whitney's GTF™ engines is already being served by EME Aero in Jasionka, Poland. At this joint venture between Lufthansa Technik and MTU, the MRO experts


**MTU LOCATION:**

## Jasionka I Poland

**EME Aero ___** *The joint venture between Lufthansa Technik and MTU Aero Engines began operations in 2020 and is setting new standards as one of the world's largest and most advanced MRO shops for the latest generation of Pratt & Whitney's GTF™ engine series.*

**MTU LOCATION:**

## Zhuhai I China

**MTU Maintenance Zhuhai ___** *The joint venture between MTU Aero Engines and China Southern Airlines specializes in the maintenance of CFM56, V2500 and LEAP engines—and continues to grow. The Pratt & Whitney PW1100G-JM is a newcomer to the shop.*

**MTU LOCATION:**

## Stara Pazova I Serbia

**MTU Maintenance Serbia ___** *With its new engine parts repair shop, MTU Aero Engines is expanding its global network. The shop is set to begin its MRO activities in 2023 with a planned volume of 470,000 repair hours a year.*

are busily working on the maintenance of PW1100G-JM engines. The shop boasts a high-tech flowline with an innovative and holistic assembly concept developed by experts at MTU in Munich. And the next highlight is just around the corner: by the middle of this year, everything will be in place for the teams to repair the PW1500G.

A new team is starting out in the Serbian town of Stara Pazova, just outside Belgrade. It's here that MTU is setting up MTU Maintenance Serbia, a repair shop for engine parts, so it can offer its customers additional capacity for maintenance solutions. Operations are scheduled to start in 2023 with an initial volume of 470,000 repair hours a year. A multidisciplinary team of MTU specialists is currently busy planning and setting up the new maintenance facility one step at a time.

All MTU sites around the world have one thing in common: they pull out all the stops to deliver high-quality work and service that is second to none.

**MTU LOCATION:**

## Stara Pazova I Serbia

**Choice location** ____ *MTU Maintenance Serbia is close to Belgrade, the country's economic and political center. The industrial park in Stara Pazova is only 25 kilometers from the international airport, offers room for expansion and has good transport connections.*

# Reinforcing the MRO specialist

*The Serbian town of Stara Pazova is where MTU Aero Engines is setting up a new engine parts repair shop: MTU Maintenance Serbia. MTU is creating additional capacity for maintenance solutions.*

**Text:** *Nicole Geffert*

Right now, the site where MTU Aero Engines will be building its new repair facility is still a green field. But the newly designated industrial park in Stara Pazova, Serbia is anything but tranquil, because starting in 2021, the 26-hectare site that MTU has acquired will be a hive of activity for construction vehicles, excavators and cranes. A new plant will emerge: MTU Maintenance Serbia. And in 2023, MTU repair specialists will be start work there on the first engine parts.

Serbia's President Aleksandar Vučić praised MTU's commitment as an essential and decisive building block in the development of the aviation industry in Serbia. MTU is playing a pioneering role, and the conditions here are excellent. The industrial park in Stara Pazova is located only 25 kilometers from Nikola Tesla Belgrade international airport and boasts good transport connections.

"This industrial park definitely has growth potential—it could well attract our suppliers and partners," says Rainer Becker, project manager and Managing Director of MTU Maintenance Serbia. The greater Belgrade area is home to universities and vocational schools for training skilled workers and offers housing for future employees.

### 470,000 repair hours per year

The ink had barely dried on the contract when Becker and his team got down to work on the detailed plans for the new MRO

**MTU Maintenance Serbia** ____ *The site is being built in Stara Pazova and is scheduled to begin operations in 2023.*

repair shop. Their first task was to define the product portfolio, decide which engine parts MTU Maintenance Serbia will repair and determine how much work the location could expect.

"In the first phase, we plan to have capacity for 470,000 repair hours per year," says Holger Sindemann, who as MTU's Executive Vice President of MRO is also responsible for MTU Maintenance Serbia. MTU Maintenance's worldwide locations perform about 1.9 million repair hours annually. The new shop in Serbia is a further reinforcement. "We were able to incorporate know-how from our maintenance locations worldwide into the planning for the new site."

## Order complex machines early

A team of about 30 MTU specialists in repair technologies, quality, logistics, finance and human resources is already working to establish the new maintenance location. The MTU office in Belgrade is now up and running, and the project team has defined the plant and process technologies. This means it will be possible to place early orders for particularly complex machinery with long delivery times.

All work areas had to be determined and the building layout had to be defined accordingly, so that the commissioned architects could work on the plans for the shop. Which processes will the shop be implementing? Which systems need to be installed and where? What building services technology is required to ensure supplies of electricity, water and compressed air?

## Licenses and approvals

There are answers to all these questions. "All the planning is being done in close collaboration with the responsible authorities in Serbia to ensure that the new building complies with all regulations and specifications," Becker explains. He and his team are also making every effort to extend OEM and customer licenses for the repair of engine parts to the new location. Applications for the necessary approvals by aviation authorities such as Germany's Federal Aviation Authority must also be filed.

*"In the first phase, we plan to have capacity for 470,000 repair hours per year."*

**Holger Sindemann**
*Executive Vice President MRO Operations and Managing Director MTU Maintenance Hannover*

To coincide with the construction of the new repair facility, MTU is starting to recruit suitable employees and train future skilled workers. Collaboration with Serbia's Ministry of Education as well as with universities, schools and the Aviation School in Belgrade had shown that the level of qualification is high. "We started an advertising campaign early on, made contacts and introduced ourselves. We're delighted with the open-mindedness, the great interest and the constructive cooperation," says Hans Triebenbacher, who heads MTU's Training Center Serbia.

## Dual-track training of skilled workers

In order to support existing qualifications, the shop will offer on-the-job training in the future. In 2019, MTU and the government of the Republic of Serbia signed a declaration of cooperation to establish close collaboration on the dual-track training of skilled workers—as practiced in Germany. This guarantees the technical foundations required for a high-tech industry such as aviation. While the on-the-job training will initially take place at MTU locations in Germany and Canada, the aim is to conduct this training exclusively in Serbia starting in 2024.

By 2027, the new repair location is expected to grow to around 440 employees. MTU's stated aim is to generate this growth out of Serbia. As Becker says: "We want to attract the most talented employees to MTU and create a working environment in which they can perform at their best. We make targeted investments in the training and development of our talented employees, helping them expand their know-how and develop their potential. MTU Maintenance Serbia will provide many people in the Stara Pazova region with career opportunities."

MTU LOCATION:

# Zhuhai I China

**Perfectly placed ___** *MTU Maintenance Zhuhai is located in the Zhuhai Free Trade Zone in southern China. The shop benefits from its proximity to the industrial and commercial centers of Hong Kong, Guangzhou, Shenzhen and Macao. It doesn't take the teams long to reach customers to perform on-site services.*

# Soaring to new heights in China

*MTU Maintenance Zhuhai began operations twenty years ago and has been growing ever since. Following recent expansion of both shop and capacity, a second facility is now in the pipeline.*

**Text:** *Nicole Geffert*

When Jaap Beijer steps onto the MTU Maintenance Zhuhai premises, he sees progress. "We completed our expansion of the facility in late 2020, increasing our capacity by 50 percent to 450 shop visits a year," says the President and CEO of MTU Maintenance Zhuhai. The successful 50/50 joint venture between MTU Aero Engines and China Southern Airlines Company Limited was established 20 years ago. Since then, business has been growing for the company favorably located in the Pearl River Delta Metropolitan Region, one of China's economic heartlands.

From the moment the first concrete strut was laid for the foundation back in May 2001, MTU Maintenance Zhuhai has gone from strength to strength. It is now the leading provider of engine maintenance, repair and overhaul (MRO) services on the Chinese market and has carved out a position for itself as a specialist for CFM56 and V2500 engines. In 2019, the company added LEAP engines to its portfolio. The recent expansion of the site enlarged the shop by some 10,700 square meters, providing additional plant and office space as well as a sports area and parking for employees.

Although it's still early in the year, Beijer and his team are optimistic about what 2021 will bring. "As market demand increases again following the acute phase of the Covid-19 crisis, we've been gradually ramping the MRO shop back up to full capacity," Beijer says. "We're now operating at nearly 100 percent once more."

## Designed with growth in mind

Senior project manager Anna Küpper helped plan and oversee the shop expansion. "The project was new territory for me and I found it really inspiring," says the mechanical engineer, who relocated to MTU Maintenance Zhuhai from MTU Aero Engines in Munich in 2019. In the planning and construction stage, she kept in close contact with the production specialists at MTU Maintenance Zhuhai as well as the specialized department back at MTU in Munich to take advantage of its expertise and experience in construction projects.

"We had plenty of space to enlarge the shop. MTU Maintenance Zhuhai was designed with growth in mind," Küpper says. Due to

**Maintenance portfolio** _____ *The site offers a full range of services for the CFM56, LEAP and V2500 engines. The PW1100G-JM is a newcomer to the shop.*

steadily increasing demand for MRO services in the Asian market, the shop was expanded in 2012 to increase its capacity by 50 percent, or from 200 to 300 shop visits a year. The employees who oversaw that project are still around and were able to bring their know-how to the table for this latest expansion.

