AEROREPORT 02|21

The aviation magazine of MTU Aero Engines | www.aeroreport.de

On the up

Modern narrowbodies powered by GTF engines are back

AVIATION

The world's fastest package deliverers

INNOVATION

On a digital mission – turbocharging digitalization at MTU

GOOD TO KNOW

To-do lists – safety first

Dear readers,

Global aviation was hit by the Covid-19 pandemic like almost no other industry. A tangible recovery is now underway, not least thanks to large-scale vaccination programs. With demand for mobility and travel returning, we are convinced that aviation will regain its old strength.

Thanks to its diversified portfolio of commercial business, maintenance and military activities, MTU has so far come through the crisis in good shape. And with our versatile, flexible network and our ability to adapt quickly to the market, we are also ideally positioned for the future.

Despite the crisis, we are pressing ahead undaunted with our efforts to make aviation sustainable. The main goal is still to achieve emissions-free flight by way of climate neutrality. With the Geared Turbofan (GTF) engine, Pratt & Whitney and MTU are already realizing the most efficient engines currently available on the market. To date, GTF technology has avoided more than five million metric tons of CO_2 emissions and saved almost two billion liters of fuel. And our engineers and technology experts are already working on the second generation of the geared turbofan; after all, further optimization of all components is an important and indispensable step on the way to making aviation climate-neutral.

MTU has established maintenance capabilities for the Pratt & Whitney GTF™ engine family at several locations worldwide. Three of them even offer full disassembly, assembly and test capabilities for the PW1100G-JM engine. That means we can provide our customers and partners with comprehensive know-how and the best possible service.

This issue of **AERO**REPORT will give you a guided tour of the GTF success story. It includes a poster explaining how a GTF engine and its main components work. In this issue, we also present a selection of the projects with which we are driving digitalization at MTU. And we address the questions of how to get hydrogen, a promising fuel for the future, into aircraft and what effect its use will have on the climate.

I hope you enjoy reading this issue!

Yours sincerely,

Reiner Winkler
Chief Executive Officer

COVER STORY

On the up

The aviation industry is beginning to recover from the Covid-19 crisis, and the market for narrowbody jets is the first to take off. Many airlines are giving preference to the modern aircraft in their fleet—such as the A320neo with its highly efficient PW1100G-JM engines.

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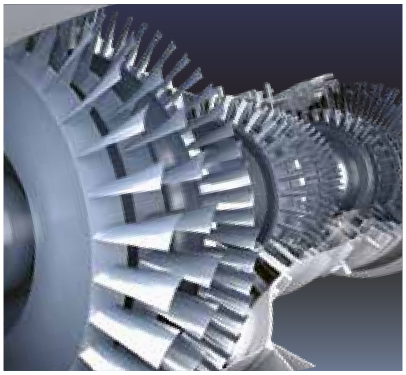

COVER STORY

How does a turbofan engine work?

Modern aircraft engines are top-class technological products that must withstand extreme conditions.
But how do they actually work?

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INNOVATION

The big question: Integration

Unmanned drones and air taxis are waiting in the wings to head for the skies. The new air traffic control concepts required will have a huge impact on traditional air travel in the long term.

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INNOVATION

On a digital mission

Turbocharging digitalization at MTU: AI and big data are opening up whole new opportunities in the high-tech engine business—right across the company. We present a selection of IT projects that show how MTU Aero Engines is powering ahead with digital transformation.

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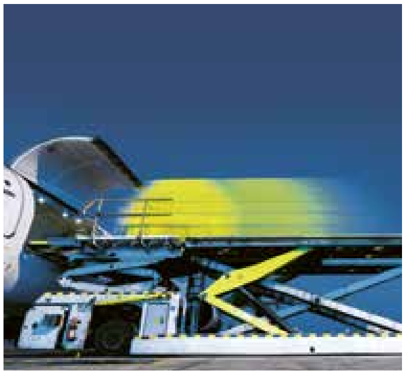

AVIATION

The world's fastest package deliverers

The air freight sector is flying high in the current crisis, with online retail responsible for major growth. To deliver goods even faster, more and more smaller, short- and medium-haul jets are being used to transport freight.

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GOOD TO KNOW

To-do lists – safety first

The use of pre-flight checklists during flight preparation is mandatory. It helps establish fixed routines for checking all functional and safety-relevant factors in the cockpit, cabin and exteriors.

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All articles from the print edition and much more are also available online at www.aeroreport.de/en. There you will find informative videos, photo galleries and other interactive specials too.

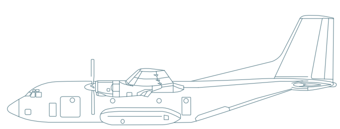
FAREWELL

Bye-bye, angel of the air!

After over 50 years, the time of the Transall C-160 is coming to an end.

The military transporter is being retired, and with it the Tyne engine. Featuring a planetary gear train comprising propeller and compressor, this twin-shaft engine had completed 2.172 million flight hours by the end of 2020.

TRANSALL



LENGTH	32.40 m
HEIGHT	12.36 m
WINGSPAN	40 m
WING AREA	160 m²
UNLADEN WEIGHT	28.50 t
CRUISING SPEED	455 km/h
RANGE WITH 14-TON PAYLOAD	(approx.) 1,200 km
RANGE WITH 5-TON PAYLOAD	(approx.) 3,800 km
ENGINE:	TYNE

MORE ABOUT THE TRANSALL AND ITS SUCCESSFUL TYNE ENGINE:

The Transall flies off into the sunset
www.aeroreport.de/en

ANNIVERSARY

50 years of the CF6

MTU manufactures parts of the CF6 turbine and compressor.

With more than 8,500 units delivered, the CF6 is the most successful GE engine program for commercial widebody aircraft.

The CF6 was the first engine MTU developed for commercial aviation and it has been a cornerstone of the company's success for decades.

There are five models in this engine family—CF6-6, CF6-50, CF6-80A/C and /E—which together have logged more than 460 million flight hours since 1971.

MTU Maintenance has been looking after this trusted workhorse for almost 40 years.

To date, MTU Maintenance has performed more than 4,000 overhaul operations on the CF6-50 and CF6-80C2 models.

The CF6: *A twin-shaft high-bypass engine for medium- and long-haul widebody aircraft.*

The V2500 engine family offers up to 33,000 pounds of thrust.

THE V2500 ENGINE

More than
250 million
flight hours

By now, the V2500 has logged more than 250 million flight hours. Produced by the International Aero Engines AG (IAE) engine consortium, this turbofan engine powers the Airbus A320ceo family and the Brazilian military transporter Embraer C-390. This engine's first flight was on an A320 back in 1987.

FUTURE

Powerful engine for the future

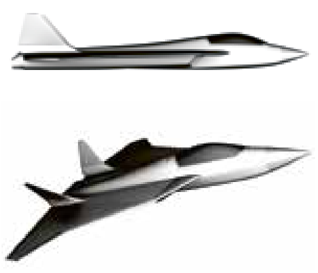
Together with partners Safran Aircraft Engines in France and ITP Aero in Spain, MTU Aero Engines will develop the centerpiece of the new European fighter aircraft: the Next European Fighter Engine (NEFE).

As part of the EUMET joint venture, Safran Aircraft Engines will oversee the engine's design and integration, while MTU Aero Engines will handle all maintenance and service activities. As EUMET's main partner, ITP Aero will be fully involved in designing the engine and will develop several components, including the low-pressure turbine and the thrust nozzle.

Future Combat Air System
In the future, a unit of manned and unmanned aircraft systems is to defend German and European airspace.

When it comes to engine technology, the requirements for the Next Generation Fighter (NGF) include innovative and advanced tools, processes and materials. MTU is also aiming to significantly enhance the engine concept itself: a variable cycle engine (VCE) will deliver increased mission flexibility, low fuel consumption and maximum thrust.

High-tech technology
For the NEFE, MTU is harnessing a variable cyclic process that greatly reduces consumption while enhancing mission flexibility.



Clearly defined requirements
Higher performance and flexibility, lower consumption: The Next Generation Fighter aircraft must offer maximum performance in extreme situations.

A powerful engine for a powerful fighter
www.aeroreport.de/en

IN A NUTSHELL

What does "bypass ratio" actually mean?

In modern turbofan engines, the core engine drives a fan, which in turn accelerates air past the core engine in the bypass flow. The ratio between this bypass airflow and the airflow that passes through the core engine itself is known as the bypass ratio.

What makes an engine efficient is when it moves large air masses at a speed as close as possible to the airspeed–in other words, while demonstrating a high bypass ratio. This in turn lowers fuel consumption and emissions, including noise.

Ultra-high bypass ratio for the future
Since the 1960s, bypass ratios have increased from 2:1 to 6:1 for the V2500, the classic 1980s engine, and on to the current record of 12:1 set by the latest geared turbofan (GTF). Developers aim to refine the GTF engine to achieve a bypass ratio greater than 12:1. Experts describe this as an ultra-high bypass ratio (UHBR).

SAVINGS ACHIEVED WITH GTF ENGINES

CO_2 — A reduction in **CO_2 of 5** million metric tons

A saving of **2 billion** liters of fuel

On more than 2.5 million flights totaling over 1,000 flight hours, GTF engines have so far saved over half a billion gallons (almost two billion liters) of fuel and reduced CO_2 emissions by more than five million metric tons.

Source: Pratt & Whitney, July 2021

Up to date on board —— *Airlines prefer aircraft models that feature the most advanced engine technology. In the case of narrowbodies, this is primarily the Airbus A320neo powered by the PW1100G-JM, which belongs to the successful Pratt & Whitney GTF™ engine family.*

On the up

The market for short- and medium-haul jets is the first to recover from the crisis. Many airlines are giving preference to their newest aircraft with highly efficient engines.

Text: *Nicole Geffert*

WIDEBODIES VS. NARROWBODIES AND REGIONAL JETS

Seats in standard seating design

Widebody: 240 - 650

Narrowbody: 100 - 240

Regional Jet: 70 - 100

Range in nautical miles

Widebody: 5,000 - 8,500

Narrowbody: 3,000 - 4,700

Regional jet: 1,000 - 2,500

A glance upward at the cloudless sky reveals a plane glittering in the sun; a second one follows shortly thereafter. And suddenly, there it is: a feeling of wanderlust. Finally, a chance to take off and travel again. Plenty of other people share this longing. And indeed, more people are now flying again—on domestic business trips and abroad on vacation. The aviation industry is beginning to recover from the Covid-19 crisis.

“What we’re seeing during the pandemic is that the market for short- and medium-haul jets, known as narrowbodies, has emerged as the one that is recovering fastest,” says Marko Niffka, expert for Business Development – MRO at MTU Aero Engines. According to market analyses, the earliest signs of recovery are in demand for domestic and vacation flights—exactly the market that narrowbody jets in particular serve.

Latest engine technology on board

Another trend is also emerging: fuel efficiency and plans to make flying more climate-friendly, to which government support is often tied, mean that airlines are giving preference to the modern aircraft models in their fleet, which have the latest engine technology on board. In the case of narrowbodies, this is primarily the Airbus A320neo powered by the PW1100G-JM, which belongs to the successful Pratt & Whitney GTF™ engine family.

“There is a clear preference for the modern fleet,” says Dr. Marc Le Dilosquer, expert in market analysis at MTU. “Airlines are looking primarily at operating costs. Here, new aircraft models with highly efficient engines are ahead of the game. This is down to the lower fuel consumption and lower maintenance costs of newer aircraft, which are the main drivers for airlines to give preference to these aircraft. For the time being, they’re using older models less than before the crisis and leaving them on the ground more often.”

A320 family production rate on the rise

Aircraft manufacturer Airbus expects the commercial aircraft market to recover to pre-Covid-19 levels between 2023 and 2025—led by the single-aisle segment, which covers aircraft with one aisle and five to six seats per row. For its A320 family, for example, Airbus confirmed in May 2021 an average production rate of 45 aircraft per month in the fourth quarter of 2021

and asked its suppliers to prepare for the future by securing a fixed rate of 64 aircraft by the second quarter of 2023. In anticipation that the market will continue to recover, Airbus expects to reach a rate of 70 aircraft by the first quarter of 2024 and is exploring options for rates of up to 75 aircraft by 2025.

Narrowbodies on long-haul routes

There is a sense in the industry that things are on the up. What's more, airlines are responding flexibly to the current situation. "The top priorities are economy and efficiency. At a time when fewer passengers are checking in, airlines are opting to use smaller aircraft with lower capacity, even for longer routes," says Bernhard Köppel, an expert in flight physics and operating cost analysis at MTU. "These are cheaper to operate and reduce commercial risk for the airline."

Using single-aisle aircraft instead of widebodies on medium-haul and shorter long-haul routes represents a huge cost saving. "Widebodies are typically 50 percent costlier to operate per flight; this is also known as trip cost. It won't make commercial sense to use them until demand returns to levels that will fill most of their seats," Köppel says.

Greater range, lower capacity

Airbus has responded to current demand by developing the A321LR (Long Range) and A321XLR (Xtra Long Range) long-haul models. With additional fuel tanks and higher take-off weight, these increase the range of the A321neo base model from 6,850 kilometers to 7,400 kilometers (A321LR) and 8,700 kilometers (A321XLR). Boeing doesn't currently offer a comparable, competitive model from the 737 MAX family.

Airbus's new long-haul models will enable connections between, for example, Western Europe and the East Coast of the United States, Europe and India, Australia and Southeast Asia, or the Middle East and South Africa. They can also serve smaller airports. And they provide plenty of power: "The PW1100G-JM engine already delivers enough thrust to get both new models safely into the air," Köppel says.

The U.S. airline JetBlue, an MTU Maintenance customer, has added to its fleet, taking delivery of its

The savings that the GTF™ engine family achieves over the previous version are impressive:

Noise footprint reduction

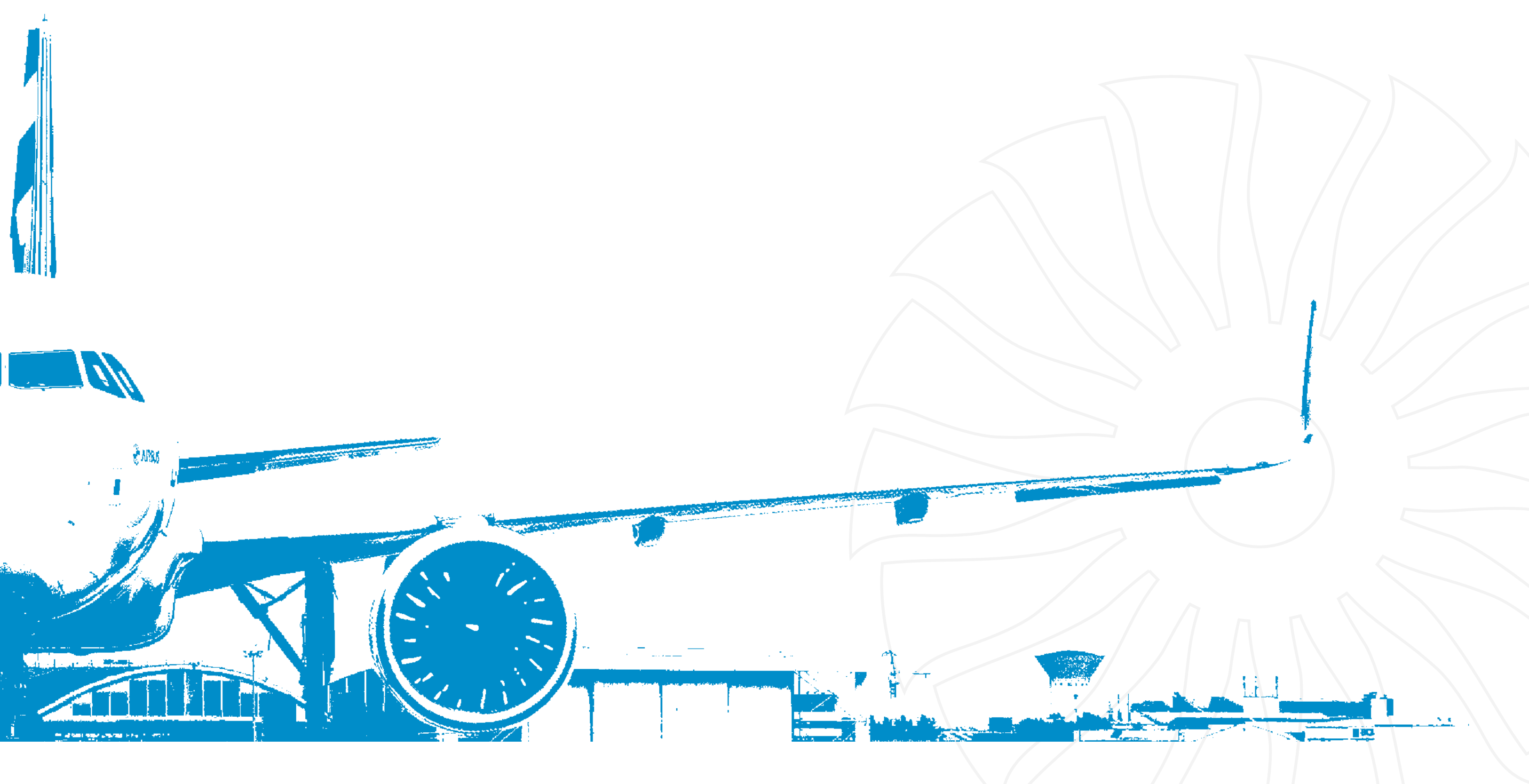
-75%

Carbon dioxide emissions reduction

-16%

Fuel consumption reduction

-16%



GTF™ engine family

The new engines offer double-digit percentage reductions in fuel consumption, pollution and noise emissions as well as operating costs.