## Business as usual during expansion

Normal operations continued as the teams expertly managed the expansion of the shop, office space and warehouse. “We left the outer wall standing as long as possible,” Küpper explains. “Once it was gone, heavy-duty tarpaulin prevented any dust from the construction site from entering the operational area.” It also kept out the rainwater, which was important given that the construction stage took place during typhoon season.

The teams have now moved into the offices and the shop will be relocated in due course. “All the machines and workstations that can be moved will get a new home now that the expansion is complete,” Küpper says. A sophisticated shop layout was devised for the high-tech machinery to ensure that shop visits are cost-effective with short turnaround times.

Having received expert training, employees carry out 80 percent of parts repairs in-house. The facility’s machinery is state-of-the-art, and the test cell has an impressive 150,000 pounds of thrust capacity. Late last year, the shop completed its 3,000th shop visit—a V2500 operated by joint venture partner China Southern Airlines. MTU Maintenance Zhuhai serves more than 70 customers from China, other parts of Asia and around the world.

## MRO network partner for the PW1100G-JM

And the company just chalked up another success: a high-profile newcomer, the Pratt & Whitney GTF™ PW1100G-JM that powers the Airbus A320neo, will soon be joining the other best-selling engines in the shop. This means the location is now a member of the global network of providers entrusted to maintain the engine on behalf of Pratt & Whitney.

**Further development** _____
*LEAP engines were added to the site’s MRO portfolio in 2019.*

**Expansion** _____ *The site expansion has been completed and existing capacity increased by 50 percent to 450 shop visits a year.*

Beijer and his team are well prepared for this new challenge: "We've already started ramping up PW1100G-JM capacity," he says. The engines are expected to start coming into the shop in mid-2021, with 1,000 shop visits planned in the next ten years. "We're the leading provider of MRO services for narrowbody engines in Asia," Beijer explains. "Adding the PW1100G-JM to our product mix will enable us to continue our growth strategy and better serve the Asian market."

*"We're the leading provider of MRO services for narrowbody engines in Asia."*

**Jaap Beijer**
*President and CEO of MTU Maintenance Zhuhai*

MTU Maintenance Hannover and EME Aero in Poland, a joint venture between Lufthansa Technik and MTU, already support the PW1100G-JM. Part repairs for the engine are also in the best of hands at MTU Maintenance Berlin-Brandenburg and MTU Aero Engines in Munich. "Zhuhai will be the third facility within the MTU network with full disassembly, assembly and test capabilities for the PW1100G-JM," says Michael Schreyögg, Chief Program Officer at MTU Aero Engines. "We're well prepared for the recovery of commercial aviation and will leverage the extensive experience we've already gained with this engine to further cement our reputation as MRO experts."

## Additional facility in Jinwan District

In line with this approach, MTU Maintenance Zhuhai plans to establish a second facility in neighboring Jinwan. The shop will specialize in Pratt & Whitney narrowbody engines, accommodate a test cell with a 65,000 pound thrust capacity and, according to current estimates, have a workforce of around 600 qualified employees. A clear plan is in place: the shop will initially offer capacity for 250 shop visits a year and is expected to start operations in 2024.

"Its close proximity to MTU Maintenance Zhuhai will enable significant knowledge transfer and synergies between the two facilities," says Beijer, who will be in charge of both sites. And MTU Maintenance Zhuhai's unwavering focus on growth certainly doesn't end there. Such determination perfectly reflects the Buffalo in the Chinese zodiac, whose characteristics are strength, hard work, patience and perseverance. Fitting, given that the Chinese Year of the Buffalo begins on February 12, 2021.

**Jinwan-District** _____ *MTU Maintenance Zhuhai plans to build a second facility in Jinwan, which is expected to start operations in 2024.*

**MTU LOCATION:**

# Jasionka I Poland

**Excellent infrastructure** ____ *EME Aero is not far from Rzeszów's international airport. More than 80 companies from the aviation industry have set up shop in the special economic zone in southern Poland known as Aviation Valley. MTU Aero Engines Polska joined the cluster in 2007.*

# A high-tech shop built in record time

*EME Aero set up its state-of-the-art MRO shop for Pratt & Whitney GTF engines in record time. An efficient flow line with an innovative assembly system is the highlight.*

**Text:** *Nicole Geffert*

In just 18 months, EME Aero, a joint venture between Lufthansa Technik and MTU Aero Engines, went from a greenfield project to one of the world's largest and most advanced maintenance shops for Pratt & Whitney (P&W) geared turbofan (GTF™) engines. "Whether we'd manage it was called into question more than once," says Derrick Siebert, CEO and Managing Director of Business at EME Aero. "It was a tremendous challenge, but we succeeded in our 'mission impossible'."

Located in Jasionka, just outside of Rzeszów in Poland, the company started operations in January 2020. "The team got going immediately," says Robert Maślach, COO and Managing Director of Operations at EME Aero. "At the start, the shop handled engines that were part of P&W's retrofit program for the low-pressure turbines. Then the first PW1100G-JM production engines began coming in for overhaul."

**Top management at EME Aero** ____ *Derrick Siebert, CEO and Managing Director of Business (right), and Robert Maślach, COO and Managing Director of Operations.*


**State-of-the-art MRO shop** —— *EME Aero is one of the world's largest and most advanced maintenance companies for next-generation passenger aircraft engines. The shop is scheduled to reach its full operating capability in 2026, with annual capacity for more than 450 shop visits.*

**High-tech flowline** —— *Engines are fitted to freely moving, floor-based carriers. The assembly and tooling concept was developed by MTU specialists in Munich together with the EME Aero team.*

## Shop highlight: The efficient flow line

To ensure it provides the highest standard of repairs, EME Aero's shop is state of the art–which is only fitting for the most advanced and efficient engine family on the market today. Setting up a shop from scratch has clear advantages, as it gave the project team a blank canvas to create the ideal layout and ensure the optimum flow of processes. Effective cooperation between MTU and Lufthansa Technik, both aviation specialists, also helped drive things forward. "We incorporated insights and best practices from both joint venture partners so we benefited from the best of both worlds," Siebert explains.

The shop's highlight is its flow line for the engines to pass through various disassembly and assembly stations. Engines are fitted to freely moving, floor-based carriers that can be pulled in and out of the production line without disturbing the overall flow. "We've installed the latest and greatest technologies currently available in this field," Siebert says. And wherever the team identified a need and opportunity for improvement, they initiated a new technology development process.

To make the shop as efficient as possible, specialists from MTU's production and facilities service in Munich worked with the EME Aero team to develop a standardized assembly and tooling concept for the various engine types. Its centerpieces are two systems "made by MTU": the mobile transport and overhaul system (MTOS) is used for complete teardown of engines along the flow line, while partial disassembly is performed in the stationary dock of the fixed overhaul system (FOS). Five FOSs have already been installed since the end of 2019, and the MTOS will go into operation in the first half of 2021.

The MTOS is made up of remote-controlled transport units that move the engine from one station to the next and hold it in an ergonomic position. What makes the two systems so ingenious is the adapter with which they attach to the engines at a single hoist point. As soon as an engine arrives at the shop, its core is mounted on one of these adapters. The engine can now be easily

disassembled into its individual modules with no need for any further rigging work. Since the stationary FOS uses the same adapter as the mobile MTOS, it takes no effort to switch the engines between the two systems.

### The world's quietest test cell

Alongside its high-tech flow line, the shop also boasts a high-tech test cell. "Rather than the usual 50 to 70 hertz, the data transfer system is designed for frequencies of 200 hertz. This allows us to work with a huge volume of data when the overhauled engines undergo acceptance testing," explains test cell manager Lutz Pfannenstiel. He joined EME Aero from joint venture partner Lufthansa Technik.

In terms of the noise protection it offers, the test cell is also outstanding. "It's currently the quietest in the world," says MTU Senior Consultant Martin Köster, who helped plan and build the test cell. "During an engine test run with takeoff (full capacity) no more than 40 decibels may reach the perimeter of the site where the test cell is located. Noise levels generated by EME Aero's test stand remain well below this limit, making it the quietest there is."

The test cell is also remarkably energy efficient. Pfannenstiel gives an example: "Shop air from two compressors is used to start the engines on the test stand. We recycle the heat produced in the process for the underfloor heating in the rigging shop."

### MRO services for customers worldwide

"We now have around 400 employees maintaining PW1100G-JM engines," Maślach says. "EME Aero is a partner in P&W's GTF maintenance network, which provides first-class MRO services to customers all over the world."

Within a year of the official start of operations, the team chalked up a huge achievement: "After concluding the project for creating EME Aero, we started–with the help of the MTU shop in Hannover and the Lufthansa Technik shop in Hamburg–one of the steepest ramp-up curves in the history of both joint venture partners. Today, we serve customers around the world," Siebert explains. "In 2021, we will continue this growth path until we reach our full capacity of 450 shop visits a year."