A320neo ____ *The aircraft features new engines and improved aerodynamics. The suffix “neo” stands for “new engine option.”*

first A321LR powered by PW1100G-JM engines in April 2021. Back in April 2019, JetBlue converted 13 aircraft of its existing A321 orders to the LR version and 13 more aircraft to the XLR version. This will enable the airline to operate transatlantic flights between the U.S. and London for the first time and offer its customers other new routes. For JetBlue, the new models open up a market that it was unable to serve it with its previous fleet—all thanks to the longer range of the A321LR.

MTU positioned for success

The first-generation GTF engine has already enabled airlines to save more than five million metric tons of CO_2 in flight to date. Compared to its predecessor, the PW1100G-JM represents a reduction in fuel consumption and associated carbon dioxide emissions of around 16 percent each and its noise footprint on the ground during takeoff is some 75 percent smaller. The new engine also brings significant improvements in terms of NOx emissions, which are 50 percent lower than those of its predecessor.

MTU is involved not only in the development and production of Pratt & Whitney’s GTF™ engine family but also in its maintenance. “In the current situation, MTU’s positioning has particular advantages,” Niffka says. “We have a strong focus on engines for narrowbodies and are benefiting from the GTF’s market success. In both the OEM and MRO sectors, we are ideally positioned as a partner for airlines and Pratt & Whitney.” For one thing, MTU is a reliable partner in the worldwide MRO service network for the PW1100G-JM. This network gives customers access to maintenance facilities—known as shops—that have experience, know-how, and capacity and offer high-quality services.

It includes fully three facilities within the MTU network, each offering full disassembly, assembly and test capabilities for the PW1100G-JM. MTU Maintenance Hannover has been providing maintenance services for the PW1100G-JM since 2016. EME Aero, the MRO joint venture between Lufthansa Technik and MTU in Jasionka, Poland, opened its doors in 2020. MTU Maintenance Zhuhai is the latest partner to join the global MRO network for the PW1100G-JM. It is setting up another site specifically to handle this work.

“Having established a successful market position for itself with the V2500, one of the most successful narrowbody engines of all time, MTU was well placed to become such a strong partner in the GTF network, too, and provide top-quality support,” Niffka says.

Plenty of space ____ *The Airbus A320 family offers the widest single-aisle cabin on the market. Depending on the model, these aircraft can seat between 100 and 240 passengers.*

Flexible in every way

Moreover, as an independent maintenance provider, MTU Maintenance is a global player—especially in the narrowbody market. This is primarily due to the comprehensive services it offers, which cover the entire lifecycle of engines and are tailored to specific customer requirements. MTU can also offer its customers MRO services at locations all over the world. “Airlines want more flexibility,” Niffka says, “and we can provide that flexibility in every way—either as an independent MRO service provider or as part of the successful OEM network for the PW1100G-JM.”

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.

Geared for more power

All around the world MTU sites are involved in the successful GTF engine. Each location brings its own unique strengths to the table.

Text: *Isabel Henrich*

Full service ——— *In addition to developing and manufacturing high-tech components such as the high-speed low-pressure turbine, MTU offers the full range of disassembly, assembly and test capabilities for the PW1100G-JM engine.*

It took just 18 months to turn this greenfield site into one of the world's largest and most cutting-edge shops for the Pratt & Whitney GTF™ engine family. EME Aero is developing at an astounding pace—and it's not about to slow down: the second GTF family member, the PW1500G, was launched in August 2021.

EME Aero is only one of several MTU locations whose development, manufacturing and maintenance expertise make a key contribution to the GTF engine program.

Depending on the application, MTU's share of the GTF™ engine family is between 15 and 18 percent: in addition to responsibility for the high-speed low-pressure turbine and the first four stages of the high-pressure compressor, MTU also manufactures brush seals and nickel blisks for high-pressure compressor components, for which it does not have development responsibility. Moreover, MTU is responsible for the final assembly of one-third of the production PW1100G-JM for the A320neo. Development work on key GTF components is being carried out at MTU in Munich, in Rzeszów and at MTU Aero Engines North America.

MTU Maintenance has more than 40 years of experience and expertise in the independent MRO business and benefits from a broadly diversified engine portfolio. MTU is ideally positioned for the successful PW1100G-JM engine in particular, which powers the Airbus A320neo. MTU Maintenance Berlin-Brandenburg repairs individual stages of the high-pressure compressor and the low-pressure turbine. MTU Maintenance Zhuhai, EME Aero in Poland and MTU Maintenance Hannover have full disassembly, assembly and test capabilities for this engine type. And in addition to manufacturing GTF components, MTU Aero Engines in Munich and MTU Aero Engines Polska also carry out parts repairs for the PW1100G-JM.

The major advantage of spreading this expertise across several sites is that each location brings its own unique strengths to the table, enabling MTU to offer its customers and partners the best possible service. Here we present six sites and the part they play in making the geared turbofan such a success:

01 ___ PW1100G-JM final assembly ___ *Since 2016, the Munich site has handled final assembly for one-third of the production PW1100G-JM engines.*
02 ___ GTF specialists ___ *EME Aero is one of the world's largest MRO shops for the GTF family and is specialized in this modern engine.*

MTU Aero Engines, Munich

It was more than 20 years ago at MTU Aero Engines' technology hub, together with its partner Pratt & Whitney, that the first ideas for a geared turbofan were born. Today, MTU's Munich facility manufactures the high-speed low-pressure turbine, several stages of the high-pressure compressor in blisk design, and brush seals developed inhouse for all GTF engine family members. In addition to carrying out parts repairs, since 2016 the site has also been responsible for final assembly of one-third of production PW1100G-JM engines. To this end, the MTU project team developed a floor-based assembly system with 16 remote-controlled carts that, coupled together depending on the stage of assembly, move forward along the assembly line as though on a conveyor belt.

Focus on the next generation ___ The engineers in Munich are already working intensively on a further development of the GTF engine. The second generation is set to save more fuel and be even quieter and more efficient: the high-speed low-pressure turbine is being further optimized and new processes and materials are being used to get the most out of geared turbofan technology. These engines are expected be flying by the start of the coming decade.

MTU Aero Engines Polska

MTU Aero Engines Polska has been involved in the GTF almost since the beginning. The site in Rzeszów supplies high-quality components for five of the six applications. It supports the GTF program in various phases of engine production, from development to large-scale production. As of July 2021, 522 employees—more than 60 percent of the workforce—were involved in GTF projects.

GTF production ramp-up ___ MTU Aero Engines Polska can present some impressive figures: in 2015, the engineers in Rzeszów began assembling the first low-pressure turbine for the PW1100G-JM, the engine for the Airbus A320neo. Six years later, the site has carried out 2,500 assemblies of this module. As of 2021, nearly 800,000 GTF parts in total have been delivered, including more than 600,000 for the PW1100G-JM model.

MTU Maintenance Hannover

As the heart of the Maintenance Group and MTU's first maintenance facility, the MTU site in Langenhagen is indispensable for MRO services for GTF engines, too. Many years of expertise and a breadth of know-how gained through various engine programs (including the V2500, GE90 and CF6) provide the necessary MRO experience and skills. MTU Maintenance Hannover offers the full range of disassembly, assembly and test capabilities for the PW1100G-JM engine.

Up to speed in no time ___ The workforce in Hannover had to prepare for the PW1100G-JM in a hurry. But that was no problem for these engine experts: thanks to their many years of MRO experience, the company was ready for the new engine program in next to no time. The employees received strong support from Ludwigsfelde, too: a team from MTU Maintenance Berlin-Brandenburg provided valuable GTF know-how in the form of a PW1100G-JM crash course.

MTU Maintenance Zhuhai

The joint venture between MTU and China Southern Airlines Company Limited is the newest member of MTU's GTF network. September 2021, the first PW1100G-JM made its way through the shop—with plans for 1,000 shop visits over the next ten years. A second site is already under construction, with a shop that will specialize primarily in Pratt & Whitney narrowbody engines. This shop will accommodate a test cell with a 65,000 pound thrust capacity and is scheduled to go into operation in 2024. As in Hannover and

03 ___ Full capabilities ____ *Hannover is one of three locations that has full disassembly, assembly and test capabilities for the PW1100G-JM.*
04 ___ A watchful eye ____ *With their expertise, the professionals at MTU always ensure the highest quality for the GTF engines.*

at EME Aero, the Zhuhai site is fully equipped for (dis)assembly and testing of the PW1100G-JM engines.

Firmly established ___ As the largest MRO provider for narrowbody engines in the whole of Asia, MTU Maintenance Zhuhai has made a name for itself in the region. With the addition of the PW1100G-JM engine to its portfolio, the site is continuing its growth strategy and can now offer excellent service to its customers as a narrowbody expert in this region for the latest generation of engines.

EME Aero

As one of the world's largest MRO shops for the GTF engine family, the joint venture between MTU and Lufthansa Technik forms the heart of the MTU's GTF network. It started repairing PW1100G-JM engines in January 2020; this was followed by the PW1500G in August 2021, with the PW1900G set to follow soon. 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. With 450 shop visits planned per year, the site has big ambitions and is set for rapid growth.

Pure high-tech ___ With a flowline designed specifically for the site, EME Aero has one of the world's most advanced assembly systems in engine maintenance. 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 in the GTF family.

MTU Maintenance Berlin-Brandenburg

The MTU site in Ludwigsfelde has been involved right from the outset. This is where individual stages of the PW1100G-JM's high-pressure compressor and low-pressure turbine are repaired. In 2020, it added the PW1500G and the PW1900G. As true repair specialists, the experts in Ludwigsfelde are the only company in the global market to provide the full range of repairs for the low-pressure turbine and the second stage of the high-pressure turbine.

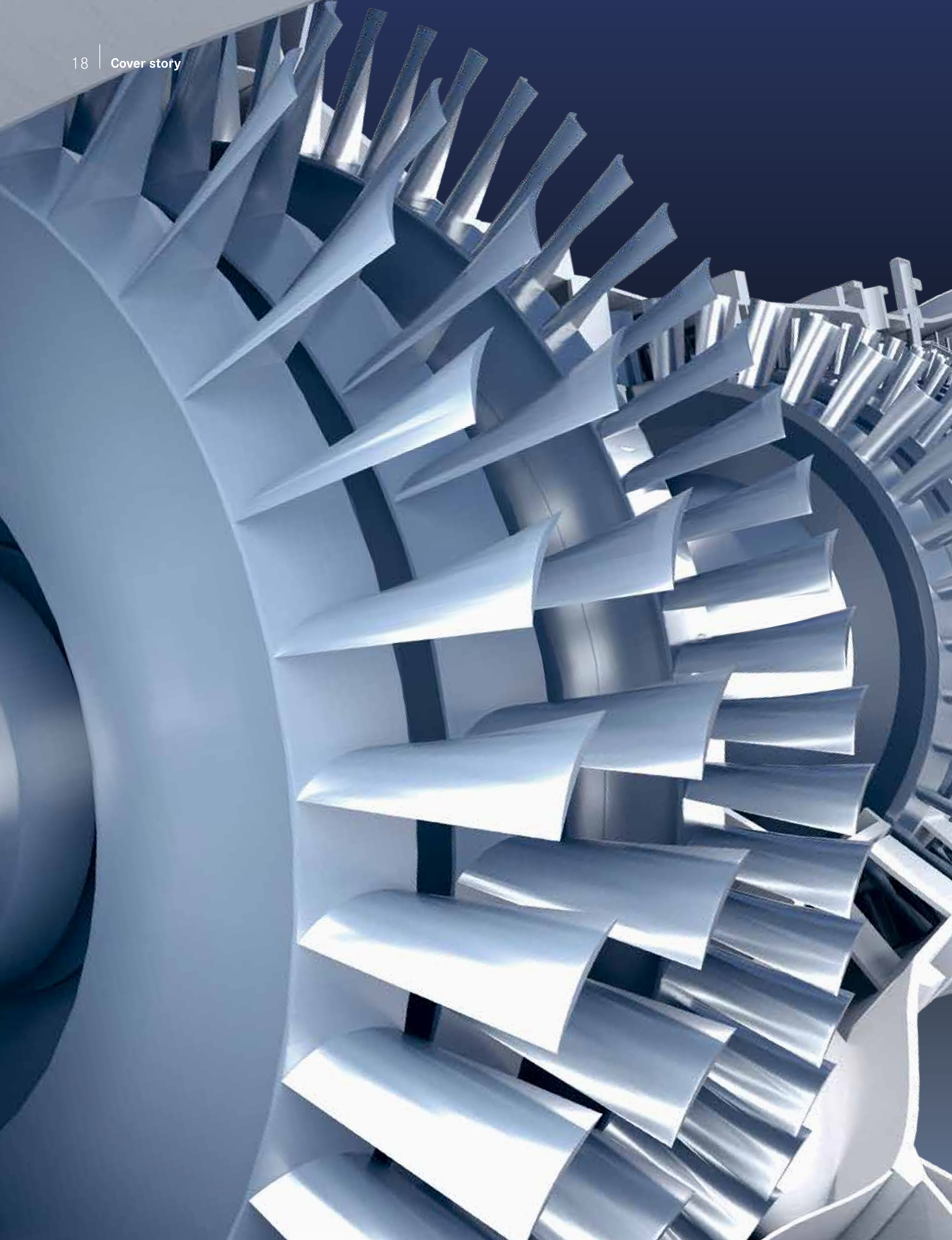
From the first moment ___ This location had already procured the required repair facilities back when its application to become a repair site for GTF engines was still being processed—a not entirely risk-free strategy, but one that proved its worth: this proactive effort secured the contract for the repair work and means that to this day, the site is an expert in MRO services for the GTF family.

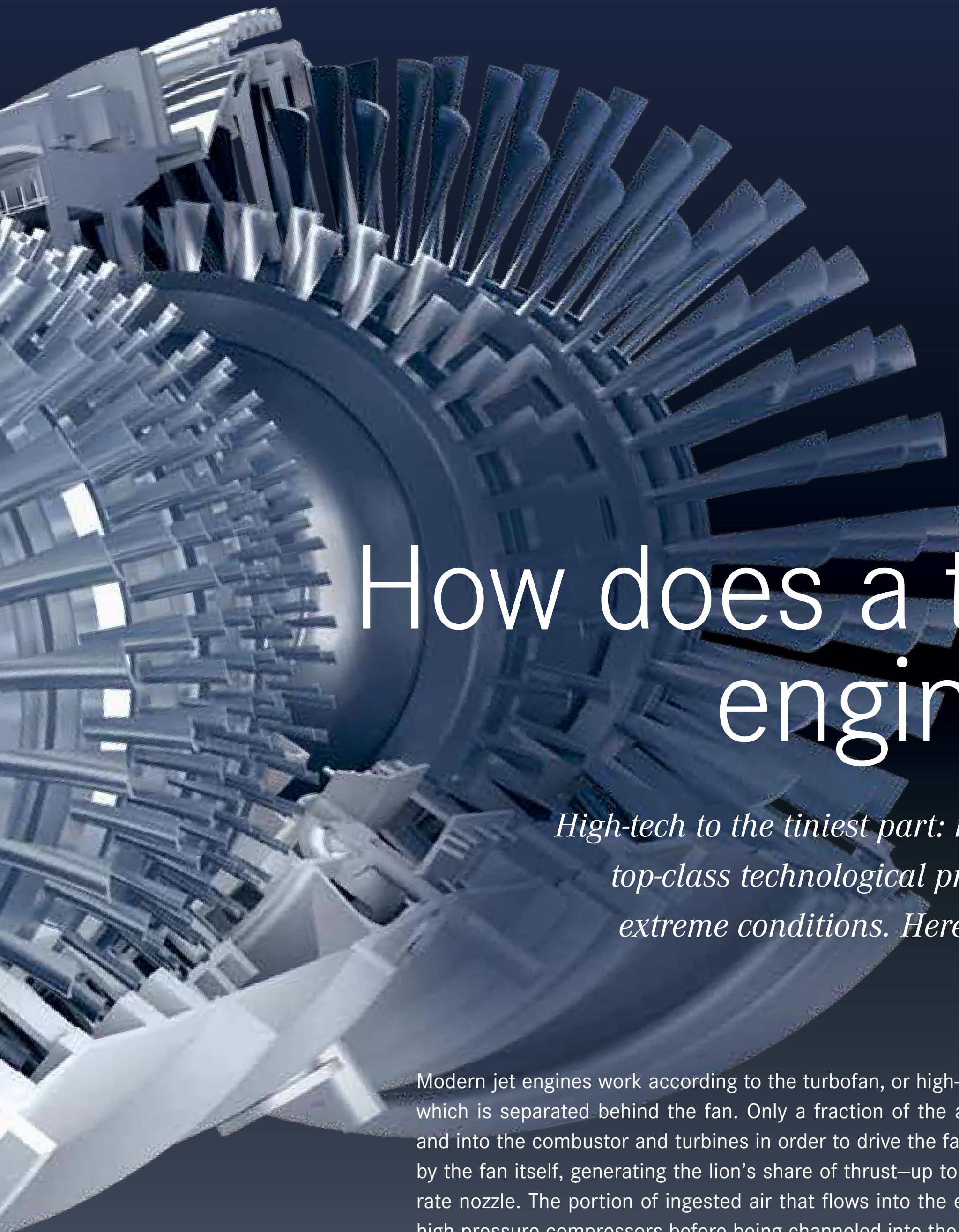
MORE INFORMATION ON THE TOPIC "ASSEMBLY CONCEPT":

Innovative assembly system
for the EME Aero MRO shop
www.aeroreport.de/en

TEXT:

Isabel Henrich studied political science and communications. At MTU, she coordinates the editorial process of **AERO**REPORT and is responsible for the conception and development of its content.





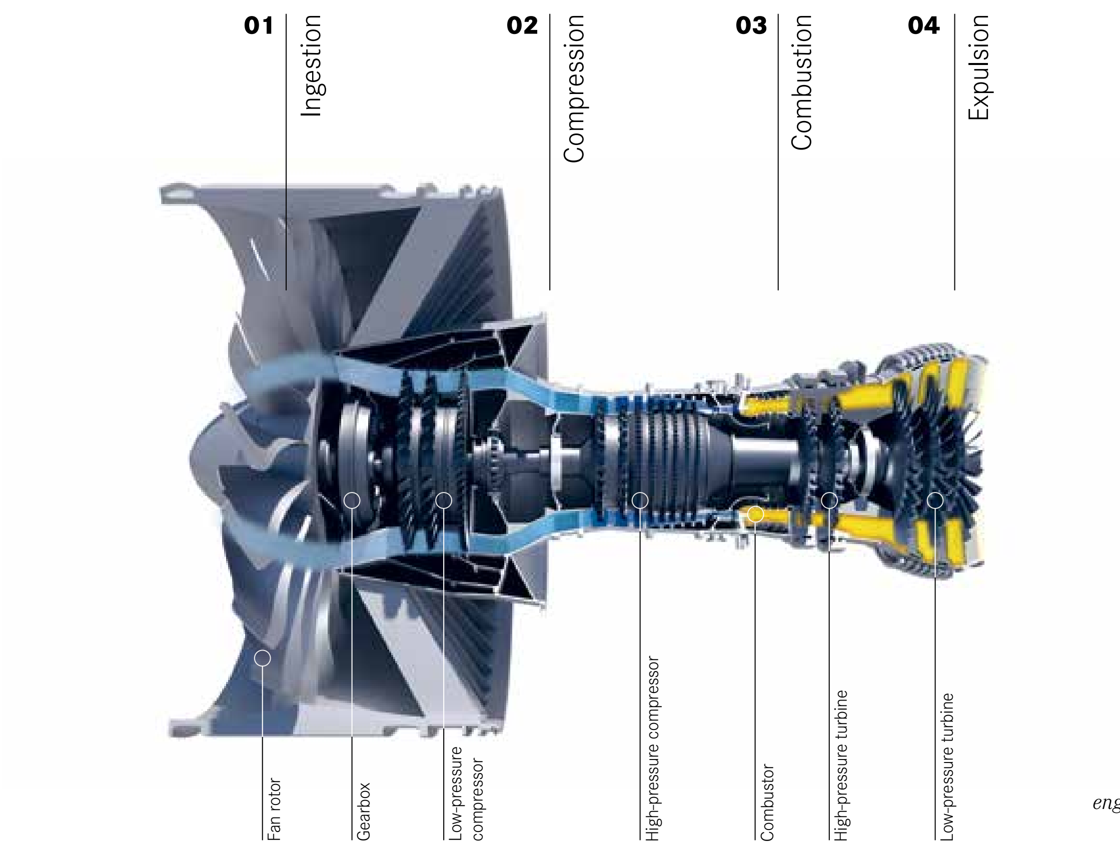
How does a turbofan engine work?

High-tech to the tiniest part: modern aircraft engines are top-class technological products that must withstand extreme conditions. Here we explain how they work.

Text: *Isabel Henrich*

Modern jet engines work according to the turbofan, or high-bypass, principle. The fan rotor ingests air, which is separated behind the fan. Only a fraction of the air passes through the compressor blades and into the combustor and turbines in order to drive the fan. The majority of the air gets compressed by the fan itself, generating the lion's share of thrust—up to 80 percent—at low acceleration in a separate nozzle. The portion of ingested air that flows into the engine core is compressed in the low- and high-pressure compressors before being channeled into the combustor. This is where the fuel is injected, producing a mix of fuel and air that combusts continuously. The buildup of heat causes the gas to expand to several times its original volume. It escapes from the combustor at high energy to race through the high- and low-pressure turbines, causing their blades to rotate. At the same time, this produces the energy required to drive the compressors and the fan. Geared turbofan engines have a special attribute: a reduction gearbox decouples the fan and the low-pressure shaft on which the low-pressure compressor and low-pressure turbine that drives the fan are seated. In this way, each component can run at its optimum speed, which is what makes this engine particularly efficient, quiet and lightweight. Find out more about a geared turbofan engine's individual components on the next page.

DESIGN AND FUNCTION OF A TURBOFAN ENGINE:



Quieter, cleaner, more efficient *The geared turbofan shown here from the successful Pratt & Whitney GTF™ engine family is one of the most advanced turbofan engines on the market today.*

01 Ingestion The fan rotor, the blade wheel at the front, draws in air. While in turbojet engines, all the ingested air flows consecutively through compressors, the combustor and turbines, turbofans separate the accelerated air stream behind the fan rotor. Here, too, a certain amount of air passes through the compressor blades into the combustor. But the rest, known as the sheath flow, is not combusted; instead, it bypasses the interior assemblies and is expanded in a separate nozzle to generate the majority of thrust—up to 80 percent. This cold bypass flow surrounds the hot exhaust gases from the engine core like a sheath, ensuring a reduction in noise emissions.

02 Compression Next, the portion of ingested air that flows into the engine core is compressed in the low- and high-pressure compressors. Also known as a booster, the low-pressure compressor is responsible for precompression. The high-pressure compressor handles main compression and offers a high degree of efficiency and low weight thanks to its innovative blisk principle, where the blades and disk are manufactured as a single part.

03 Combustion After compression, the air flows into the combustor. This is where fuel-injection nozzles create a mix of fuel and air, which is then combusted at a temperature of approximately 1,700 degrees Celsius. The buildup of heat causes the gas to expand to several times its original volume and escape from the combustor at high energy.

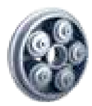
04 Expulsion The hot gas races through the high- and low-pressure turbines, each of which has several turbine wheels and numerous blades that are rotated by the exhaust gas stream. This causes the stream to expend up to 60 percent of its energy to drive the booster, compressor and fan. This happens by way of two concentric shafts—the outer shaft, which couples the high-pressure turbine to the high-pressure compressor, and the inner shaft, which connects the low-pressure turbine to the booster and fan. Only then do the combustion gases leave the thrust nozzle, generating an additional burst of residual thrust.

THE MOST IMPORTANT ENGINE COMPONENTS:

Fan rotor

The fan rotor is the first and very large rotor in the compressor. Its primary task is to accelerate a large mass flow of air in the bypass flow and thus provide the main thrust. The fan is driven by the low-pressure turbine via the low-pressure shaft. In the geared turbofan engine, the fan is optimized for maximum air flow.

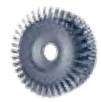
Did you know?
It's always a special sight for the engineers when the fan blades of the Boeing 777 engine GE90 come to MTU Maintenance: these blades measure a full 1.25 meters and weigh 25 kilograms each.



Gearbox

In conventional engines, the low-pressure turbine and the fan sit on one shaft, but in one of the most advanced turbofan engines, the geared turbofan, the gearbox decouples the two components. This lets the components run at their optimum speed: the large-diameter fan slower, and the smaller-proportioned low-pressure compressor and low-pressure turbine considerably faster. The gearbox is a planetary gear train with a reduction ratio of 3:1 or higher.

Did you know?
Pratt & Whitney, MTU and Fiat Avio began their first preliminary studies into a geared turbofan in the 1990s.



Low-pressure compressor

The task of the compressors is to ingest air and compress it before it is fed into the combustor. Advanced engines have both a low-pressure and a high-pressure compressor. Also known as a booster, the low-pressure compressor is responsible for pre-compressing the air. Developing the technology to extend the operating range and manufacturing the blades out of composite materials to reduce the overall weight will deliver further improvements.

Did you know?
The low-pressure compressor of the EJ200, the Eurofighter's engine, is the first compressor with a blisk design ever to go into production. MTU developed linear friction welding at that time specifically for manufacturing the blisks.

High-pressure compressor

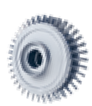
The highly efficient high-pressure compressor handles main compression. What sets an advanced turbofan engine apart is that the blades and disk are manufactured as a single part–known as a "blisk." These high-tech components not only save space and weigh less than conventional rotors with individual blades, but they also provide for better blade aerodynamics. Furthermore, they reduce assembly work and thus costs.

Did you know?
MTU built a specially designed shop for blisk production at its Munich site, where it manufactures up to 5,000 blisks a year.

Combustor

Inside the combustor, the compressed air flowing into the chamber is mixed with fuel, where it burns at a temperature of about 1,700 degrees Celsius. New combustor concepts with lean combustion are being developed to reduce nitrogen oxide emissions; they require advanced cooling concepts.

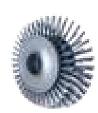
Did you know?
MTU developed a special laser-welding technique for repairing the combustor insert for the T64 engine, which is used, for example, in the Sikorsky CH-53G transport helicopter. This method was then adapted to other engine programs.



High-pressure turbine

In a turbine, the energy contained in the gas flow emerging at high pressure and temperature from the combustor is converted into mechanical energy. The turbine is divided into high pressure and low-pressure sections: the high-pressure turbine drives the high-pressure compressor. Advanced technologies such as new materials, new cooling concepts and air cooling will help to further increase the engine's efficiency in the future.

Did you know?
MTU has been manufacturing high-pressure turbine parts for the GP7000 since the program was launched in 2005. The two-stage design of the high-pressure turbine powering the Airbus A380 mega-liner is based on the GE90 - the engine for the Boeing 777.



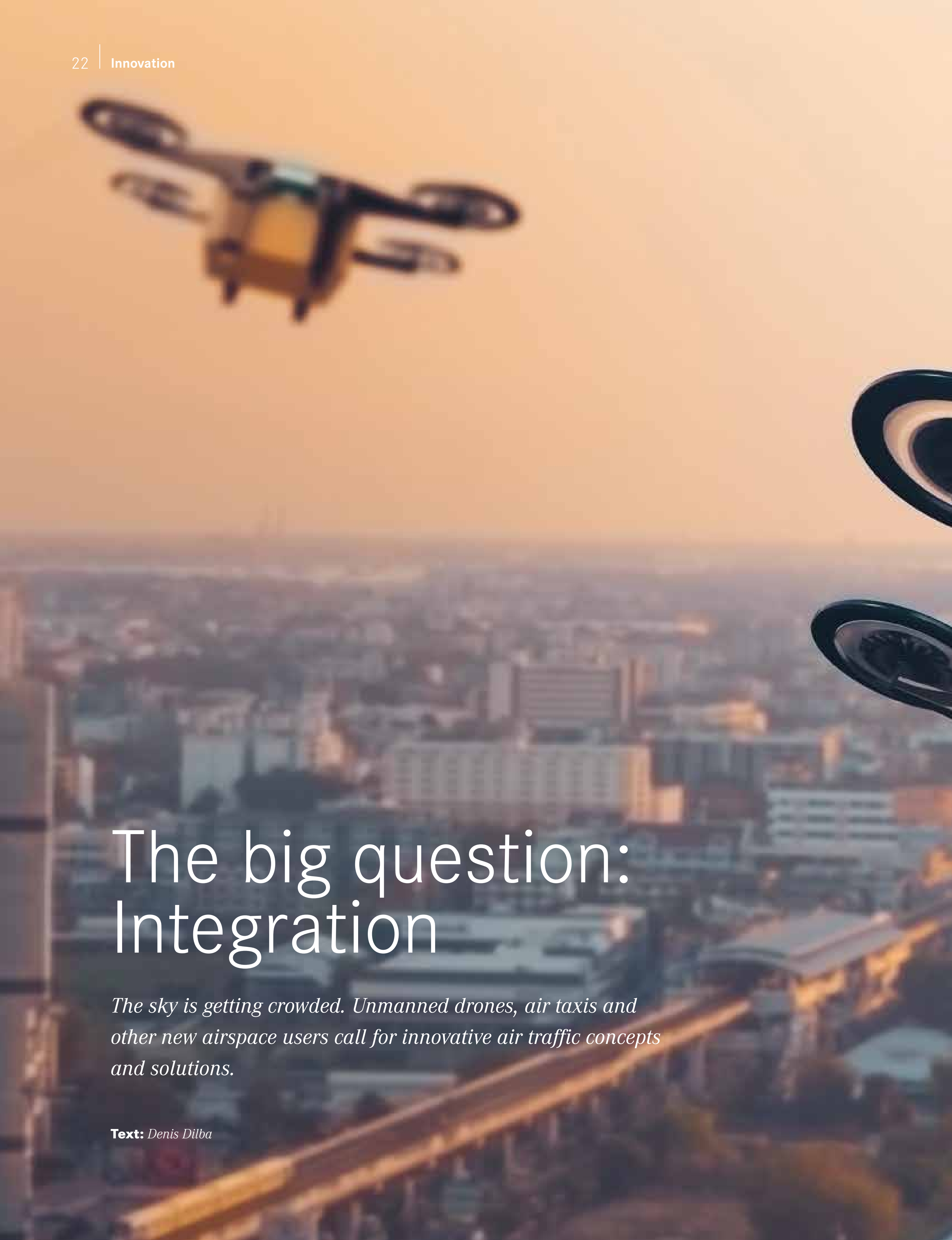
Low-pressure turbine

The low-pressure turbine drives the low-pressure compressor and the fan that in turn generates the bulk of the thrust. The GTF's low-pressure turbine rotates much faster than that of a conventional turbofan engine. This makes it possible to significantly reduce the number of stages and thus the size and weight of the engine.