**Outstanding test cell** ___ *The test cell is currently the quietest in the world and is also remarkably energy efficient.*

*"In 2021, we will continue this growth path until we reach our full capacity of 450 shop visits a year."*

**Derrick Siebert**
*CEO and Managing Director of Business at EME Aero*

The shop is scheduled to reach its full operating capability in 2026, when EME Aero is set to have a workforce of more than 1,000 qualified employees.

"By mid-2021, we'll have everything in place to maintain, repair and overhaul PW1500G engines," Maślach says. "We're optimistic about our future. The strong sense of team spirit we developed from the project and the ramp-up will stay with us. In these challenging times, this will play a key role in helping us prepare for the next ramp-up."

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More on this topic: **www.aeroreport.de**

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**Nicole Geffert** has been working as a freelance journalist covering topics such as research and science, money and taxes, and education and careers since 1999.

# Climate-friendly routes

*In addition to further technical improvements to aircraft, climate-optimized flight routes and fuel-saving approach procedures will make air travel greener in the future.*

**Text:** *Denis Dilba*

Efforts to reorganize air travel to make it more climate-friendly have been well underway for a long time. More efficient engines, lighter composite materials and improved aerodynamics have been key to the considerable reduction in aircraft kerosene consumption over the past few decades. In turn, this successfully put the brakes on the rise in $CO_2$ emissions caused by the sector's continuous growth. And despite the current coronavirus crisis, the industry's ambitious efforts to further cut emissions through improved designs continued unabated. However, even if technical upgrades could save still more fuel in the future, stakeholders all agree that a further improvement in the industry's ecological footprint requires measures in other areas as well. For this reason, rather than looking solely at the technical side of air travel, focus has expanded in the past few years to include operational aspects: optimizing flight routes to limit their impact on the climate and improving air traffic management promise to play an auxiliary but significant role in more eco-friendly air travel. This approach should also minimize detours and holding patterns.

"A whole host of scientific studies over the past few years has shown that the impact aircraft emissions have on the climate is highly location-specific," says Robert Sausen from the Institute of Atmospheric Physics at the German Aerospace Center (DLR) in Oberpfaffenhofen, Germany. "The basic idea behind climate-optimized flight routes is to fly around those areas of the atmosphere where emissions have a particularly strong impact on account of the predominating weather conditions," he explains. Nowadays, flights are plotted to keep flight time to a minimum and consume as little kerosene as possible. Those measures have of course made considerable progress toward more efficient operation of aircraft and greener air traffic. Sausen, a pioneer in this research field, continues: "To proceed further, however, we have to shift the focus of our optimization efforts. $CO_2$ emissions actually account for just about one-third of an aircraft's total climate impact."

## Avoiding persistent contrails

The remaining impact consists of the warming effect caused by persistent contrails (responsible for two-thirds) and ozone production as a consequence of nitrogen oxide emissions. Water vapor and soot particles emitted when kerosene is burned play a smaller role, Sausen says. "If you put all the factors together in a climate cost function that assigns a current value of overall climate impact to every location in the atmosphere, then you can work out which flight routes would have the least effect on the climate," he explains. His calculations have shown that this approach can reduce climate impact by 20 percent—without making technical changes to aircraft. Sausen says that purely theoretically, this figure could go higher if aircraft also slowed down their air speed.

**1–2%**

*of all persistent contrails, known as the 'Big Hits,'*

*are responsible for more than* **80%** *of warming*

*"One to two percent of all persistent contrails, known as the 'Big Hits,' are responsible for more than 80 percent of warming. It makes sense to concentrate on these first."*

**Robert Sausen**
*Researcher at the Institute of Atmospheric Physics at the German Aerospace Center (DLR)*

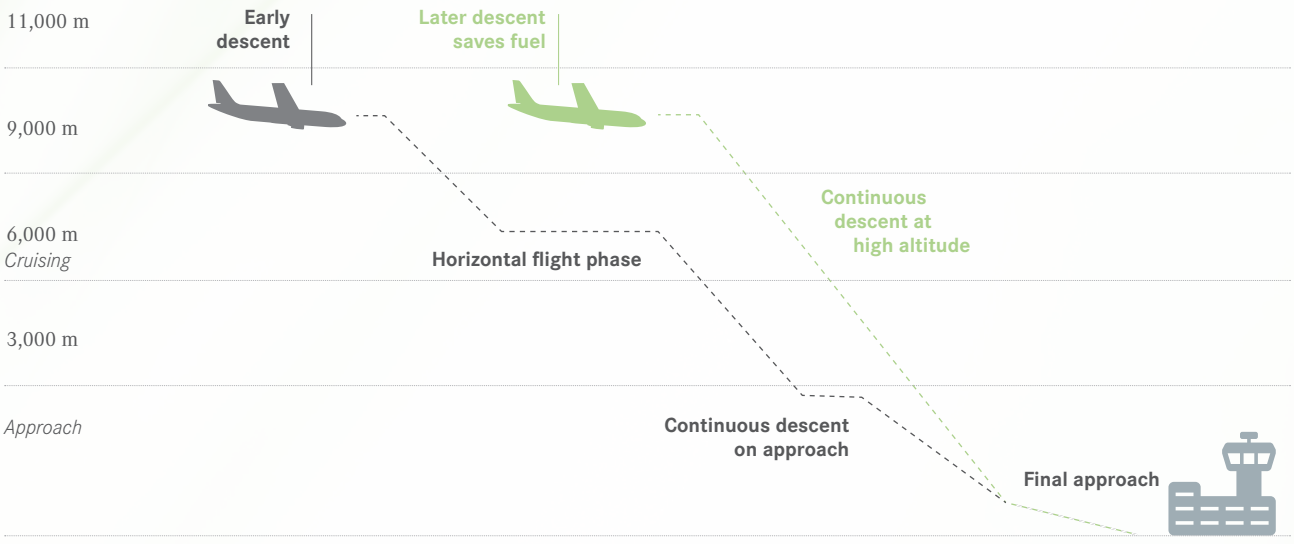
He estimates that it could take 10 to 15 years before air traffic managers start applying a comprehensive calculation of climate-optimized flight routes. One faster way to help—and one that doesn't involve major intervention in the global air traffic system—would be to simply avoid areas where persistent contrails form. Contrails account for the lion's share of the portion of non-$CO_2$ emissions that impact the environment, Sausen says. However, it is not necessary to prevent all of them. "One to two percent of all persistent contrails, known as the 'Big Hits,' are responsible for more than 80 percent of warming. It makes sense to concentrate on these first," Sausen says. Since the Big Hits form only in very cold, moist layers of air, which are often just a few hundred meters thick, all the aircraft has to do is fly a bit higher or lower to suppress their formation almost completely. Sausen believes no-fly zones for Big Hit areas or toll solutions may arrive in as few as five years from now.

## Continuous descents and freer choice of route

An adjustment in air traffic management is never simple, as Michael Finke, a researcher at the DLR Institute of Flight Guidance in Braunschweig, Germany, can attest. He coordinates the European-Chinese research project, Greener Air Traffic Operations (GreAT), which hopes to make flying more climate-friendly. Launched at the beginning of the year, the project's goal is to limit $CO_2$ emissions, a departure from Sausen's climate cost function. This alone is already a key step toward eco-friendlier air travel. "Currently, detours and holding patterns are not rare occurrences," Finke says. The reason is that a great many factors go into the planning of a flight route, some of which—say, maintaining the necessary airspace capacity—essentially hinder the minimizing of $CO_2$ emissions. "For safety reasons, for example, the aircraft have to be staggered at various altitudes; however, each aircraft has only one altitude that is optimal for fuel consumption," Finke continues. Another factor is the fees that accrue when flying through other countries' airspace. As Finke puts it: "Airlines save money by flying around more expensive countries, but doing so creates more $CO_2$ emissions."

One promising idea the GreAT researchers are looking into has already been around for a while: the continuous descent approach, or CDA. "This is where the aircraft goes directly from its cruising altitude to its descent, maintaining a constant angle until landing," Finke explains. This saves fuel compared to conventional descents. However, there's a catch: since every aircraft has its own vertical flight profile, the distancing regulations currently in force would initially lead to losses in capacity. "Our task includes investigating how we can broadly apply CDAs without incurring these losses," Finke says. As for long-haul flights, the part of GreAT for which the Chinese partners are responsible, expanding the flexibility of route selection could open up options for shorter routes. "At the moment, this is possible in only a few countries. In other parts of the world, there are stricter provisions in place regarding flight routes," Finke says. "It could lead to some massive improvements if routes could be selected freely around the world."