Did you know?
MTU has won two German innovation awards for the high-speed low-pressure turbine. It is the only company in the world to have mastered this technology in large-scale production.

MORE INFORMATION ON THE TOPIC

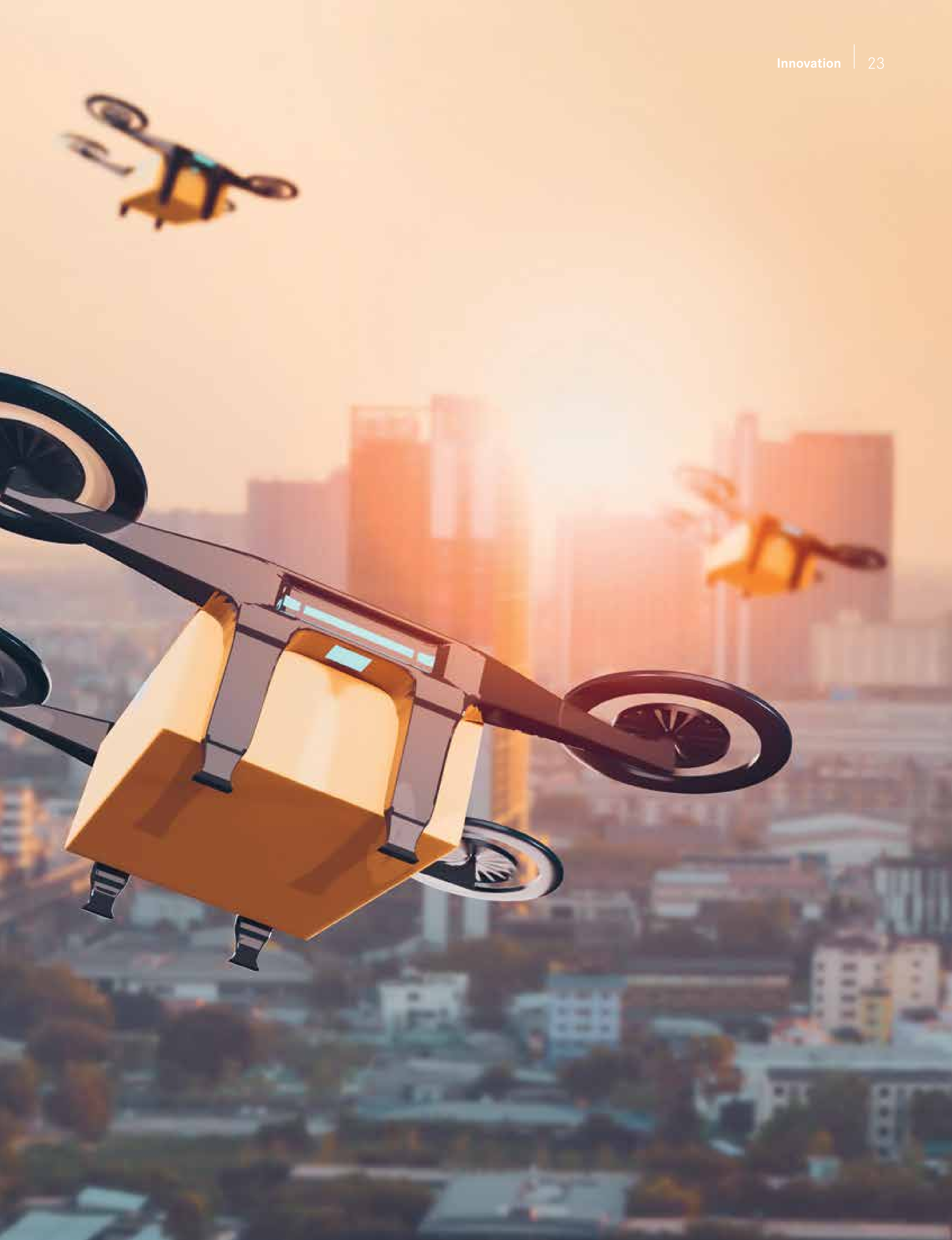
Link to the video: Quieter, cleaner, more efficient. How does a turbofan engine work?
www.aeroreport.de/en



The big question: Integration

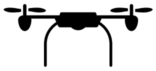
The sky is getting crowded. Unmanned drones, air taxis and other new airspace users call for innovative air traffic concepts and solutions.

Text: *Denis Dilba*



Everything under one roof ___ *Unmanned drones and air taxis must be safely integrated into the airspace in the future. This growth area calls for automated air traffic management.*

Airport no-fly zones ___ *Uncontrolled airspace around airports that is also used by commercial aircraft is off-limits to drones.*



Drone market in Germany up to 2030

Commercial drones:
525%
growth
(≈126,000 drones)

Private drones:
721,000

Total approx.
850,000

Unmanned drones that ferry blood and tissue samples back and forth from one hospital to another or check for damage to bridges and rail tracks with onboard sensor systems. Air taxis to take passengers the last mile from airports directly to their destinations downtown. Large, fully automated freighters with a single pilot. Virtually zero-emission light aircraft with fuel cells or battery-powered propulsion systems at regional airports. And supersonic jets that cross the Atlantic in just three hours. All the above are currently under development, with some prototypes already being field-tested. But it doesn't necessarily follow that this diverse group of new aircraft will be a common sight anytime soon. "Apart from some outstanding issues regarding their commercial viability, one of the biggest obstacles is integrating these new airspace users safely and efficiently," says Dr. Bernd Korn, Head of Department Pilot Assistance at the Institute of Flight Guidance of the German Aerospace Center (DLR) in Braunschweig, Germany.

As far as that goes, unmanned drones and air taxis—the fastest-growing sector—easily pose the greatest challenge. According to a study by the German Unmanned Aviation Association, the commercial drone market in Germany alone is set to increase by 525 percent between 2019 and 2030, totaling some 126,000 drones. At the same time, 721,000 private drones will also be in operation. So it is hardly surprising that Korn considers airspace integration to be a matter of the utmost urgency—and a huge dilemma. "The deployment of unmanned drones and air taxis, and their mode of operation, are strikingly different from traditional aviation," Korn says. "Both fly at significantly lower altitudes than commercial aircraft, while the time between takeoff and landing is much shorter." Just a few thousand unmanned drones and air taxis could add up to several hundred thousand aircraft movements each day. By comparison, Frankfurt Airport recorded 513,912 aircraft movements for the whole of 2019.

Drones and air taxis call for automated air traffic management

The management system used for highly conservative, yet extremely safe, traditional aviation is simply not equipped to deal with this multitude of airspace users. It is based on procedures and processes that were established decades ago. Although they are still highly efficient, as DLR specialist Korn acknowledges, many of them date back to a time when neither the internet nor satellite navigation were available. To this day, radio transmissions are the primary means

Clear regulations ___ *Unmanned drones with a takeoff weight under 25 kilograms are permitted to fly at altitudes of up to 120 meters.*

of communication when managing traditional air traffic movements, with air traffic controllers using them to direct the aircraft and ensure they keep their distance. In principle, then, apart from plenty of nitty-gritty details, integrating the new supersonic jets, light aircraft and fully automatic freighters with a single human pilot into the airspace doesn't pose a significant problem. First, the communication channel is undisputed. Second, the number of aircraft will remain at a manageable level for the time being. In other words, the existing air traffic management system is able to cope. But when it comes to unmanned systems and air taxis, it's a different story.

It would be technically feasible for larger, unmanned drones to convert aircraft movement information to radio signals using text-to-speech software and, vice versa, to understand and process spoken instructions from air traffic controllers. "That means larger drones could be integrated into normal airspace, as long as there aren't too many of them," Korn says. He expects solutions of this kind to become a reality within the next five years. "All the same, it won't be possible to manually handle 100,000 or more flights every day in confined airspace, say over a city, so the process will have to be automated," he insists. The challenge here is not just implementing a new, automated air traffic management system, but also the fact that modern commercial aircraft aren't yet compatible with such a system. To all intents and purposes, a new system will have to work instantaneously for both old and new airspace users. In this regard, it works in the experts' favor that unmanned drones and air taxis fly at low altitude.

They are allowed to operate only in what is known as the uncontrolled airspace, up to an altitude of 2,500 feet (762 meters). That means they will never cross paths with commercial aircraft, whose territory—the controlled airspace—begins above that. Air traffic control ensures the smooth handling of all flights in this airspace. Drones and human pilots in the uncontrolled airspace abide by the rule of "see and avoid," and take responsibility for observing the prescribed minimum distance from other aircraft, obstacles and clouds. Nonetheless, despite being separate from commercial aviation, there is still the dilemma of how to handle the numerous aircraft movements within this discrete airspace automatically in the future. Technology known as a UTM (unmanned air traffic management system) will ensure the safe operation of drones and air taxis. "First and foremost, a UTM must be able to reliably detect all unmanned air vehicle systems and air taxis,"

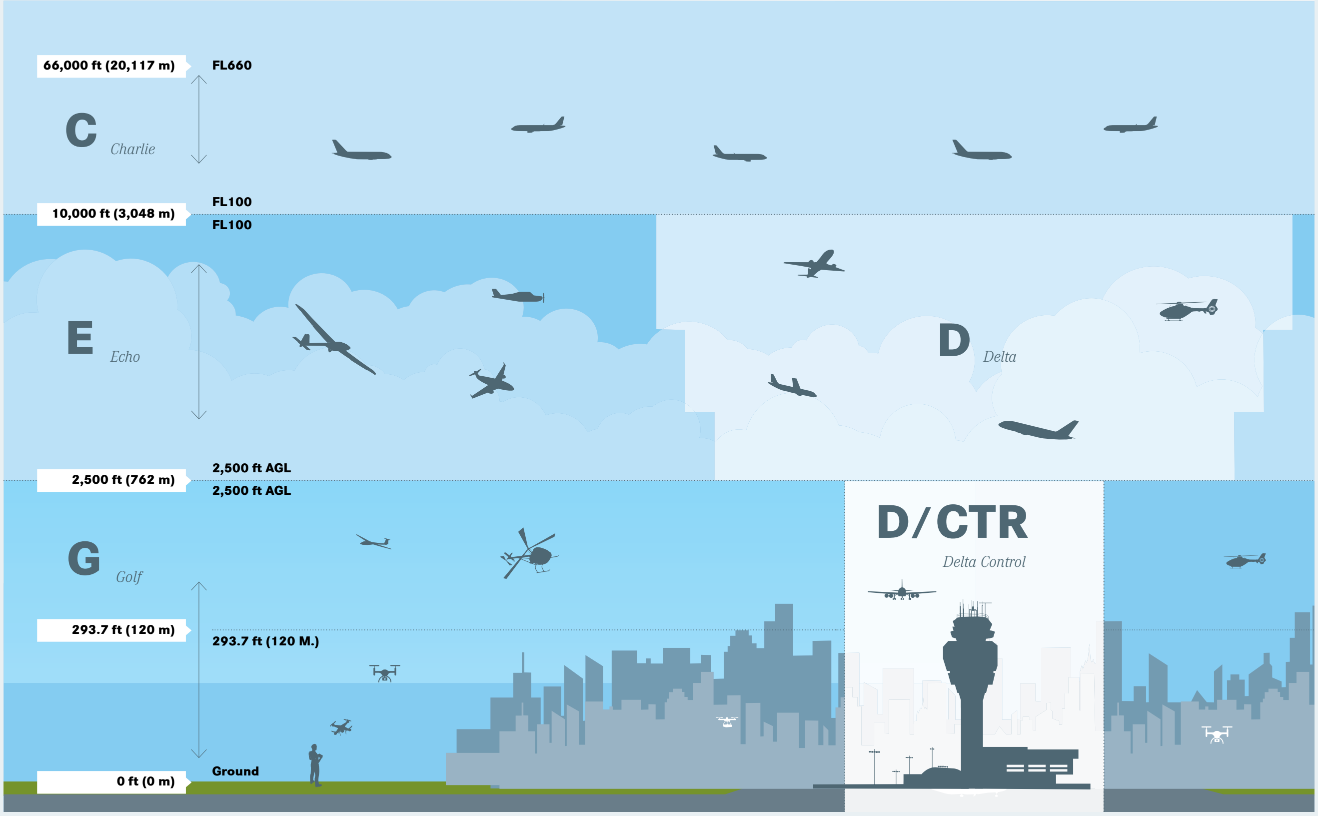
Tight maneuvers ___ *A concept for compact takeoff and landing sites—known as vertidromes—is a development goal for the coming years.*

"All the same, it won't be possible to manually handle 100,000 or more flights every day in confined airspace, say over a city, so the process will have to be automated."

Dr.-Ing. Bernd Korn
Head of Department Pilot Assistance at the Institute of Flight Guidance of the German Aerospace Center (DLR) in Braunschweig, Germany.

Who can fly where

In a typical year, Deutsche Flugsicherung DFS records about 50,000 visual flights and three million commercial aircraft movements over Germany. Unfortunately, complete freedom above the clouds is something that exists only in songs and poetry. To ensure that the growing number of airspace users can all operate safely, clear rules dictate who is allowed to fly in which part of German airspace, and in which conditions.



(simplified depiction)

Up to 120 meters

A rule that came into force at the start of 2021 prohibits unmanned drones with a takeoff weight under 25 kilograms from flying at altitudes above 120 meters. In addition, drone pilots must always fly within their own line of sight. The aviation authorities can issue exemptions upon request.

Class G airspace (Up to 2,500 feet/762 meters)

Class G airspace, which incidentally includes the first 120 meters above ground level, is also referred to as "uncontrolled airspace." Visual flight rules based on "see and avoid" apply, which means pilots must keep clear of clouds and maintain visibility of at least 1.5 kilometers.

Class E airspace (Up to 10,000 feet/3,048 meters)

Air traffic control begins at 762 meters above ground level. For visual flights, the minimum visibility must be 5 kilometers. Air traffic controllers are responsible for staggering the movements of commercial aircraft. A speed limit of 250 knots (463 km/h) applies to all air traffic operating below 3,048 meters.

Class C airspace (Up to 66,000 feet/20,117 meters)

Visual flights are also permitted above 3,048 meters—but only if pilots can see at least 8 kilometers into the distance. As in Class E, they must maintain 1,000 feet (305 meters) vertical separation and 1.5 kilometers lateral separation from the clouds. Entry into Class C airspace is always subject to clearance from air traffic control.

Class D airspace

(Variable altitudes below 10,000 feet/3,048 meters)

To increase safety around airports, the floor of Class C airspace gradually decreases with increasing proximity to the terminal, and the designation eventually changes to Class D. Visibility for visual flights must be at least 5 kilometers in this area; for cloud clearance, the Class C specifications apply.

Class D / CTR

Directly above and around airports, the stricter requirements of Class D apply to flight operations below 762 meters. This control zone is known as Delta control or CTR and is off-limits to drones. Additionally, for aircraft to take off and land safely, the cloud ceiling must not be below 457 meters.

says Angela Kies, Head of Unmanned Aircraft Systems at DFS Deutsche Flugsicherung in Langen, near Frankfurt.

”This provides a complete overview of the situation in the air, allowing for automated, long-range drone operation beyond the line of sight of the drone’s pilot on the ground.“

Angela Kies
Head of Unmanned Aircraft Systems at DFS Deutsche Flugsicherung in Langen, near Frankfurt

UTM systems for drones will also change the face of traditional aviation

Developments in air traffic control can do all that and more besides. Weighing in at just 35 grams, an LTE mobile communications transponder developed by Droniq GmbH, a joint venture between DFS and Deutsche Telekom, is mounted on the aircraft. Via the cellular network, this hook-on device transmits the aircraft’s tracking data to the DFS UTM, which also supplies further data on the position of manned aircraft. “This provides a complete overview of the situation in the air, allowing for automated, long-range drone operation beyond the line of sight of the drone’s pilot on the ground,” says drone expert Kies. Approved beyond-visual-line-of-sight flight in particular paves the way for countless potential practical and commercial uses for drones, and thus forms the basis for their cost-effective operation. “The Droniq system has already provided convincing proof of its practical benefits in DLR projects such as City-ATM (air traffic management),” says DLR expert Korn.

Having said that, he adds, it still needs a great deal of development before it can guarantee the smooth operation of unmanned systems. Projects like City-ATM and the recently launched HorizonUAM (urban air mobility), which carry out practical tests with drones and air taxi models to identify and subsequently eliminate weak spots in technical interactions, are therefore crucial, says Korn’s colleague at DLR, Dr. Bianca Schuchardt, manager of the HorizonUAM project. “An integral part of air traffic management for unmanned drones and air taxis is a concept for a compact takeoff and landing site; these vertidromes are one of our development goals in HorizonUAM for the next three years.” Korn is confident that, in the medium to long term, UTM systems for drones will also change the face of aviation as we know it.

“In my view, the excellent results that we’re sure to obtain with an automated traffic system for drones and air taxis over the next five years will also lead to a boom in automation technology for traditional airspace users,” Korn says. He predicts that ATM for traditional aviation and the UTM systems for drones and air taxis will merge in the long term into a combined automated air traffic management system.

DRONIQ

Many applications *The unmanned air traffic management (UTM) system is paving the way for drones to fly beyond the pilot’s line of sight.*

HorizonUAM

HorizonUAM *One thing that this German Aerospace Center project is researching is the feasibility of unmanned systems.*

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.

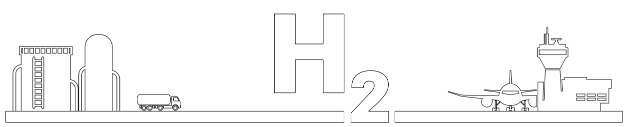
MORE INFORMATION ON THE TOPIC “AIR TAXI”:

Air taxis: A wide range of concepts are on approach
www.aeroreport.de/en

Won’t work without it

Emissions-free flight with hydrogen—for this vision to become reality, alongside development of the fuel cell, we also need to promote the building of hydrogen infrastructure.

Text: *Denis Dilba*



Standing at almost 150 meters tall and with a base of 230 by 230 meters, the Great Pyramid of Giza is not one of the Seven Wonders of the Ancient World for nothing. You would need just under three structures of this size to store around ten million metric tons of kerosene. In the years before the coronavirus pandemic, this was the amount of kerosene that was used for refueling at German airports every year. In a fictional future in which aircraft engines run exclusively on hydrogen, it would take nine of the pyramids to hold all the fuel. In fact, it is very likely that much more space would be needed, as hydrogen storage facilities are supposed to be double-walled with a vacuum in the cavity between them: the hydrogen needs to be kept in a liquid state at minus 253 degrees Celsius. However, storing the liquid hydrogen is just one challenge. The cryogenic fuel of the future would still need to be transported to the airports and then pumped into the aircraft fuel tanks.

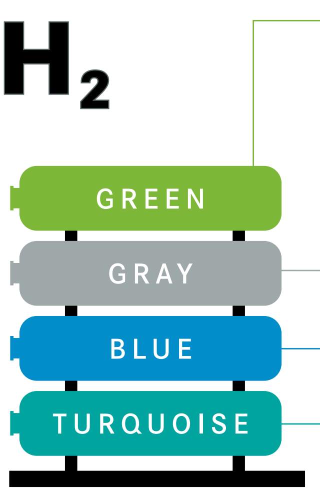
> *“Aviation’s demand for hydrogen will be small at the beginning and increase gradually.”*
>
> **Barnaby Law,**
> *Chief Engineer Flying Fuel Cell at MTU Aero Engines*

“Luckily, we won’t need such volumes overnight. Aviation’s demand for hydrogen will be small at the beginning and increase gradually,” says Barnaby Law, Chief Engineer Flying Fuel Cell at MTU Aero Engines. And as far as we can tell today, not every aircraft that takes off in 2050 will have liquid hydrogen in its tank, Law says. For long-haul flights, the tanks would simply be too large. In order to get commercial aircraft with climate-friendly hydrogen propulsion into our skies, building up a suitable infrastructure is at least as important as developing the flying fuel cell and cryotanks and integrating these two components into aircraft. After all, even a hydrogen-powered zero-emission aircraft is rather useless if it can’t be refueled. Although the industry doesn’t expect the first hydrogen aircraft to be with us before 2035, work has already begun on building the infrastructure.

From blue to green hydrogen

“First of all, the hydrogen needs to be produced in sufficient quantities,” Law says. And ideally it should be green—as only when hydrogen is manufactured by electrolysis with CO_2-free “green” electricity generated from wind, solar or other renewables does it also cut overall CO_2 emissions almost completely. “Green hydrogen is naturally the goal,” Law says, “but to allow only hydrogen produced using renewables at the beginning would ignore intractable global realities.” By no means all countries are in a good position to produce renewable power or have the money to import large quantities of green hydrogen, Law notes, adding that some countries possess large reserves of natural gas. “If these

All the colors of hydrogen explained



Green hydrogen *is produced by the electrolysis of water in a process that uses only renewable energy. Regardless of the electrolysis technology chosen, as long as 100 percent of the power used comes from renewable sources, the production of hydrogen is carbon-free.*

Gray hydrogen *is derived from fossil fuels. It is normally produced by adding heat to natural gas, which separates the latter into hydrogen and CO_2 (steam reforming). The CO_2 is subsequently released unused into the atmosphere, contributing to the global greenhouse effect. Every metric ton of hydrogen produced in this way generates around 10 metric tons of CO_2.*

Blue hydrogen *is the same as gray hydrogen, but a technique called carbon capture and storage (CCS) is used to catch and sequester the CO_2 produced. This way, the CO_2 generated in the process is not released into the atmosphere and hydrogen production can be considered carbon-neutral on the balance sheet.*

Turquoise hydrogen *is hydrogen obtained by the thermal decomposition of methane using a method called methane pyrolysis. This generates solid carbon rather than CO_2. Heat from renewable energy sources for the high-temperature reactor and continuous carbon sequestration are prerequisites for making the process carbon-neutral.*

Source: German Federal Ministry of Education and Research

countries don't participate because it's cheaper for them to continue with kerosene made from fossil fuels while at the same time neglecting to invest in building up a hydrogen industry and the corresponding logistics chains, then not only will we have squandered a lot of potential for reducing CO_2 emissions, but we will have also reinforced these countries' dependency on fossil fuels."

In Law's view, this is why what is known as blue hydrogen should also be considered for use in air transport at the outset. Blue hydrogen starts out as "gray" hydrogen, which is produced from conventional natural gas. The difference is that with blue hydrogen, the CO_2 emissions generated during production are captured, and not released into the atmosphere, in a process known as carbon capture and storage (CCS), Law explains. For a transition phase on the road to 100 percent green hydrogen, he finds this solution acceptable and sensible: "Compared to kerosene from fossil fuels, with blue hydrogen less CO_2 escapes directly into the atmosphere, where it is much harder to control than if it's compressed in a storage facility on the ground." Moreover, the proportion of blue hydrogen will decrease sharply in the medium to long term, since green hydrogen will become increasingly more cost-effective as production rises. There are also other very interesting "blue alternatives" such as hydrogen produced through methane (natural gas) pyrolysis, whereby carbon is co-produced in solid form and not as gaseous CO_2.

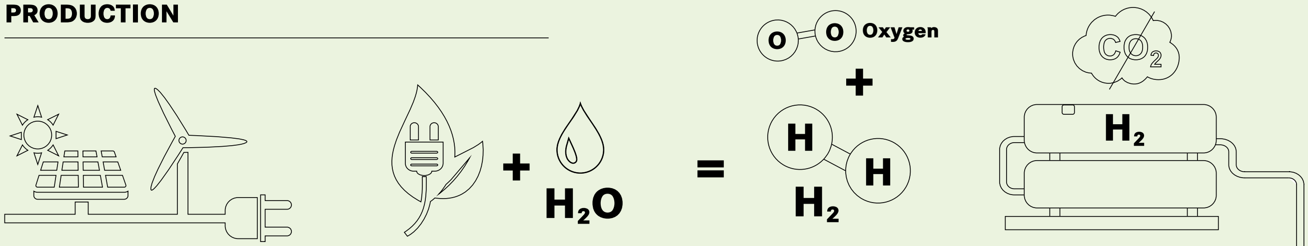
Airports need hydrogen in liquid form

According to a recent McKinsey study, in some regions of the world it will be possible to produce green hydrogen at prices that are competitive with gray and blue hydrogen by as early as 2030. The price of green hydrogen is determined first and foremost by the conditions at the production location: "A lot of wind and a lot of sun get more out of the electrolyzers and so increase cost-effectiveness," explains Dr. Valentin Batteiger, Head of Alternative Fuels at the Munich-based Bauhaus Luftfahrt aviation research institution. As to getting the hydrogen to airports, meanwhile, the nature of the logistics chain depends on the local circumstances at the respective airport. Batteiger cites the example of Frankfurt Airport, where liquid hydrogen would most probably be transported on inland waterways to the nearest port on the river Main, with trucks transporting it from there to the airport in the initial phase up to 2050. Subsequently, as demand for hydrogen increases, a liquid hydrogen pipeline will most likely become economically viable, Law says. Fundamentally, though, he thinks logistics chains would not have to change very much. In other places, rail transport offers an attractive alternative.

Irrespective of the mode of transport, however, the hydrogen will generally be delivered to airports in cryogenic liquid form in cryotanks—because the hydrogen is needed there in liquid form and also because in its gaseous form hydrogen takes up too much volume. Transporting high-pressure hydrogen gas by

The hydrogen journey

PRODUCTION



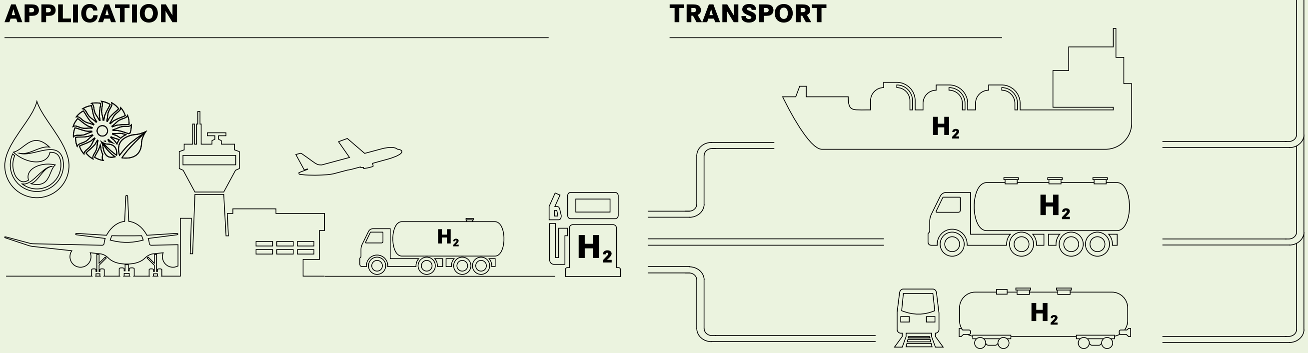
Green power production
Wind, photovoltaics and other renewables are sources of green power.

Electrolysis
In the electrolysis plant, an electric current is passed through the water to break it down into hydrogen and oxygen.

Green hydrogen
One hundred percent of the power used comes from renewable sources, which means the production of hydrogen is free of carbon dioxide.

APPLICATION

TRANSPORT



New propulsion systems
Whether for sustainable alternative fuels, for carbon-free combustion in the gas turbine, or for zero-emission conversion into electricity in the flying fuel cell to power electric propulsion—the aviation industry has high hopes for hydrogen.

Hydrogen distribution
For the hydrogen to be used as fuel, it must be transported from the electrolysis plant to the consumer.

road would likely take at least ten times more trucks. “Hydrogen liquefaction facilities are generally situated right at the hydrogen production site, as they need a large throughput in order to work cost-effectively, and they can be run there on cheap renewable power.” Returning to the example of Frankfurt Airport, there will be a big liquid hydrogen tank either directly at the port on the river Main or on the grounds of the airport itself. “Where such interim storage facilities are located, and how large they are, depends on many factors,” Batteiger says, “but often the space available at the airport will determine the decision.” At Hamburg Airport, to take another example, Jan Eike Blohme-Hardegen, Deputy Head of the airport’s Environment department, is already planning a hydrogen storage facility for the period after 2040: “From the initial idea through to completion, that’s very much a common timeframe.”

Reaching cost-effectiveness more quickly with higher hydrogen consumption

That being so, airports across Germany are already engaging with the subject of hydrogen fuel today. “With a hydrogen tank that is three—really closer to four—times the size of the current kerosene tank, we’re coming up against the limits of what’s feasible at our site,” Blohme-Hardegen says. That’s why he’s looking for alternatives, such as a pipeline: “We’re keen to be integrated into the hydrogen supply network, which in the coming decades will also reach the north of Hamburg.” This would mean that the hydrogen storage facility at Hamburg Airport can be smaller, as the hydrogen will be transported to the airport as a gas. Over the next few years there are already plans to build a smaller demonstrator tank with a test liquefaction facility, Blohme-Hardegen says. Hamburg Airport wants to use the boil-off gas—the gaseous phase that forms as a result of heating the liquid hydrogen in the tank—to run a portion of its fuel-cell airfield vehicles with zero emissions.

Increasing hydrogen consumption at the airport in this way makes a lot of sense, Law says. “The more hydrogen that is consumed, the faster the investments in the infrastructure will pay off.” In addition to airfield vehicles, there are also taxi and rental-car fleets and buses that could at least partially be run on hydrogen. Essentially, though, the investments will have to be amortized through the sale of hydrogen, Law says: “If you consume more than 400 kilograms of green hydrogen per day, then it already pays for itself.” This makes hydrogen a viable prospect even for smaller regional airports. As at larger airports, the procedures for refueling aircraft with hydrogen would hardly change, says Markus Bachmeier, Director Sales & Products at the gas specialist Linde: “Trucks with cryotanks will drive the hydrogen to the aircraft. Similarly to how it already works with hydrogen cars today, a hose is then connected to the tank.” The refueling process itself then takes—depending on the size of the aircraft—about the same amount of time as with kerosene.

Gulf region can be hub for hydrogen air traffic

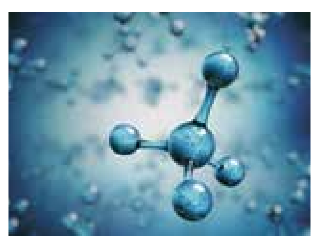
“It’s important to ensure that the same standards for the technology apply worldwide,” Bachmeier says. This is a precondition for being able to fully utilize the predicted range of the fuel cell aircraft of almost 4,600 kilometers and to refuel again at the destination airport. This would allow the aircraft to fly emissions-free from Munich to Dubai and back again in the future, Bachmeier says. Windy and sunny locations, of which there are many in the Gulf region, will be hubs for hydrogen air traffic, in the opinion of the Bauhaus Luftfahrt researcher Batteiger: “Since the local conditions are ideal for solar power plants, the production of green hydrogen can be set up directly beside the airport, which makes for cheaper, easier logistics.”