**CONTINUOUS DESCENT SAVES KEROSENE**




**Continuous descent saves kerosene** ___ *To reduce carbon dioxide emissions during landing, Deutsche Flugsicherung GmbH (DFS) has been working with airlines to further develop the continuous descent approach. Now, the aircraft begin their descent later. Landing simulations show that this can save up to 85 liters of kerosene per flight. Source: Deutsche Flugsicherung (DFS)*

Overall, Finke explains, we have to keep an eye on the big picture: "Optimizing air traffic management is a step toward sustainable aircraft operations. However, this is just one piece of the puzzle, not a complete solution for achieving eco-friendly air travel. We have to keep on with our work and research on all fronts."

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**Denis Dilba** holds a degree in mechatronics, is a graduate of the German School of Journalism, and founded the "Substanz" digital science magazine. He writes articles about a wide variety of technical and business themes.

# The flying fire department

*Aircraft and helicopters can help battle forest fires quickly and effectively, adopting different models depending on the geography of the area. An overview.*

**Text:** *Denis Dilba*


Firefighting aircraft over Australia, the Amazon rainforest, Indonesia, California and the Arctic–images of devastating forest fires repeatedly dominated the news last year. The online platform Global Forest Watch Fires counted more than 4.5 million fires larger than one square kilometer for 2019, an increase of 400,000 from the previous year. Even though there were already a good 5 million fires of this magnitude in 2004, and even though that figure fluctuates, it is clear that the risk of forest fires is steadily increasing around the world: “Climate change is making extreme weather more frequent, leading to more extreme fires: increasing drought provides more and more fuel for forest fires, so they become hotter, bigger, more intense–and increasingly difficult to extinguish,” says Alexander Held, forest fire expert at the European Forest Institute in Bonn. He adds that in densely populated and built-up countries like Germany, even small forest fires can cause plenty of chaos and damage.

*"However, in areas that are more difficult to access, or where there is an extreme danger of forest fires, firefighting aircraft are the only option for a truly rapid first attack."*

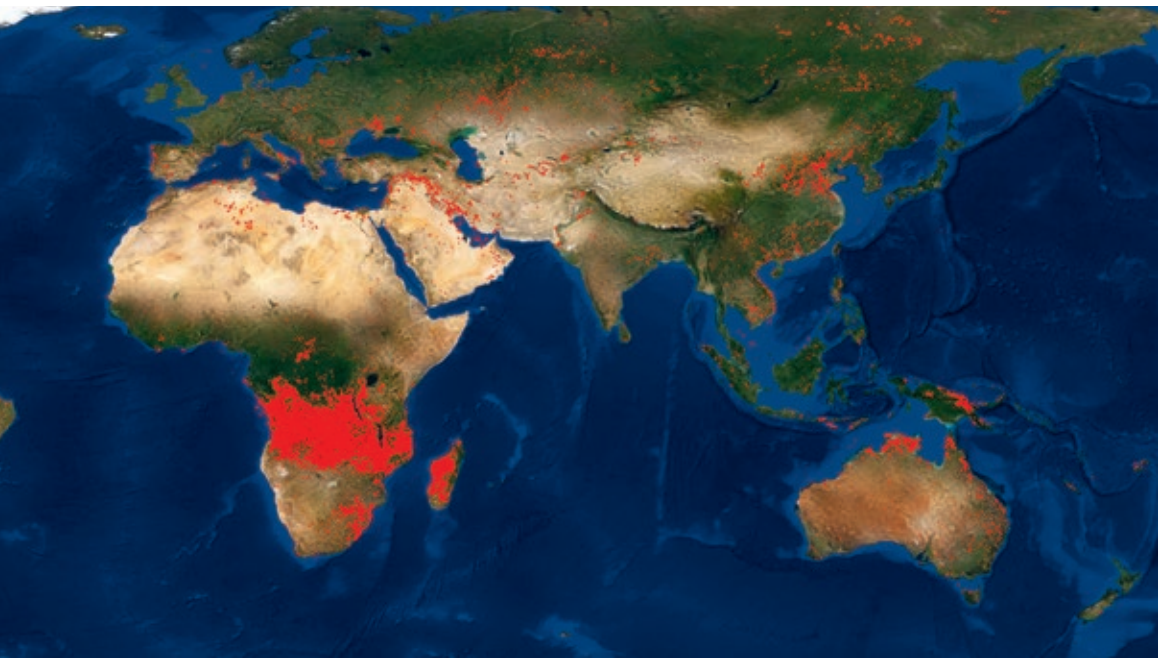
**Alexander Held**
*Forest fire expert at the European Forest Institute in Bonn*

**Firefighting aircraft are the fastest and most effective means of initial attack**

This is why, Held explains, it is important to arrive at the scene as soon as possible after a forest fire has broken out–when the fires are still small, the extinguishing measures are particularly effective. Where possible, this should be done from the ground. "However, in areas that are more difficult to access, or where there is an extreme danger of forest fires, firefighting aircraft are the only option for a truly rapid first attack." To be able to get to the source of the fire quickly, it's best to keep the aircraft parked on the runway ready for takeoff–better still is to have them already in the air on patrol. In regions of southern Europe with a history of forest fires, this has long been the case. Because the risk of forest fires is rising in Germany, there are calls for the country to procure its own aircraft, including from Mike Goldhahn, director of the German Aerial Firefighting Brigade (Deutsche Löschflugzeug Rettungsstaffel, DLFR). "This would be especially practical for the many areas contaminated with munitions, particularly in Brandenburg," he says. He proposes starting with three aircraft: "With these and with three pilots, you can keep two firefighting aircraft on standby during the season." Over the long term, Goldhahn recommends a fleet of six to eight aircraft.

Held can also envision firefighting aircraft in Germany: "I'm talking about small aircraft such as the Air Tractor 802, not the big Canadair amphibious aircraft you find in southern Europe." The latter work most efficiently on large bodies of open water, of which Germany does not have many. Moreover, the Canadair aircraft are significantly more expensive than smaller models. Goldhahn therefore believes small firefighting aircraft are the way to go. However, all types of aircraft and helicopters in firefighting operations require experienced pilots: turbulence is to be expected above the fires, and visibility is often poor due to the smoke. In addition, the pilot must keep the aircraft flying at a stable attitude when dropping the water, which often weighs several metric tons. One particular challenge for amphibian firefighting aircraft is scooping up water while still in the air: pilots have to contend with waves, changing winds and obstacles on the water's surface.

In addition, pilots are put under high levels of stress lasting several hours, because unlike on a scheduled flight, for example, firefighting op-



**Overview of fires worldwide** ___ *Satellite images from NASA show where the world is currently burning. Each red dot on NASA's world fire map represents a fire. With large parts of Central and East Africa bright red, it appears that a whole chunk of Africa is going up in flames. However, the zoom effect means the points are not to scale, but instead show many smaller fires. Nevertheless, while the fires there bring death and devastation, they are also the lifeblood of the African savannah.*
*https://firms.modaps.eosdis.nasa.gov/map*

**Airbus Super Puma** ___
*Operated by the German Federal Police, this helicopter can hold 2,000 liters of water.*

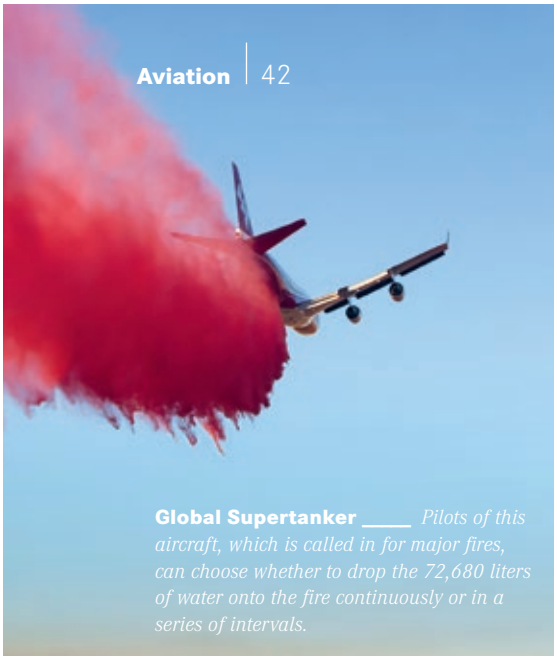
erations are flown without an autopilot. The pilots steer by sight and, on flights with contact to the water's surface, they have to manage without guidance from a tower. Water dropped onto a fire often contains chemicals. Special equipment is used to mix them with the water in the tanks or external containers, sometimes even while in the air. The chemicals give the water a gel-like property, allowing it to adhere better to trees and bushes and protect them more effectively from the flames. Foams for fighting forest fires, on the other hand, are usually applied from the ground. Color added to the water, usually red, helps the pilots see where they have already been.

## Aerial missions of little use without fire management on the ground

"In Germany, you need 'spray authorization' to conduct firefighting operations from the air," Goldhahn explains. The license is valid for aircraft and firefighting helicopters. The latter offer the flexibility to collect water from smaller lakes not used for other purposes with a specialized bucket and then discharge it at precisely the right point in areas inaccessible to aircraft, such as a slope in a narrow valley. For this purpose, the helicopters must be equipped with special external cargo hooks and, ideally, their own weight should also be reduced. The heavier the helicopter is, the less water it can pick up—in some cases, none at all. Firefighting experts are therefore constantly advising the authorities to keep more large helicopters, such as the military's Sikorsky CH-53 transport aircraft, ready for action during the forest fire season. A small police helicopter can hold 5,000 liters, but larger models can pick up ten times that amount.