VARIOUS APPROACHES: HOW HYDROGEN GETS TO THE AIRPORT

Liquid organic hydrogen carriers ——— *The gas is chemically bonded to a special oil. This way, the hydrogen can be transported in tanker trucks. At the site where it will be used, it is released from the oil again by inputting energy.*

Pipeline ——— *Hydrogen pipelines offer continuous supply. They transport hydrogen in gaseous form. This means liquefaction plants must be built at airports, as aircraft refuel the hydrogen in liquid form.*

Fraunhofer “Powerpaste” ——— *Hydrogen is stored in highly concentrated form in a viscous paste. This paste is easy to transport; mixing it with water releases the hydrogen as a gas.*



Bonded in ammonia ——— *Hydrogen is converted into the chemical compound ammonia, then transported via existing infrastructure to the airport, where the compound is converted back into hydrogen.*

Pressure and cryogenic tanks ——— *In pressure tanks, gas cylinders are bundled together in a protective frame and transported under pressure. Cryotanks transport hydrogen as a liquid at below minus 253 degrees Celsius.*

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.

MORE INFORMATION ON THE TOPIC “HYDROGEN”:

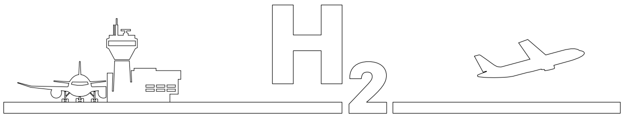
New propulsion systems: Hydrogen is the future
www.aeroreport.de/en

Integrating hydrogen propulsion into aircraft
www.aeroreport.de/en

Less is more

Fuel cells and engines that burn hydrogen produce water vapor that can form contrails. MTU Aero Engines is already working on minimizing the possible climate effects.

Text: *Denis Dilba*



A lack of water vapor in the atmosphere would make life on Earth extremely unpleasant. As the greatest contributor to the natural greenhouse gas effect, water vapor plays a key role in maintaining the average temperature of our planet at around 15 degrees Celsius—and not at freezing point or below. Without it in the Earth's atmosphere, there would be no clouds or rain. In other words, water vapor is critical to enabling life as we know it. However, if water vapor enters the atmosphere through aircraft engines rather than through natural evaporation from rivers, lakes and oceans, it contributes to anthropogenic global warming in the same way that carbon dioxide (CO_2) does—especially if it forms long-lasting contrail cirrus clouds at high altitudes. Scientists still do not fully understand this phenomenon or the climate effect caused by nitrogen oxides, and research into the complex processes that take place in the atmosphere continues to this day.

In the past, aviation goals have focused on minimizing the direct impact of CO_2, an area in which the industry has indeed made great strides: between 1990 and 2019 alone, the average fuel consumption of Germany's passenger aircraft fleet, and by extension its CO_2 emissions, was reduced by 43 percent—thanks in part to more efficient engines. Over the past two decades, however, countless research findings have painted an ever-clearer picture: CO_2 is only one aspect of aviation's impact on the climate. "On a global scale, we can now say that about one-third of air transport's climate impact is attributable to carbon dioxide emissions and about two-thirds to the formation of persistent contrails, nitrogen oxides and other aerosols," says Reinhard Herbener from the German Environment Agency (UBA) in Dessau-Roßlau, who is an expert on air transport's climate impact.

The new goal: Reduce all factors that impact climate

Published in September 2020, the most comprehensive study to date on aviation's climate impact confirms and clarifies these findings. It is the first time that researchers have also accounted for the impact of spatially inhomogeneous effects in their calculations. These include the occurrence and effect of contrail cirrus clouds, which have a different distribution around the world depending on the air traffic and weather conditions. "Generated by water vapor emissions, these clouds can have either a warming or a cooling effect on the Earth's temperature," says Professor Robert Sausen of the Institute of Atmospheric Physics at the Ger-

"We have to pull out all the stops to reduce our climate footprint, period. That of course applies to conventional engines, too. A variant of the GTF engine that offers even greater fuel efficiency has been in the works for quite some time."

Fabian Donus, *Innovation manager at MTU*

Fabian Donus
Innovation manager at MTU

Dominik Wirth
Expert in advanced propulsion systems at MTU

“From a technical perspective, we believe the effort involved in retrofitting current engines to work with hydrogen will be moderate.”

Dominik Wirth,
Expert in advanced propulsion systems at MTU

man Aerospace Center (DLR) in Oberpfaffenhofen. The study was able to quantify their climate impact with greater precision than previous research. “We found that contrail cirrus clouds are less than half as damaging to the environment as previous estimates suggest. Nonetheless, they are still aviation’s greatest contributor to global warming,” Sausen says.

MTU Aero Engines, too, has been following all the recent developments in the scientific findings, says Fabian Donus, Innovation manager at MTU: “We’ve been working for quite some time to incorporate the new insights into our climate targets and technology developments.” One approach Donus and his colleagues are taking is to re-examine today’s engines from this new perspective to find the best solution overall for minimizing factors that affect the climate. That’s because even modern engines are capable of generating persistent contrails under certain environmental conditions: when kerosene is burned, water vapor is the second main product of the reaction after CO_2. Another major focus for MTU’s engineers is the climate impact of next-generation, hydrogen-based engines, as these are still not 100% climate friendly. Because even though the two solutions in focus—modified engines that burn energy-rich hydrogen directly and fuel cells that use it to power electric propulsion systems—no longer generate CO_2 emissions, they do still produce water vapor.

Direct hydrogen combustion

The technology for direct hydrogen combustion could be ready somewhat sooner and pave the way for the flying fuel cell, which MTU estimates might take off as early as 2035. “From a technical perspective, we believe the effort involved in retrofitting current engines to work with hydrogen will be moderate,” says Dominik Wirth, an expert in advanced propulsion systems at MTU. Burning hydrogen produces water vapor and nitrogen oxides as the only emissions. “We’re currently conducting an elaborate study to determine what climate impact this will have and how it will compare with the impact from conventional engines and the fuel cell,” Wirth explains. What we can be certain about, he says, is that hydrogen combustion produces more water vapor than conventional fuels do—but that’s not necessarily a bad thing: “The vast majority of contrails evaporate again just a few hundred meters behind the aircraft and are completely irrelevant in terms of their climate impact.”

In the opinion of UBA expert Herbener, hydrogen combustion offers the advantage that it produces significantly fewer aerosols than conventional engines. “It doesn’t emit any sulfur or soot, which can become condensation nuclei and stimulate cloud formation.” While this cleaner form of combustion is certainly advantageous, it does not prevent the resulting water vapor emissions from condensing, since natural aerosols such as dust particles or organic molecules are also present in the atmosphere and act as cloud seeds. For that reason, Wirth and his team are also investigating how to minimize the climate impact of persistent contrails—quite a challenge given the countless parameters involved. According to Wirth, these include the size and number of ice crystals that form around the condensation nuclei, the solar radiation and the brightness of the backdrop. However, he believes that deeper knowledge of the processes behind cloud formation could hold the key to reducing the effect that contrails have on the climate.

Barnaby Law
Chief Engineer Flying Fuel Cell at MTU

Flying fuel cell

With the exception of water vapor, fuel cells will be emissions-free. "And because operating processes in fuel cells use much lower temperatures than those involved with hydrogen combustion, they emit more water in liquid form," explains Barnaby Law, Chief Engineer Flying Fuel Cell at MTU. That's why propulsion systems based on fuel cells don't generate any nitrogen oxides either, as these start to form only at temperatures of 1,300 to 1,400 degrees Celsius and above. One aspect Law and his colleagues are working on is how to recirculate a certain amount of the water produced back into the fuel cell. "The system needs a certain amount of moisture, which you don't get at high altitudes," he explains. As a way to further minimize the fuel cell's climate impact, Law plans to alter the emitted water as required: "We can produce large or small water droplets or even draw liquid water out of the system as a small trickle."

But as is the case with hydrogen combustion, he explains, the first step is to refine our understanding of how various factors—such as the size and distribution of the droplets, different temperatures, and altitude—interact and what impact this has on the environment. "It might even be possible to design the fuel cell to emit no harmful water content at all," Law says. Time will tell if that will work or not, he adds, "but what we do know is that we have some scope to influence water emissions." Other methods can be employed alongside these technical solutions to minimize the potential effects of water vapor. Sausen from the DLR is confident it will be possible to plan climate-friendly flight routes for hydrogen engines in the same way as for conventional engines. "We have to pull out all the stops to reduce our climate footprint, period." Donus says. "That of course applies to conventional engines, too. A variant of the GTF engine that offers even greater fuel efficiency has been in the works for quite some time."

"It might even be possible to design the fuel cell to emit no harmful water content at all."

Barnaby Law,
Chief Engineer Flying Fuel Cell at MTU

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.

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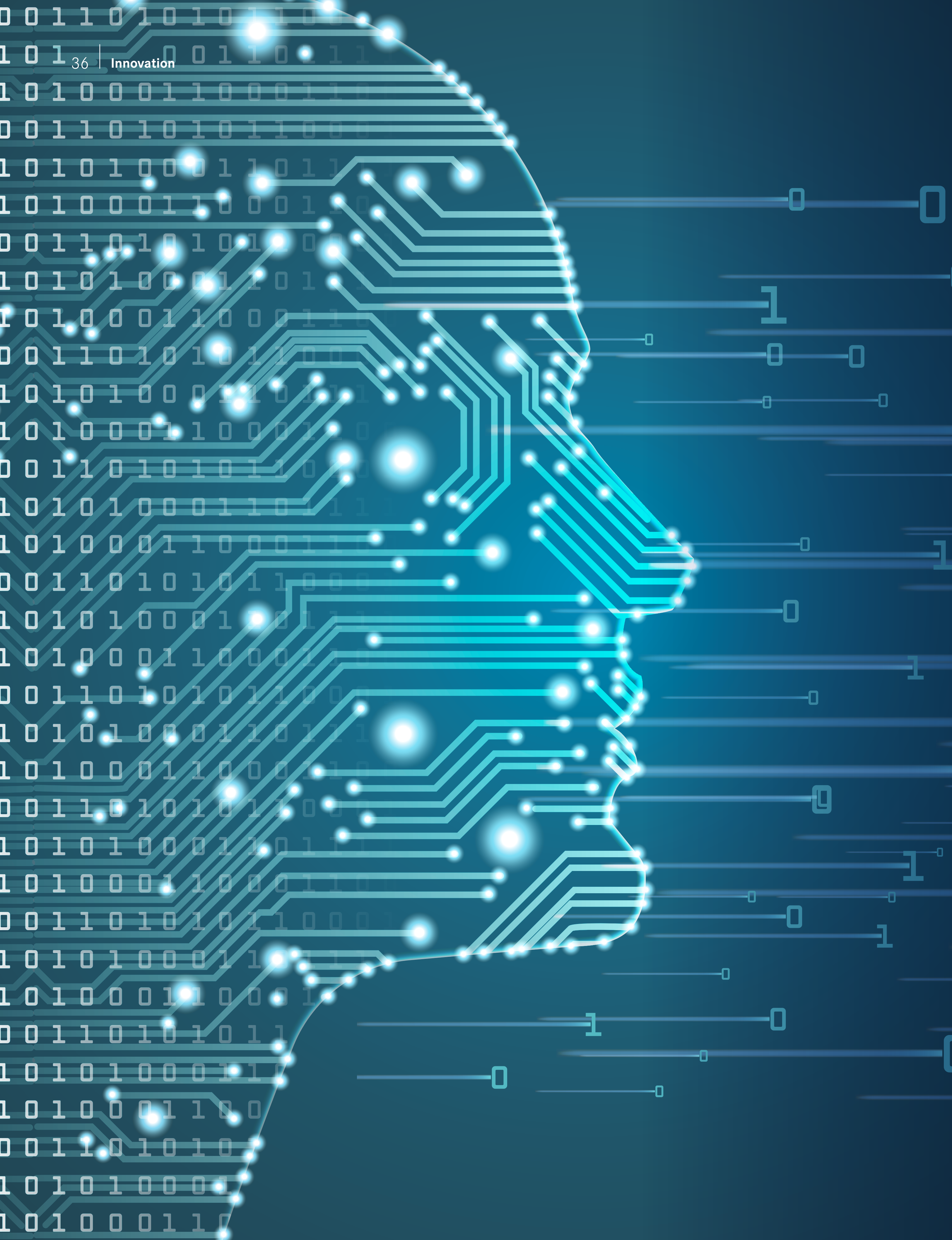


On a digital mission

MTU is turbocharging digitalization: AI, big data and algorithms propel the engine business to the next level. What's powering them? A host of IT projects right across the company.

Text: *Thorsten Rienth*

Things change, and when it comes to IT, there's nothing quite like a trip down memory lane to remind us of that. Not so long ago, the primary purpose of information technology was to serve corporate infrastructure. If someone needed a new screen, the IT specialists would see to it. If a new network was required, organizing it was a job for IT.

Now, just a few years down the line, IT plays a fundamental role in shaping the company as the key driver of its digital transformation. The aviation industry exemplifies how big data and artificial intelligence (AI) can pave the way for new levels of automation in production, for more efficient development and manufacturing processes, and for cost-effective and bespoke service solutions—to name just a few examples.

MTU Aero Engines is seizing the opportunities that big data, AI and heuristics offer across the entire company. Whether from the production line, the test stand or maintenance, all the information MTU gathers from the world of operations is incorporated into its development of new engines—making them even more robust and, above all, more efficient.

Some years ago, Germany's leading engine manufacturer launched a comprehensive digital transformation program. Now, the company is reaping the benefits from all the digitalization projects it set up across the company. But unlike product developers, digital experts drive their companies forward in unseen ways. Initially, their work is visible only as bits and bytes on a screen or behind the scenes, where data analysis, self-learning algorithms and AI are ushering in a new era in engine development. In other words, anywhere that the digital and real worlds come together.

Join us on our digital mission.

Digital masterminds: Five selected projects that are driving forward digitalization at MTU.

"I've been working with big data and data analytics for a very long time: first in my business informatics studies, then in IT consulting, and now at MTU. The entire field of big data has undergone a tremendous change. It wasn't all that long ago when its focus was primarily on administrative processes. Now its focus is very much right on the product. That's exactly what makes my job at MTU so thrilling: I can influence product quality very directly through my work."

Dr. Sonja Hecht, *IT expert at MTU Aero Engines*

"We data engineers act as interfaces between the IT infrastructure team, the technical departments and the data scientists in the company. To carry out this function properly, we need to have some understanding of the work of these other roles. When I started at MTU a little over a year ago, I first read up on low-pressure turbines and their manufacturing processes. Big data projects are always interdisciplinary projects, which I find extremely exciting."

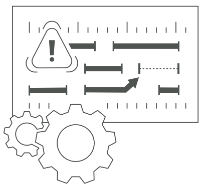
Dr. Galina Baader, *IT expert at MTU Aero Engines*

"Artificial intelligence has fascinated me since I first heard about it. But it is not an end in itself. The challenge for us AI developers is to tailor it to specific use cases and provide a user-friendly front end. This is the only way we can also directly support colleagues who will later work with the software."

Thomas Piprek,
Specialist in PLM (product lifecycle management) data exchange at MTU Aero Engines

Making the invisible visible
Big data is pushing storage capacity to the limit. MTU's IT experts Dr. Galina Baader and Dr. Sonja Hecht are working on a solution for the engine business.

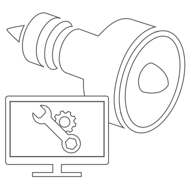
Searching documents using artificial intelligence
MTU is also making use of AI beyond the traditional engine manufacturing business; for example, in the classification of documents.



Mastermind for MTU production
MTU currently uses a great many different systems to manage its production activities. The time has come for a unified manufacturing execution system (MES).

"I was working for MTU back when I wrote my degree thesis, which was on simulated pull control. I went on to hold various supply chain positions, both at MTU Aero Engines Polska and here in Munich. Now I'm in charge of the IT side of the MES rollout, so it's all coming together nicely for me. What I find most exciting about the MES project is how much I'm learning. I'm gaining real insights into all our areas of production. In return, I can give them a specific idea of how the IT will benefit their applications and together we can craft a vision for the future."

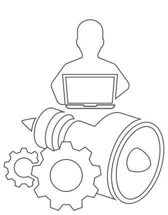
Ralf Teufel, *Senior Consultant IT Manufacturing, Logistics & Quality at MTU Aero Engines.*



Predicting the future
In the future, MTU will use artificial intelligence and heuristics to enable airlines to make more reliable engine maintenance forecasts.