However, firefighting helicopters and even aircraft alone are usually not enough to extinguish a forest fire. "The crucial thing is that, before anything else, we do our homework in fire management on the ground," Held says. "Fighting forest fires from the air doesn't help much if we don't have trained and well-equipped crew for forest firefighting and if we neglect preventive fire protection in the forests."

**The most common causes of forest fires:**
- *Heat and drought*
- *Lightning strike*
- *Negligence by forest visitors*
- *Arson / starting fires*



**Global Supertanker** ____ *Pilots of this aircraft, which is called in for major fires, can choose whether to drop the 72,680 liters of water onto the fire continuously or in a series of intervals.*

**Canadair CL-215 and CL-415** ____ *Powered by two Pratt & Whitney turboprop engines, the amphibious aircraft can scoop up 6,137 liters of water while flying over a body of water.*

### Global Supertanker

Various firefighting aircraft are in service around the world. The largest one, the Global Supertanker, is a converted Boeing 747-400. Stationed in the U.S., the aircraft is called to major fires, such as the one in the Amazon rainforest in 2019. The firefighting jumbo jettisons its 72,680 liters of water from heights of 60 to 90 meters above the forest fire at a speed of 278 km/h. During these missions, the pilot can choose whether to drop the water onto the fire continuously or in a series of intervals. The Supertanker requires airports with runways at least two kilometers long.

### Canadair CL-215 and CL-415

Probably the most famous firefighting aircraft in the world are the Canadair CL-215 and CL-415. The former was developed by Canadian manufacturer Canadair, which was acquired by Bombardier Aerospace in 1986. In 2016, the aerial firefighting business was sold to Canadian company Viking Air. Powered by two Pratt & Whitney turboprop engines, the firefighting aircraft can refill their tanks while flying over a body of water. To scoop up 6,137 liters, the CL-415 needs twelve seconds and a distance of around 400 meters. The typically yellow aircraft are particularly popular in countries with large open bodies of water and coastal areas at risk of forest fires.

### Air Tractor AT-802F

The small Air Tractor AT-802F from the U.S. manufacturer of the same name is considered the most efficient and versatile firefighting aircraft on the market. It can scoop up 3,100 liters of water—a staggeringly large amount considering its size. The robust single-propeller aircraft can also take off and land on gravel and grass runways. Thanks to its smaller dimensions and therefore better maneuverability, the AT-802F can also operate in narrow valleys. The PZL M18 Dromader from Polish manufacturer PZL has similar qualities: a monoplane with comparable dimensions and capacity for 2,200 liters of water.

**Air Tractor AT-802F** ____ *The most efficient and versatile firefighting aircraft holds up to 3,100 liters of water and can take off and land on gravel and grass runways.*

**Sikorsky CH-53** ____ *The large Sikorsky helicopter operated by the German Armed Forces is able to drop water (up to 5,000 liters) with pinpoint accuracy and can transport equipment and crew to any terrain.*

## Firefighting helicopters

Germany currently uses only helicopters for fighting forest fires. For this purpose, they are equipped with external water tanks of various sizes. Smaller helicopters, such as the Airbus Helicopters H135, carry around 500 liters; larger models, such as the Airbus Super Puma operated by the German Federal Police, or the very large Sikorsky CH-53 operated by the German Armed Forces, carry 2,000 and 5,000 liters, respectively. Helicopters can be used for precise water drops and transporting equipment and crew in any terrain. Since German fire departments don't have their own aircraft, they have to contact the police or the military in the event of forest fires.

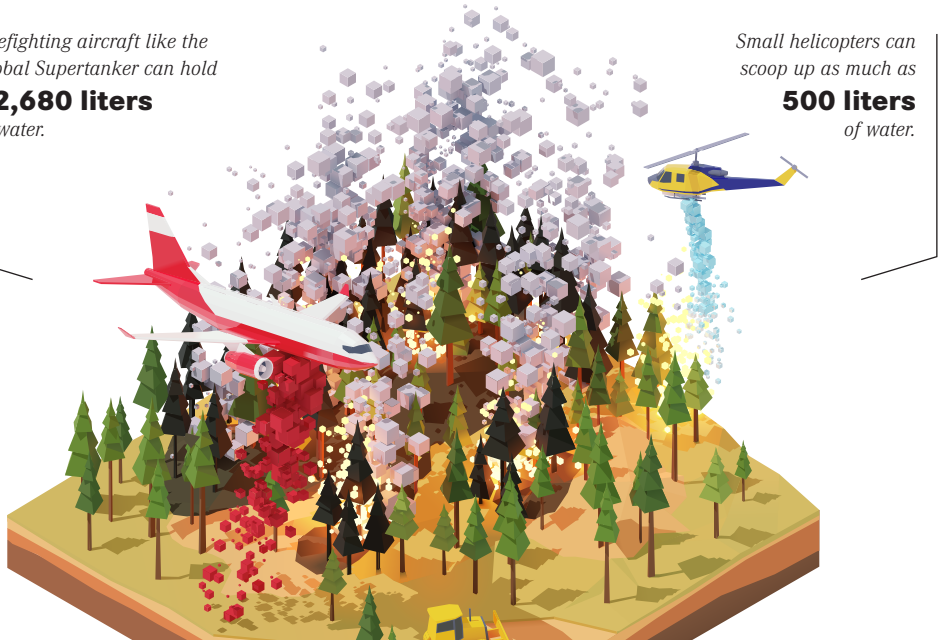
## Drones to fight forest fires

Equipped with thermal imaging sensors, drones are increasingly used for early detection of forest fires. This technology is already being tested in Brandenburg, Germany. The aerial images and temperature data make it easier for the emergency services on the ground to decide where to position which crew and equipment. British start-up Faradair Aerospace reports that it is even working on a large firefighting drone: the Beha M1-AT has a span of eleven meters and a payload of ten metric tons, and is intended to fight forest fires completely autonomously. The company is already conducting test flights.

**Drones** ____ *The aerial images and temperature data make it easier for the emergency services on the ground to decide where to position which crew and equipment.*

*Firefighting aircraft like the Global Supertanker can hold*
**72,680 liters**
*of water.*

*Small helicopters can scoop up as much as*
**500 liters**
*of water.*



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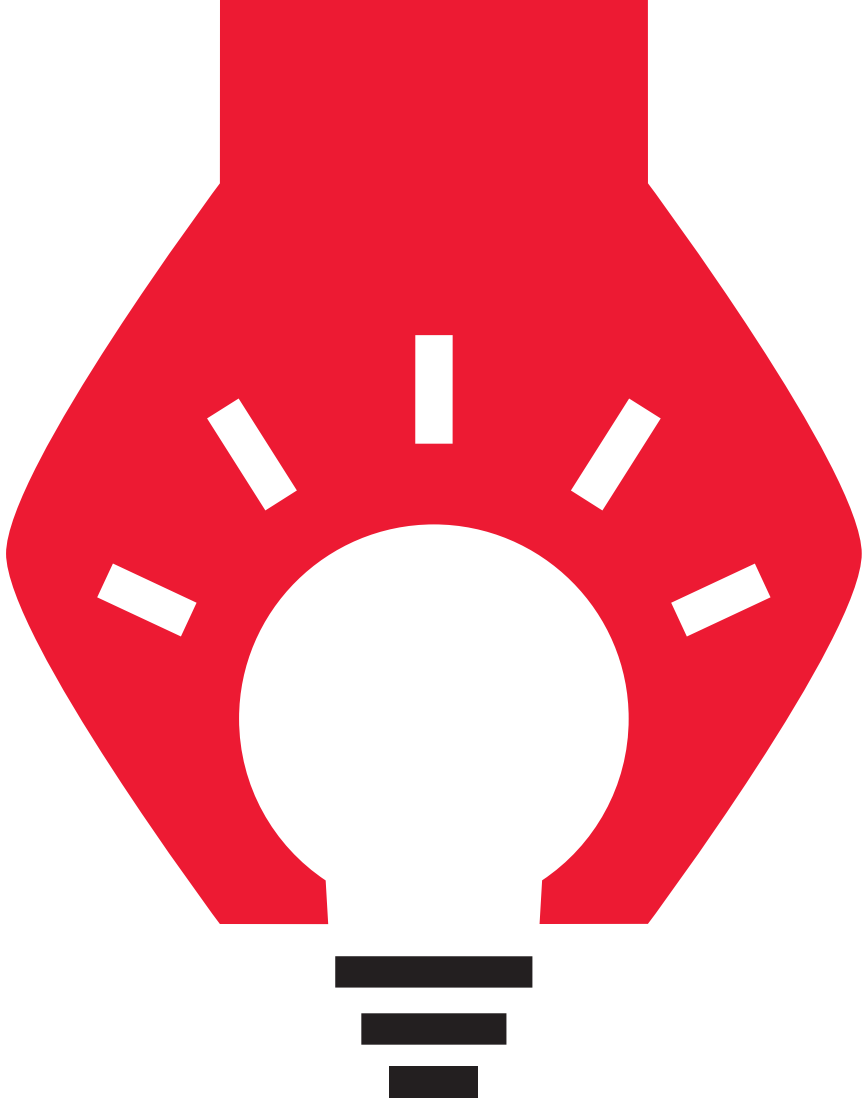

# DIY in the prototype workshop

*MTU Aero Engines is supporting its community of inventors. In the high-tech MakerSpace workshop in Munich, they tinker with their own products and turn their ideas into reality.*

**Text:** *Nicole Geffert*


**Community of inventors** ____
*The MakerSpace is where MTU Aero Engines employees tinker with software, tools and machines to create prototypes of their product concepts.*

Dr. Giovanni A. Brignole is an expert in compressor aerodynamics, working in development at MTU Aero Engines. Some of his inventions have even been patented. Not many of his colleagues know this, but one of Brignole's great passions in life is playing the guitar and synthesizer. At MTU, patents have been filed for some of his inventions but his creative mind is always ticking, even outside of work, where he also likes to spend his time tinkering. "I was thrilled with MTU's offer to explore my creativity at MakerSpace," he says.

Located in the north of Munich, MakerSpace is one of the largest prototype workshops in Germany. It's a place where hobbyists, researchers, students, company founders or anyone can go to use high-tech machinery for water-jet cutting, inert-gas welding, sandblasting and powder coating, for example. Where ambitious do-it-yourselfers work alongside start-ups, tinkering with software and professional tools to create prototypes of their product ideas.

MTU became a member of MakerSpace in 2020 to give twenty of its employees the opportunity to turn their own ideas into reality. It didn't take Brignole long to decide which of his ideas he wanted to bring to life at MakerSpace. "I'm designing and building an effects unit to hook up to the guitar and amplifier," he says. He recalls his first experience of dabbling with electronics at home: "Back in the 1980s, we'd etch circuit boards in etching baths in the basement. Thankfully, more elegant solutions are available these days." The circuit board milling machine at MakerSpace, for instance. Brignole had already simulated the electronic circuits for his effects unit on the computer at home.

Christian Grünberger, head of Intellectual Property Management at MTU, keeps in regular contact with the 500 or so inventors in the MTU Group: "We want to give our community of inventors an even stronger incentive to realize their innovative ideas. At MakerSpace, they can tap further into their individual creativity by working on their own, very personal projects," he says. This fosters new, imaginative patterns of thinking that they can then apply to their work at MTU. MakerSpace's innovative and productive environment is the perfect setting for the inventors to keep coming up with new ideas.

Grünberger recognizes the benefits: "It doesn't take long for your imagination to start stalling when you're dealing with new subject matter; I know that from experience," he says. He himself has


**DIY enthusiast** _____
*Petra Kufner, an expert in Advanced Programs at MTU Aero Engines, discovers completely new possibilities at MakerSpace.*

*"We want to give our community of inventors an even stronger incentive to realize their innovative ideas. At MakerSpace, they can tap further into their individual creativity by working on their own, very personal projects."*

**Christian Grünberger,** *Head of Intellectual Property Management at MTU Aero Engines*

MAKERSPACE

**A paradise for inventors and creative types** _____

*MakerSpace offers members access to machines, tools and software. The 1,500 m² high-tech workshop has everything a tinkerer's heart desires. MakerSpace is a place to bring ideas and innovations to life as prototypes and small batches. Members have access to various areas, such as a machine, woodworking and metal workshop as well as a textile and electrical corner. In addition, 3D printers, laser cutters and water jet cutting machines provide ways to create new shapes and process a wide range of materials.*

*www.maker-space.de*

worked at MakerSpace, where he developed a prototype for an idea his kids came up with. It now stands in front of his house: a garden bench that is comfortable to sit on and incorporates a locked storage space for parcel deliveries.

"The inventors are in their element here, where they can completely lose themselves in their work," says Florian Küster, Sales and Marketing Manager at MakerSpace. "In today's increasingly digitalized world of work, very few people actually make things with their hands anymore. But here they get to physically hold their inventions. This makes the product development experience tangible and brings it to life."

But the first draft doesn't always immediately translate into a prototype. Paper is patient, as the saying goes. But even the best drawing of an idea is useless if you can't actually produce it. Brignole: "Experimenting with ideas at MakerSpace teaches you to think ahead: Will my design work in practice? Is it possible to process the materials the way I want?" In his role at MTU, too, he's always thinking about the production side of the concepts he develops. "If you want to do a good job, you have to look beyond your own field," he says.

Before inventors can start their production experiments at MakerSpace, they have to complete a course on how to use the high-quality machinery. "You're not allowed to operate the machines until you've had the proper training," Küster explains.

Petra Kufner, who works as an expert in MTU's Advanced Programs department where concepts for future engines and components are developed, has already been trained on four machines at MakerSpace, including for the CNC wood milling machine, the laser cutter and the 3D printer and scanner. The idea she wants to bring to life is a cylindrical stand with an oval base to hold her cats' water bowl. She developed a 3D model of the stand on her computer at home. Kufner is an

**Creative mind** ____
*Dr. Giovanni A. Brignole, compressor aerodynamics expert, trains himself to think ahead by experimenting in the MakerSpace.*

**Germany's largest prototype workshop** ____
*At MakerSpace, hobbyists, researchers, students or company founders can use high-tech machinery for water jet cutting, inert-gas welding, sandblasting, powder coating and more.*


enthusiastic DIYer and also enjoys working with fabric and paper, but at MakerSpace she is discovering a whole new world of possibilities: "Here I have access to high-tech machinery and professional tools."

Like Brignole, she works closely with the production department in her job. As an engineer, she is always very mindful about using materials and other resources sparingly. "Materials like plexiglass, for example, are expensive. You don't want to use more material than you actually need, so it's important to make a detailed plan of how you're going to realize and produce your idea before you start." And if the researchers get stuck at any point, there is a professional crew—usually master craftsmen—on hand in the workshop to assist and advise them.

Kufner's water bowl stand is still in the development stage, but working at MakerSpace is already giving her a creative boost and that feel-good factor. "And, unlike at work, I don't need to wait for authorization or approvals for my own invention, so it doesn't take as long to make it a success," Kufner says.

Do you have any questions, requests or suggestions?
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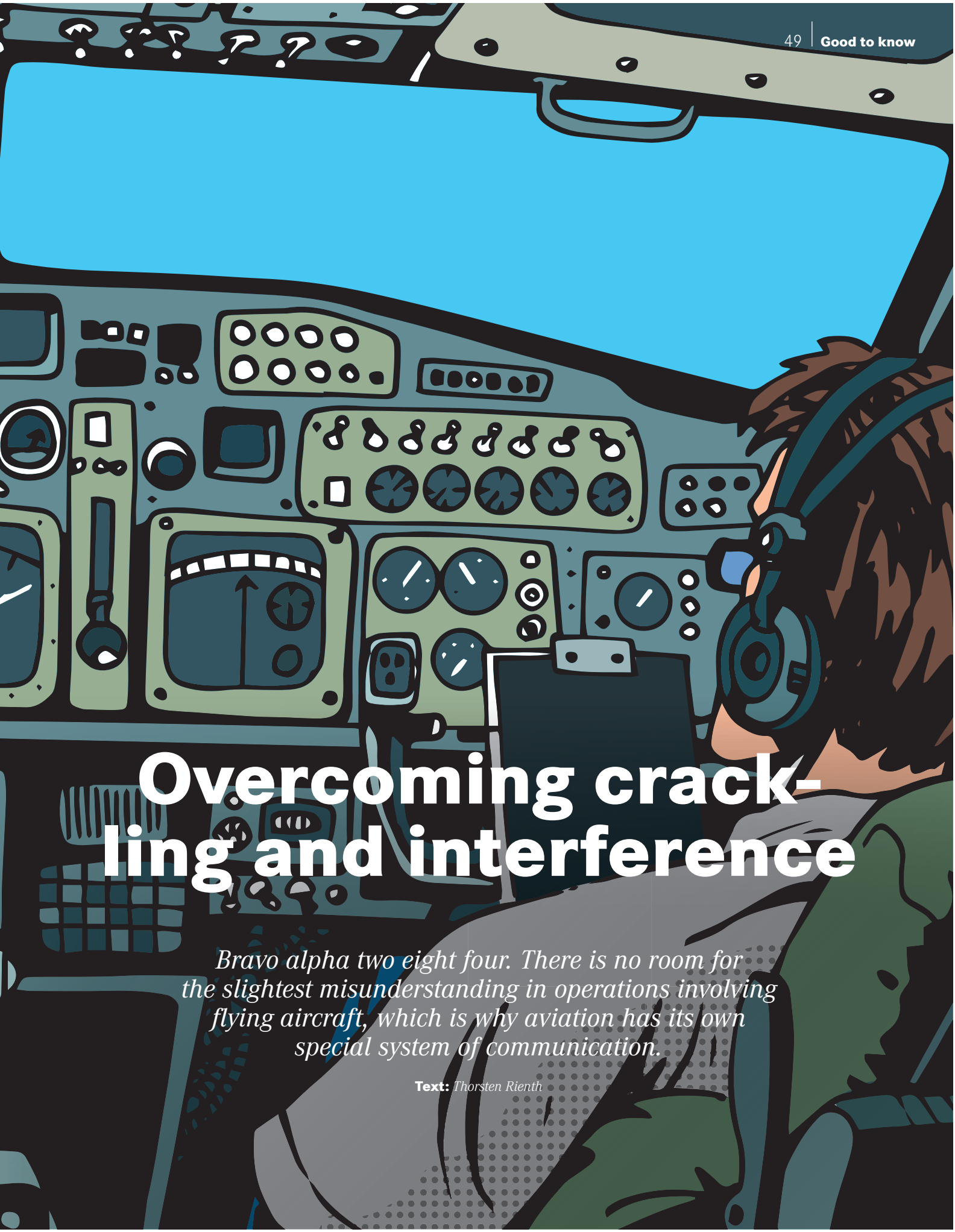
Text:
**Nicole Geffert** has been working as a freelance journalist covering topics such as research and science, money and taxes, and education and careers since 1999.