"The path to APC 2.0 is a challenge of the first order in terms of complexity: data science models, expert knowledge, artificial intelligence, algorithms—and a project setup that spans numerous MRO sites and functionalities. As with all major digitalization projects, we mustn't underestimate the degree of culture change involved. At the end of the day, expert knowledge is being passed to a machine here. That makes winning the experts' trust and getting them motivated for the project another challenge to overcome. It calls for everyone to be willing to embrace change. I'm thrilled at how quickly our colleagues can adapt to new software and programming languages."

Claus Bullenkamp,
Senior Manager Engine Programs at MTU Maintenance Hannover



Hub for engine test data
MTU engine developers are getting a new test data management system that gives them access to all of MTU's test data worldwide in just minutes.

"What brought me to MTU was an EU research project I worked on while completing my studies in 3D metal printing at TU Munich; the project's outcome is now in productive use at MTU. That means MDM2020 is already the second project I've worked on where I don't just program software, but also see every day how it connects directly to technical applications. I really enjoy the in-depth communication with the users in the department and finding solutions together in an atmosphere of trust."

Dr. Fabian Bayerlein, *IT project manager and developer at MTU Aero Engines*

Making the invisible visible

To make machine data more useful, data analysts must put gigantic amounts of data into context. This calls for a completely new kind of storage.

If you wanted to illustrate the abstract concept of data overload, you could use a common milling machine of the kind that MTU Aero Engines in Munich operates to manufacture, say, the blisks used in engine compressors. With a frequency of 250 hertz, i.e. 250 times a second, the machine's sensors pick up about 70 different signals: torque, temperature, axis positions or values for cooling lubricant quality. A complex component can keep the milling machine busy for ten hours, easily. This means the resulting data set has over ten million rows—for just this one work step.

Even advanced databases have limits

However, to be able to extract relevant information from this raw data later on and derive knowledge and an understanding of products and processes from it, ten hours of data recordings aren't enough. If unknown patterns and relationships between different variables are to come to light, the requirement for machine operation data quickly expands to a complete year. Millions of rows become billions of rows. Yet at some point, even advanced databases reach their limits. As the amount of storage increases, their speed falls off rapidly. That's why Dr. Galina Baader and Dr. Sonja Hecht, IT experts at MTU, are working on a "turbocharger" solution.

"If we want to continue handling this data, we have to completely rethink the structure for storing it," Baader says. "We need a new structure that can be accessed in a powerful way and ensures data takes up as little storage space as possible." The road to this goal is long—but there is a shortcut: instead of thinking in terms of rows, the developers want to start thinking in columns. "A column usually contains homogeneous data that can be significantly compressed using a suitable algorithm," Baader explains. The result is very compact files; depending on the use case, these are four to ten times smaller than previous storage solutions.

Columns and parallelization make data storage efficient

Saving the data in columns has other advantages as well. If, for example, a data analyst wants to look at the temperature curve, the computer has to read only the relevant column and can ignore all the others. "The computer is quick to home in on precisely where the data required for the task in question is located," Baader says.

Storing the data this way also allows very large volumes to be processed simultaneously by means of parallelization. While one process is working on data from one time period, a second process is already checking the data from another. Theoretically, a large number of such processes can run simultaneously and accelerate the processing speed many times over.

Maintaining an overview ____ *With a special way of storing data, the two IT experts make it easier for their colleagues from data analysis and manufacturing to place the data in patterns and relationships.*

The technical term for this column-based approach is Parquet format. "Record-shredding and assembly" is the name of the algorithm that disassembles and reassembles the nested data structures in fractions of a millisecond. This makes use of MTU computing power highly efficient. "Depending on the use case, we can reduce an algorithm's runtime from several hours to one hour," Baader says.

Recognizing patterns in machine data, statistical assumptions and empirical values

What makes this stage so important is that it allows Baader's and Hecht's colleagues in data analysis to step out into a new world. Suddenly, they are able to analyze the proverbial "big data" from machine operations, and are no longer limited to smaller slices of the whole. "For genuine pattern recognition, we rely on readings taken over longer periods of time," Hecht says. In extreme cases, these periods span several years.

As engine components become increasingly complex, so too does their production. "Ultimately, the quality of a component depends in no small part on the interactions between its individual production steps," Hecht explains. What if machine data, statistical assumptions and empirical values could be linked to form reliable forecasts? That would create a data-driven prediction of product quality—true predictive quality.

Predictive capability gives production engineers insight into hitherto invisible relationships

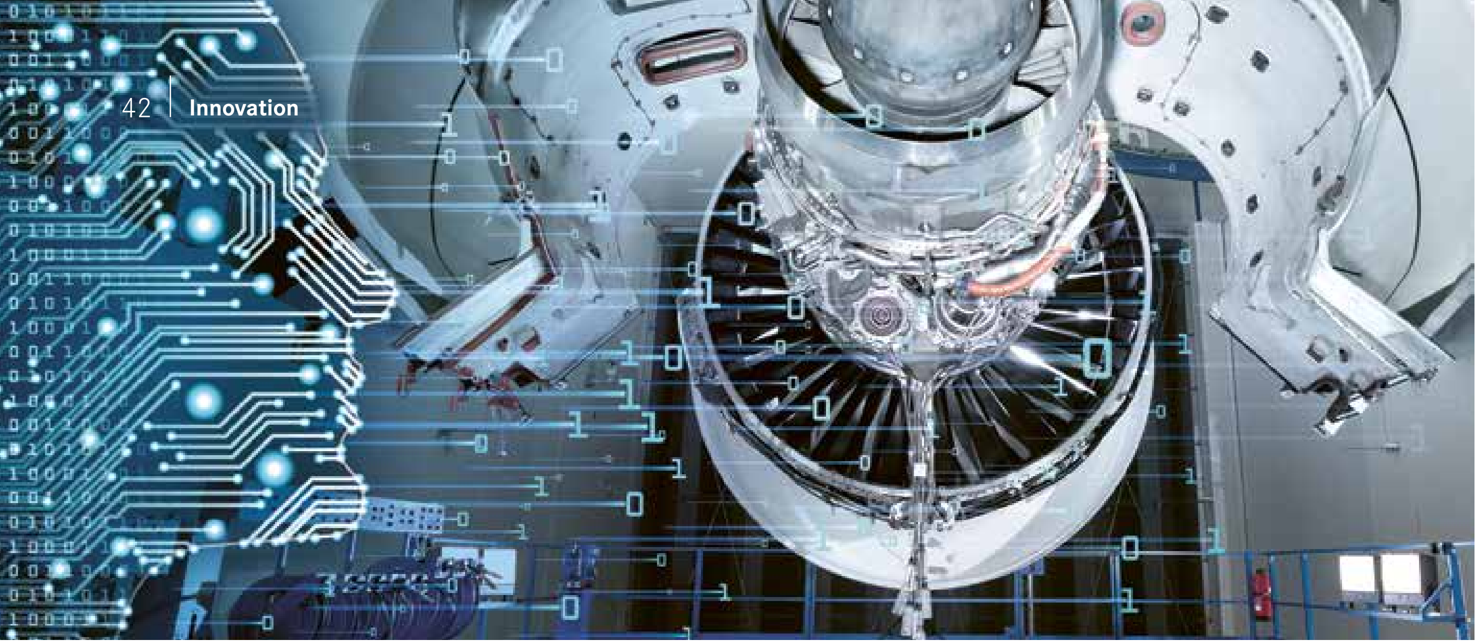
"What if there's a certain dependency among pressure, torque and temperature at a particular manufacturing step, but it doesn't set off a quality warning until several steps later?" Hecht asks. Snipping relevant readings from the data sets as if with digital scissors, extracting them as patterns and visualizing them in dashboards—this gives the production engineers an insight into previously invisible relationships directly on their line. "This might allow them to counteract a potential mistake well before they would otherwise have even suspected it might arise," Hecht points out.

Similarly, forecasts of tool wear patterns become conceivable as well. Engine components are highly resilient—including to the milling tools that produce them, unfortunately. In order to not jeopardize the low manufacturing tolerances of engine components, the tool runtimes are always furnished with a certain material buffer. Better utilization of a component's remaining service life could noticeably improve the production flow by making time-consuming tool changes less frequent. In addition, tooling costs are a real cost factor in the engine business.

A hardware "backbone": High-performance computing (HPC) at the MTU data center

When the two IT specialists set up the new data storage and analysis tools, one MTU-specific feature played right into their hands. "Engine developers make extensive use of simulations, especially when it comes to aerodynamics and structural mechanics," Hecht says. This requires enormous computing power in MTU's data center.

Data analysis algorithms can now also run on the high-performance computing cluster available there without having to set up a second computing environment. "That, of course, is incredibly appealing from an IT infrastructure perspective," Hecht says.



For the past 40 years, the measurement database has provided developers and engineers at MTU with valuable services. Now a large-scale operation is under way to build the next-generation database.

Hub for engine test data

Around 1980, a group of engine and software developers at MTU Aero Engines put their heads together. There had been some major innovations in two areas that significantly impacted their work: computers had just made a huge leap in performance and were being widely adopted in engine development, and test stands were being equipped with a new generation of sensors. Never before had it been possible to record engine data in such detail. Now a database was needed to merge these two systems.

The engine and software developers opted for a file structure with binary containers. Computer programs use this format to structure data for further processing or to optimize storage for certain data fields, the smallest unit of a dataset. Dr. Fabian Bayerlein, an IT project manager and developer, explains the main disadvantage with this: "The stored data is highly fragmented and it sometimes takes days to run comprehensive analyses of engine test runs."

Of course, the MTU measurement database has grown in step with advances in technology over the past 40 years. "We greatly expanded storage capacity, multiplied access speeds and implemented new programming interfaces," Bayerlein says. But a further disadvantage remained: "The choice of architecture that was made back then really limits the options for combining measurement data with higher-level metadata."

Access to measurements from all departments in just seconds

The trouble is that this kind of data linkage is absolutely essential for modern engine development. Michael Kern, a calculation engineer who works in engine performance calculation, gives this example: in a turbine, some physical values can be measured directly, such as pressure at the component inlet. "But other values, such as an engine's thermal efficiency, are determined through analysis calculations. These analyses are based on complex engine models that draw on a great many measurements." The developers have to set hundreds or even thousands of measurements in context. "With the current measurement data management system, it takes a huge amount of effort to set the values—because it takes so much effort to access them in the first place."

That's why, together with Kern, Bayerlein began to establish a standardized and central management system for test data. In their

Interdisciplinary teamwork ___ *A full team from various departments has been enlisted to help Fabian Bayerlein establish a standardized management system for test data.*

project, which goes by the name MDM2020—short for "measurement data management 2020"—they and their team are working across departments and disciplines on nothing less than building a completely new MTU measurement data management system.

The aim is, first, to facilitate the simplest possible acquisition of the measurements from all tests and test runs and, second, to give developers the easiest possible access to them with the tools they already have. The development team will have to build most of it from scratch. There is no blueprint they could use for orientation. These kinds of IT-based solutions bolster the efficiency of MTU's design processes and, with it, the company's competitiveness.

Standardization meets customized tools in engine development

Their approach turns the previous, decades-old strategy upside down. "Instead of each department accessing the file structure directly, we're working on a server-based database with a wide range of interfaces for searching metadata," Bayerlein says. The structure uses an open source software that runs on an established standard. "This provides a solid foundation while also enabling the technical departments—from engine performance calculation to aeroelastics to structural mechanics—to connect to it with their requirements, which, particularly in engine development, can be very distinct."

In which measurement channels of a particular prototype engine were temperatures of 500 degrees Celsius exceeded in test runs? Which measurement series were conducted with a particular combination of hardware and software and which sensors were used? Bayerlein and the team also want to channel conventional measurement data searches, for instance for long-term performance assessments in MRO, through the same interfaces. How do certain readings from a particular engine change over its service life? And how high was the share of particularly high speeds during that service life? Value by value, the developers want to create an ever more finely meshed network of measurement efficiencies, relationships and ratios—and then draw valuable conclusions from them in designing the next generation of engines.

Data hub for OEM and MRO business

The route to this goal sometimes follows the road, even in aviation. In creating this measurement data management system, MTU is cooperating with a number of partners, including some German automotive manufacturers. A cross-industry consortium has been working with standardized measurement data management systems for several years now. "We're taking advantage of features that have already been implemented, and thus also tested, and adapting them for use in our system," Bayerlein says. In return, the partners get the opportunity to use the MTU-specific features in their own applications.

MDM2020 can be thought of as a data hub. "Let's say an overhauled engine completes acceptance testing at MTU Maintenance Zhuhai: we want the data from that to benefit our colleagues in repair development at MTU Maintenance Hannover, for instance, or the developers who are working on the next engine generation in Munich."

The framework for this kind of data hub is currently being designed. The new measurement data management system is set to go into operation sometime in 2022, succeeding its predecessor. Bayerlein says that the architecture could also certainly be expanded to include applications beyond testing and engine development, should any such requirements materialize.

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Searching documents using artificial intelligence

Over and over again, the AI software retrieves familiar patterns and applies them to new scenarios requiring a decision. That's how it learns – and how it gets better and better.

Either mountains of documents or empty pages because nothing relevant to the question came up: document research has always been a time-consuming endeavor. The more specific the question, the more time-consuming the search for answers—and the more time it takes developers. Thomas Piprek is developing a program that pre-sorts, classifies and assigns documents—with the help of artificial intelligence.

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Mastermind for MTU production

MTU is rolling out a unified manufacturing execution system (MES) with which the company will orchestrate all its production activities in the future.

Countless work steps take place in MTU's production facilities. Highly complex components with new aerodynamic designs are particularly difficult to manufacture. This calls for the organization of a great many processes and procedures. Ralf Teufel is developing a "mastermind" for this. The aim is to have an overview of all procedures and processes in manufacturing and production—and to control them automatically.

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MTU production
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Predicting the future

MTU Maintenance's Advanced Proposal Calculation 2.0 is a pioneering new digital project that will benefit airlines and MRO providers equally.

If you want to operate engines as cost-effectively as possible, you really need the power to see into the future. Maintenance contracts tend to run for 10, 12 or sometimes even 15 years. A lot can happen over that span of time: the oil price rises and falls; new aircraft replace older ones; material prices suddenly skyrocket in the face of shortages. Calculations that add up early on can end up way off.

Data sets, artificial intelligence and heuristics enable novel approaches for reliable forecasts

Claus Bullenkamp's job title at MTU Maintenance Hannover might be Senior Manager Engine Programs and not Senior Clairvoyant, but in fact the two roles have more in common than you might think. True, Bullenkamp doesn't have a crystal ball in his toolkit. Instead, he has software that uses data sets, artificial intelligence and heuristics to calculate scenarios and the probabilities behind them.

After all, when it comes to the complex issue of calculating proposals in the MRO business, almost everything depends on the scenarios underpinning them and on the probability of these scenarios actually playing out during an engine's service life. "The spare parts market fluctuates enormously—and so do the availability and prices of components and materials that are essential for maintenance," Bullenkamp says. Might it make more sense to send an engine for a general overhaul after eight years instead of ten? That's a move that could well pay off if, say, "certain material costs, which again make up a considerable share of maintenance costs, are likely to shoot up in the following two years."

These calculations also work the other way around. If, for example, it were foreseeable that a large number of engines of a certain type would soon be coming onto the market as a result of a major airline changing its fleet, "then in that case, running your current engines to the end of their remaining service life without leaving much of a margin would be an acceptable risk—and would probably end up being more cost-effective." And in the unlikely event that everything turns out differently? "Then we'd be able to provide the customer with a replacement engine without fuss, thanks to MTU Maintenance Lease Services, our joint venture with Japan's Sumitomo Corporation."