"Bravo alpha two eight four heavy taxi to runway 28R via alpha, Quebec, bravo, foxtrot, hold short of 01 Lima."



# Overcoming crackling and interference

*Bravo alpha two eight four. There is no room for the slightest misunderstanding in operations involving flying aircraft, which is why aviation has its own special system of communication.*

**Text:** *Thorsten Rienth*


**ICAO ALPHABET**

| | |
|---|---|
| A | Alpha |
| B | Bravo |
| C | Charlie |
| D | Delta |
| E | Echo |
| F | Foxtrot |
| G | Golf |
| H | Hotel |
| I | India |
| J | Juliet |
| K | Kilo |
| L | Lima |
| M | Mike |
| N | November |
| O | Oscar |
| P | Papa |
| Q | Quebec |
| R | Romeo |
| S | Sierra |
| T | Tango |
| U | Uniform |
| V | Victor |
| W | Whiskey |
| X | X-ray |
| Y | Yankee |
| Z | Zulu |

If you look out the window on the approach to Geneva Airport, you can catch a glimpse of the number and letter combinations on the neighboring runway. Depending on the runway and direction of approach, you'll see a large white "04," "22," "04L" or "22R" painted on the gray tarmac.

They represent the bearing of the runway the aircraft is approaching on in relation to the North Magnetic Pole. A runway pointing directly south gets an "18," which corresponds to 180 degrees on a compass. This covers the range between 175 and 184 degrees. If the runway is pointing in the opposite direction, i.e. north, it will be at 360 degrees and labeled with a "36." By the same logic, runway 22 in Geneva points roughly southwest. On parallel runways, the "L" and "R" stand for left and right, as you might expect. If there are three runways all pointing in the same direction, as you find at major airports like Frankfurt or Chicago, the middle one is given the suffix "C" for center.

## No superfluous syllables

Abbreviations like these are common in every facet of aviation, where the highest possible level of precision and unambiguity is absolutely essential. That is especially true for the communications between the cockpit and air traffic control, or ATC for short. Any superfluous syllable, number or series of letters could lead to potential misunderstandings. So the command "reduce to minimum" doesn't apply just to altitude and speed when an aircraft is on approach, but to the whole way aviation phraseology is developed.

Aviation language is based on the alphabet of the International Civil Aviation Organization—the ICAO alphabet. While it's easy to mix up the letters "M" and "N" through headphones when there is crackling and interference in the background, confusing "Mike" and "November" far less likely. In pilot lingo, flight "BA 284" from San Francisco to London becomes "Bravo Alpha Two Eight Four."

If this flight is to keep its slot for takeoff based on the calculated takeoff time (CTOT in aviation-speak), the pilot must request clearance to taxi from the ATC tower in good time. Toward runway 28R, for example. The answer from the tower might be as follows: "Bravo Alpha Two Eight Four heavy taxi to runway 28R via Alpha, Quebec, Bravo, Foxtrot, hold short of 01Lima."

"Heavy" refers to the Boeing 787-9 Dreamliner, the aircraft operating the flight, indicating a takeoff weight of more than 300,000 pounds. Alpha, Quebec, Bravo and Foxtrot signal the way across the apron. Next comes the instruction to wait up ahead of runway 01L, which crosses runway 28R. It is in that direction that BA 284 will taxi to next.

What sounds like secret code is really only pared-down command language: "rotate," "positive climb," "gear up." The weather might be CAVOK: "clouds and visibility OK."

In addition to normal radio communication systems, commercial aircraft are equipped with transponders—a portmanteau of the words "transmitter" and "responder." The main use of these telecommunications devices is to identify aircraft. But they are also deployed for emergency communications if the radio is down or a radio message isn't appropriate in the given situation.

If the aircraft is being hijacked, for example, the code "7500" is entered. To help them remember this, trainee pilots learn the rhyme "75—man with knife." The code for radio failure is "7600," while "7700" means there is an emergency. Assigned to the respective flight number, the code then ap-

pears on the screens of all air traffic controllers who are currently monitoring that flight's airspace.

### Airbus aircraft designations even indicate the engine variant

Also displayed on these screens is the respective aircraft's registration number. But that's not the only place it appears: the designation is invariably painted on both sides of the fuselage as well, where it is clearly visible. It functions in the same way as a car license plate—as unique identification for every commercial aircraft. In Germany, such designations are governed by the country's Air Traffic Licensing Order (LuftVZO).

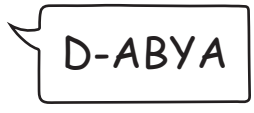
They begin with a "D-"—for example, D-ABYA. The next letter defines the maximum takeoff weight category. If this is over 20 metric tons, it will be an "A". This is followed by the airline's own designations; at Lufthansa, for example, a "B" stands for Boeing and a "Y" represents the 747-8 aircraft model. The final letter "A" indicates that this jet is the first 747-8 model delivered to the airline. Subsequent aircraft deliveries simply receive the next letter of the alphabet in the final position of their designation, i.e. D-ABYC, D-ABYD, D-ABYE.

Airframers can determine the name and classification of their aircraft types themselves. Airbus, for instance, calls an A320-200 an A320-230 if it is equipped with engines produced by the IAE consortium. The third number indicates the engine series, so the designation A320-231 denotes V2500-A1 engines.

Boeing aircraft don't provide such information, as the manufacturer opts to supplement its aircraft type designations with customer numbers only. For example, you can deduce that a Boeing 777-328ER belongs to the Air France fleet because "28" is the Boeing customer code for the French airline. Lufthansa has been allocated "30" as its Boeing reference. In Boeing code, therefore, D-ABYA would be a 747-830 aircraft operated by the German flag carrier.

Note that the runways in Geneva have not always been called 04/22 and 04L/22R; they were renamed from 05/23 and 05L/23R as recently as fall 2018. The reason is that unlike the Geographic North Pole, the Geomagnetic North Pole, to which compass needles are aligned, moves. Due to the varying distance between the two, the runways have to be renamed from time to time to ensure correct orientation. But that's a whole other story.


**Cabin lingo** ___ *"SPML" stands for special meal, "galley" is the on-board kitchen, "bin" is where overhead luggage is stored, "crotch watch" refers to checking that everyone's seat belt is buckled, and a "deadhead" is a crew member flying as a normal passenger. "Pax 11 alpha, extensions please" means the passenger in seat 11A needs a seat belt extender. When flight attendants refresh their makeup before landing, they put on their "landing lips."*




**Aircraft registration numbers** ___ *They function like a car license plate–to clearly identify each and every commercial aircraft.*


**Code for an aircraft hijacking** ___ *To help them remember this, trainee pilots learn the rhyme "75–man with knife."*

Do you have any questions, requests or suggestions?
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**Recycling**

*Recycling a certain material or product means using it again after it has served its original purpose. If a recycled item is of lower quality than the original product, its reuse is called downcycling.*

**Upcycling**

*Upcycling is when products that have reached the end of their useful life and are technically considered as waste are simply turned into new products. Another name for upcycling is creative reuse. This is where unwanted or waste products are used as materials that are reworked and upgraded to create new products.*

# A treasure trove with wings

*Too good to throw away:*
*Decommissioned aircraft contain spare parts, valuable materials and even elements for making stylish upcycled furniture.*

**Text:** *Monika Weiner*

For decades, no one paid much attention to the defunct commercial aircraft parked on the edges of remote airfields. Only gradually did it become clear what treasures lay dormant in these "aircraft graveyards": engines, turbine components, avionics and landing gear can serve as spare parts, and fuselage elements contain valuable metals such as aluminum, titanium and copper that can be reused. Even seats, wall fixtures and wing sections can be upcycled to produce exclusive furniture.

In Europe, the business of aircraft recycling is still in its infancy, but it is gaining ground fast. The biggest player is French company TARMAC Aerosave, in which Airbus has an interest. In Germany, the market is shared by a number of SMEs specializing in aircraft demolition and recycling. The aim is to reuse as many materials as possible.

Taking apart an entire aircraft, sorting all the components by type and reprocessing them is an art in itself. For instance, engines and landing gear that are to be harvested for spare parts must be professionally dismantled. Next, all pollutants must be removed, such as extinguishing agents, kerosene and oils from hydraulic lines.

"Once all the prep work is done, dismantling the aircraft takes two to six days depending on its size," says Marc E. Keske, CEO of MoreAero GmbH. The company specializes in disposing of aircraft at the location they last touched down. "On-site demolition benefits the owner in that they don't have to transport the aircraft, which saves them money," Keske explains. His teams are set up to work anywhere. Everything they need is brought to the site by rail or sea in a standard container, including pumps to


**Aircraft recycling** ___ *Heavy machinery and equipment is required to dismantle an aircraft. Removal of potential replacement parts like engines and landing gear must be done by experts. Following the prep work, it takes between two and six days to disassemble an aircraft, depending on its size.*

drain the kerosene tanks and brake lines, tools to remove compressed air cartridges or oxygen tanks that are still pressurized, and scrap shears that can be mounted on excavators. All that is left once the "demolition" is complete is a pile of torn-up parts.

### Turning waste materials into new raw materials

Recycling companies are brought in to deal with this scrap, shredding the parts and separating the various materials. "In this way, it's possible to reclaim a variety of metals as well as complex alloys, which industrial companies can then use in the manufacture of new products," explains Gregor Zenkner, Manager Business Development at CRONIMET, a company specializing in metal recycling. From aircraft scrap, it's possible to harvest the likes of temperature-resistant superalloys containing titanium and nickel, which can be reused by the aerospace sector. Any material that cannot be repurposed is incinerated.

Each change to the way aircraft are constructed creates new challenges for recyclers. In the past, the fuselages of aircraft earmarked for disposal have been made of aluminum, which is easily recyclable. But now, aircraft manufacturers are increasingly using lightweight fiber-reinforced composites—in particular carbon fiber reinforced polymers (CFRPs). Sooner or later, these CFRPs will also have to be demolished and processed on a large scale.

### New life for carbon fiber reinforced polymers

Torsten Müller from the Fraunhofer Institute for Chemical Technology ICT is researching the technical and economic aspects of how this can be done. "Even carbon fiber reinforced polymers can generally be recycled. But so far, this has been more complicated and expensive than disposal through incineration or, provided the country in question allows it, landfills," Müller says. One polymer typically used in aircraft construction is epoxy resin, in which the fibers are embedded. Reclaiming the fibers means separating the epoxy resin from the fibers in the absence of oxygen as part of a process called pyrolysis, which requires special equipment.

Less of a technical challenge is the recycling of expensive carbon fiber reinforced thermoplastics. As Müller explains, these can be shredded before being heated and molded into new shapes: "Because shredding shortens the fibers, the recyclate doesn't have the same properties as the primary material. But it can be used to produce things like cable ducts, which could then be used in a new aircraft." But Müller says that the closed-loop economy of polymer recycling is fast approaching its limits because the materials are rarely available in separated form.

### Upcycling: Giving scrap a new splendor

Alongside traditional recycling, a new market is emerging—one that allows old parts to shine in new splendor: upcycling. In this


**Plastic recycling** ____ *Backrests made of commercially available hybrid yarns with recycled carbon fibers are produced using LFT injection molding at the Fraunhofer Institute for Chemical Technology. reCa-HiT is funded by the Baden-Württemberg Ministry of Economics, Labor and Housing.*

case, creativity knows no limits. Whole aircraft are transforming into apartments or hotels, small "aeropods" made from fuselage sections are being used as conservatories or gazebos, and various companies are offering trolley furniture as well as bags and accessories made from seat covers and life jackets.

Marius Krämer, one of the founders and CEOs of Wilco Design, and his team manufacture exclusive furniture out of old aircraft parts. He procures the raw materials from airlines and waste disposal contractors. "Upcycling is all the rage at the moment. People are increasingly seeing the value in repurposing things rather than throwing them away," Krämer says. His furniture range includes wall bars made from fuselage parts, restored trolleys and seats, and tables made from wing sections. There is even a whirlpool that in its previous incarnation was an Airbus engine inlet.

The airlines have also recognized and marketed this trend. Lufthansa, for example, offers its Miles and More customers its own upcycling collection, featuring a variety of products ranging from the Messenger Backpack to the Flying Coffee Table—each featuring details of where the decommissioned parts came from. In short, aircraft recycling is becoming a lifestyle.

Do you have any questions, requests or suggestions? Contact the editors here: **aeroreport@mtu.de**

More on this topic: **www.aeroreport.de**

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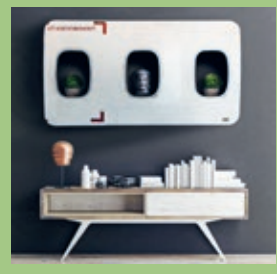
**UPCYCLING—CREATING NEW TREASURES**



**Another kind of upgrade** _____ *Upcycling is all the rage: old aircraft parts are turned into exclusive furniture.*

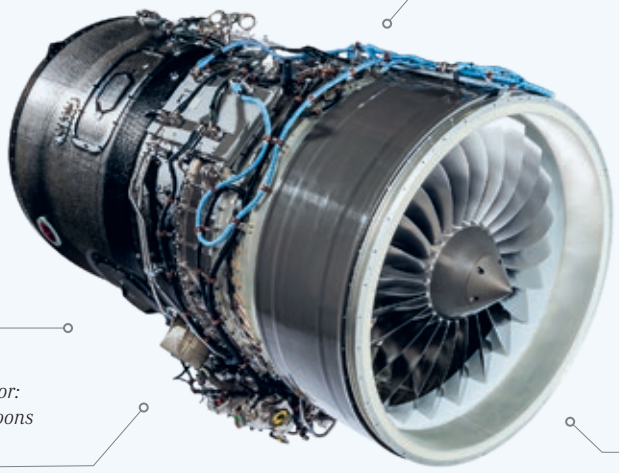
# *PW800: The trusty powerplant for business jets*

***The Dassault Falcon 6X, a new business jet powered by PW800 engines, is ready for takeoff.***

When the first Dassault Falcon 6X rolled out of the hangar in early December 2020, the business jet carried a PW800 engine either side of its fuselage. As the powerplants for the Gulfstream G500 and G600, PW800 family engines are no strangers to the business jet market. MTU holds a 15 percent share in the engine program, providing the high-pressure compressor and various stages of the low-pressure turbine—its flagship products. As a member of Pratt & Whitney's innovative PurePower® family, the PW800 engine incorporates groundbreaking technological innovations and the same proven core technology as the P&W GTF engine family.

*Double-digit percentage improvements in fuel consumption, environmental emissions, engine noise and operating costs*

*State-of-the-art cooling of the high-pressure turbine with active tip clearance control*



*10,000 to 20,000 pound thrust class*

*High-pressure compressor: High-stiffness design; cantilevered stages*

*Advanced materials and design technologies and improved aerodynamics*

*High-efficiency and low-maintenance single-piece fan: Improved noise and vibration characteristics*

*Low-emissions TALON™ combustor: Low levels of unburned hydrocarbons and smoke*

*MTU holds a 15 percent stake in the engine program*

*Large access panels in the engine bypass ducts allow mechanics to quickly and efficiently access the engine core*

*MTU's workshare encompasses the high-pressure compressor (various stages) and the low-pressure turbine*

**Falcon 6X** ____ *With a top speed of Mach 0.9 and a range of 10,186 kilometers, the Dassault Falcon 6X can fly routes such as London to Hong Kong nonstop. Its entry into service is expected in 2022.*

# *The AEROREPORT editorial team wants your opinion!*

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We have come up with a few questions that will help us provide our readers with an even better **AERO**REPORT in the future.


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**AERO**REPORT 01|21
The aviation magazine of MTU Aero Engines | www.aeroreport.de

**Publisher**
MTU Aero Engines AG
Eckhard Zanger
Senior Vice President
Corporate Communications and Public Affairs

**Editor in chief**
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**Layout**
SPARKS CONSULTING GmbH, Munich

**Photo credits**
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*56_57* MTU Aero Engines, Dassault Falcon

**Printed by**
Eberl & Koesel, Altusried-Krugzell

**Online**
ADVERMA
Advertising und Marketing GmbH, Rohrbach

**Translation**
Klein Wolf Peters GmbH, Munich

# $H_2$

**AERO**REPORT

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