More efficient maintenance ____ *Thanks to the new forecasting quality provided by APC 2.0, MTU can improve operational planning and increase efficiency in material procurement. This benefits MTU and airlines at the same time.*

Seeing ahead ——— *Using AI, Claus Bullenkamp is able to make more reliable forecasts for realistic scenarios, enabling airlines to plan their maintenance activities with foresight.*

Unique selling proposition: MTU data engineering couples data from flight operations with decades of engine development expertise

That's by no means the end of the long list of ifs, buts and maybes that all need to be factored in. What kinds of repairs an engine might need over its lifetime, and when it might need them, depends on its specific flight profile. On whether the aircraft mainly flies short-haul routes, which cause lots of wear, or spends three or four hours per flight cruising, which causes little wear. Or whether the jets in question mainly operate in desert areas, where the sandy air acts like the finest sandpaper.

This is where a decisive MTU plus point comes in. "We can contribute not only our knowledge of data from day-to-day engine operations, but also all the expertise we've gained from decades of engine development." Putting this knowledge into context and feeding it into MTU Maintenance's engine fleet management for optimum shop-visit scheduling delivers a truly unique selling proposition. "No one else in the industry can do that to the same extent or as fast as we can," Bullenkamp says.

Sophisticated heuristics and algorithms give airlines foresight for maintenance planning

Everything flows together into a giant data hub of a project called APC 2.0, which stands for Advanced Proposal Calculation. The 2.0 indicates that this is the next generation. "The previous version already put us in a very good and successful position in the industry," Bullenkamp says. Now, the next stage is taking shape. With artificial intelligence classifying and evaluating big data drawn from MRO operations. With sophisticated heuristics and algorithms, peppered with developer and MRO know-how as well as market data from all corners of the world. It's as if Bullenkamp is turning a spyglass on tomorrow's market environment. Calculating the best forecast for the most realistic scenario is what it's all about. And adapting that forecast in real time to constantly changing circumstances.

APC 2.0 is of equal benefit to airlines and MTU Maintenance. "We're literally in the same boat here," Bullenkamp says. "Or, to stick with the imagery, on the same plane." Airlines benefit from proposals based on much more reliable calculations, which will soon take only days instead of the weeks that they so often took in the engine business in the past. In the fast-paced world of aviation, this is a real advantage. In the project's second generation, proposal calculations also have a completely new "point of truth": since the data is of such high quality and dependability, it provides a much more reliable view of the future, with risk spread less widely.

APC 2.0 is expected to become operational in 2023

As for MTU, the new forecasting quality arising from the interaction of engine fleet management and APC 2.0 enables increased efficiency in material procurement. But more importantly, MTU can improve its operational planning.

APC 2.0 will become operational in phases throughout 2023 for individual applications, and its underlying model should be scalable for further engine types.

TEXT:

Thorsten Rienth writes as a freelance journalist for **AERO**REPORT. In addition to the aerospace industry, his technical writing focuses on rail traffic and the transportation industry.

Successful year at MTU Maintenance

Foundation stone laid, portfolios broadened, site expanded: 2021 has been quite a year at MTU Maintenance. An overview of the highlights.

Text: *Victoria Nicholls*

Over the past few years, MTU Aero Engines has remained committed to its network expansion plans and progressed with facility expansions, program and capability introductions as well as pursuing numerous operational, digitalization and efficiency improvement initiatives. Despite the Covid-19 crisis, MTU Maintenance is therefore prepared for the maintenance, repair and overhaul (MRO) ramp-up expected in 2022/23.

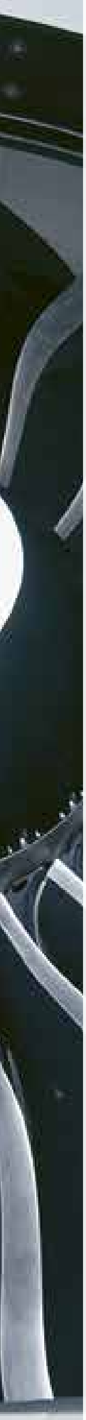
Domestic and regional air traffic in particular is showing signs of recovery, resulting in narrowbody engines tending to be reactivated first. MTU Maintenance is well-positioned to support these engines, as it now has capabilities for CFM56 and V2500 engines at three facilities worldwide. Furthermore, airlines have turned to younger engine types as they have moved their fleets out of storage. Here too, MTU Maintenance is ready to support. Three MTU facilities have capabilities for full engine disassembly, assembly and test for the successful PW1100G-JM engine. The LEAP family was also introduced in 2019 to MTU Maintenance Zhuhai and the team in the Pearl Delta region of China has been working hard to increase capabilities, in particular for its on-site team with for instance borescope inspections.

Furthermore, cargo operations even experienced a real boom throughout the crisis and MTU Maintenance has seen great demand for services on engines such as PW2000 and CF6-80C2. MTU Maintenance should return to pre-Covid levels by 2022/23 earlier than the market – thanks to its product mix and ability to offer alternatives, such as used serviceable material (USM).

This year in particular, MTU Maintenance had a number of milestones to celebrate around its sites. Groundbreakings, portfolio additions, facility expansions – to name just a few.

TEXT:

Victoria Nicholls is a specialist for aftermarket topics such as engine MRO, leasing and asset management, as well as international market trends.



MTU Maintenance Hannover

9,000 shop visits reached

In July 2021, MTU Maintenance Hannover celebrated delivery of its 9,000th engine, a CFM56-7B for the Saudi Aramco fleet. MTU Maintenance has had the CFM56 family in its portfolio since 2000. As number one among independent CFM56 service providers worldwide, it has maintained well over 2,000 engines from this family over the past twenty years, holding a market share of over 10 percent.

MTU Maintenance Berlin-Brandenburg

A 30-year success story

P&WC Customer Service Centre Europe

MRO for PW307

Pratt & Whitney Canada Customer Service Centre Europe (CSC for short), a 50:50 joint venture between MTU Maintenance Berlin-Brandenburg and Pratt & Whitney Canada (P&WC), welcomed a new member to its engine portfolio in September: the PW307. MTU Aero Engines has manufactured PW300 engine parts since 1985. The CSC manages the service requests for these engines.

EME Aero

New GTF family member on board

MTU Maintenance Canada

New home

With the move from Richmond to Boundary Bay in Delta, British Columbia, and the successful restructuring of a former helicopter maintenance company that went along with it, from now on MTU Maintenance Canada will have around 60 percent more space available. Over the past two years, MTU Maintenance Canada has added the successful V2500 and CF6-80C2 engine types to its portfolio.

MTU Maintenance Serbia

Foundation stone

MTU Maintenance Dallas

More space for customer needs

In June 2021, MTU Maintenance announced the launch of its new ON-SITE^{Plus} product family, which expands its portfolio of customized service solutions. The largest ON-SITE^{Plus} location is MTU Maintenance Dallas. Just recently, MTU Maintenance Dallas expanded its available dock space by 3,700 square meters. Now it is able to accommodate engines for short- and long-term stays according to customer needs.

MTU Maintenance do Brasil

FAA approval to deliver more thrust

There were several reasons to celebrate at Ludwigsfelde in 2021: MTU Maintenance Berlin-Brandenburg has reached the grand old age of 30–and it has looked after over 400 customers in the past five years alone. It possesses the most varied product portfolio of the entire MTU Maintenance network. And it added a new engine type to its portfolio this year, with the arrival of the first CFM56-7B in July.

In August, the first PW1500G engine was commissioned at the EME Aero shop. Its launch marks an important milestone in the short history of the joint venture between MTU and Lufthansa Technik. EME Aero is ideally prepared to welcome the new GTF family member. An assembly system designed especially for the location enables it to overhaul every engine type in the GTF family.

MTU Maintenance Zhuhai

New arrival: PW1100G-JM

MTU Maintenance Zhuhai had two highlights to announce in September 2021: The joint venture between MTU and China Southern Airlines Company Limited broke ground for the construction of a new site and welcomed the first PW1100G-JM in the shop. This makes MTU Maintenance Zhuhai the third MTU location to possess full assembly, disassembly and test capabilities for the engine type.

On July 5, 2021, the groundbreaking ceremony took place at Nova Pazova for MTU Maintenance Serbia. At the new site near Belgrade, the wholly owned subsidiary of MTU will exclusively look after the repair of commercial engine parts. MTU is planning to commence operations at the end of 2022, and the training of skilled personnel has already begun.

Airfoil Services Sdn. Bhd.

Site expansion

In April 2021, Airfoil Services Sdn. Bhd., a joint venture between MTU Aero Engines and Lufthansa Technik completed its 5,200 square meter expansion, taking its yearly repair capacity from 650,000 to 900,000 parts. The facility near Kuala Lumpur in Malaysia is specialized in airfoil repairs for low-pressure turbines and high-pressure compressors, in particular for CF34, CF6, CFM56 and V2500 engines.

As of last year, MTU's Brazilian location, which in the past had specialized in the maintenance of industrial gas turbines, is now also looking after aircraft engines–for CF34, CF6, CFM56, GE90 and V2500 types, do Brasil has already received ANAC and EASA certification and has carried out initial on-site activities on engines. FAA approval is due to follow at the end of this year.

MTU Maintenance Lease Services

Engine leasing gains momentum

Throughout the Covid-19 pandemic and resulting crisis, lessors have become even more involved in asset management. Their technical teams are now becoming busier with the return to service of the parked fleet, which is reflected at MTU Maintenance currently through increased demand for on-site support and technical asset management services.

The world's fastest package deliverers

Online retail is causing a package boom that is benefiting the air freight business. Fast deliveries are ensured by widebody freighters with backup from smaller jets.

Text: *Nicole Geffert*

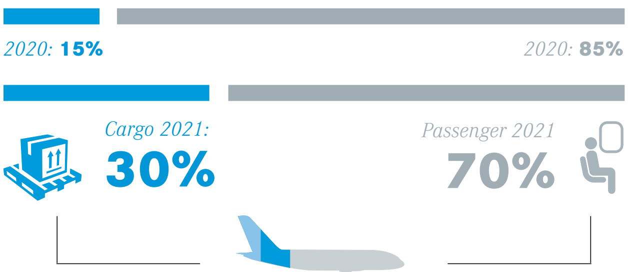
A topflight consignment of air freight: 247 sport horses along with their grooms, feed and tons of equipment were flown on board a specially converted Boeing 777 freighter on a total of eight special charters from Liège Airport in Belgium to the Tokyo Olympic Games.

When it comes to transporting premium and time-sensitive goods, aircraft have the edge over ships as the means of transportation. This became even clearer in March 2021, when the Ever Given ran aground in the Suez Canal, blocking this key waterway between Asia and Europe for six days and causing major disruption to global trade. Meanwhile, air freight boomed—and this sector continues to soar while passenger air travel begins to slowly recover from the consequences of the Covid-19 pandemic.

“For many airlines, cargo business is currently playing a much more important role than it did prior to the pandemic,” says Marko Niffka, Director Business Development – MRO at MTU Aero Engines. According to the International Air Transport Association (IATA), air freight will account for approximately 33 percent of the entire aviation industry’s global revenue for 2021. By comparison, before the pandemic that figure was between 10 and 15 percent.

Other forecasts inspire confidence as well. IATA predicts that the global aviation industry will handle 63.1 million metric tons of freight in 2021. This will come close to equaling the record volume of 2018, the best year in the history of air freight, when 63.5 million metric tons of freight were handled. The total of

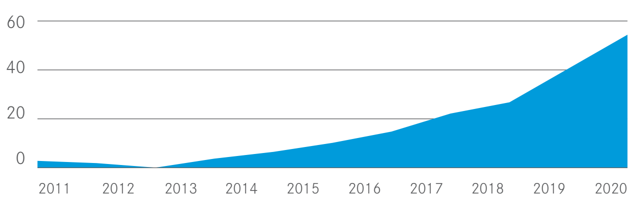
GLOBAL SALES DISTRIBUTION IN THE AVIATION INDUSTRY – CARGO VS. PASSENGER



Getting there faster ___ *Online retail has skyrocketed because of the pandemic, which has led to a considerable boom in freight business. No one ordering online wants to wait weeks to get their hands on their eagerly anticipated goods. Deliveries must be made swiftly–and that's where transport via air has the edge.*

Source: International Air Transport Association (IATA)

INCREASE IN AIRCRAFT IN SERVICE IN THE CARGO SECTOR PER YEAR MEASURED AGAINST 2010 (%)



Air freight is gaining momentum ___ *Since 2010, the proportion of narrowbodies and widebodies in service in the cargo sector has increased by almost 50 percent.*

Source: Cirium

cargo tonne-kilometers (CTKs) for 2021 is expected to rise by 13.1 percent compared to 2020, an increase driven by economic growth in trade and production. That economic growth has been estimated at 8 percent over 2020, according to figures published by the World Trade Organization (WTO).

E-commerce allows the market to stretch its wings

Global exports dropped for a while in spring 2020. "Prior to the pandemic, around half of all air freight wasn't transported in freighters, but rather as belly freight—in other words, as additional cargo on passenger aircraft," Niffka says. Once the pandemic forced airlines to suspend some routes, especially long-haul ones, this capacity for belly freight vanished, which in turn caused transport costs to skyrocket. At the same time, demand for fast deliveries of desperately needed goods increased.

"Especially at the beginning of the pandemic, it was essential to ensure swift, secure and reliable transports of masks, gowns, medical devices and medications," Niffka says. "But these transports had only a short-term effect. Much more important are the drivers that are allowing the cargo market to stretch its wings over the long term—in particular e-commerce, which has further accelerated the package boom."

Even consumers who, until the pandemic, had rarely ordered anything on the internet got more accustomed to shopping online as shops and restaurants closed for weeks or even months at a time. No one ordering online wants to wait weeks to get their hands on their eagerly anticipated goods. Deliveries must be made swiftly—within one to two days, if possible. "By keeping delivery and handling times short and offering a high level of flexibility and reliability, air freight logistics providers pulled out all the stops to ensure goods are delivered on time," says Daniel Giesecke, Strategy Consultant – Aftermarket Analysis at MTU.

Amazon, for instance, wants to deliver a portion of its customers' orders using its own aircraft in the future. Up to now, the online retailer has mainly been leasing aircraft, a common practice in the freight business. At the beginning of 2021, Amazon announced it had purchased 11 Boeing 767-300 aircraft for its freighter fleet. It bought these aircraft secondhand from Delta and WestJet, airlines that are operating few or no passenger services due to the pandemic.

From passenger jet to freighter

The Boeing 767-300ER—a version of the 767-300 that offers extended range and an additional fuselage tank—counts as one of the trusted workhorses of the skies, operating predominantly on long-haul routes. Other such aircraft include the Boeing 777-200LRF, 747-BF, 747-400ERF and 747-400BCF, the McDonnell Douglas MD-11F and the Airbus A300-600F. All of these make good freighters because of their range, cargo capacity and operating costs. Goods are being transported in new cargo aircraft as well as in former passenger jets that have been converted into freighters.

"Up to now it's mainly widebodies that have been converted to start a new life as freighters after fulfilling their intended purpose as passenger aircraft," Giesecke says. "In response to the global boom in e-commerce, logistics companies have also been increasingly using converted narrowbodies—in other words, short- and medium-haul jets. These can be loaded more quickly and thus get the goods to their destination faster."

Smaller aircraft are becoming an increasingly integral part of freight transport. "Goods are transported on widebodies from the central pick-up point to an international air freight hub, where they are transferred to smaller freighters bound for smaller destination airports. This is much faster than the alternative, which would be for the goods to complete the last leg of their journey on trucks," Niffka explains.

Customers expect ever shorter delivery times

There can be no question that narrowbodies are the rising stars of the booming cargo business. Passenger jets like the Boeing 737-800 or the Airbus A321 are being converted into freighters. This is how Lufthansa Cargo, for instance, is expanding its own freight capacity. Starting in 2022, the company will be using two A321 aircraft that have been converted to transport freight rather than passengers on continental routes within Europe. As part of the conversion, these medium-haul jets are fitted with cargo doors so that they can carry containers on the main deck as well. Lufthansa Cargo says that since customers expect shorter and shorter delivery times, demand for air freight connections within Europe is also on the rise. The A321 can accommodate 28 metric tons of cargo at a time—considerably more than can be transported in the belly of a short-haul jet.

When passenger jets are converted into freighters, many cargo companies choose older models. "Most popular are aircraft that are around 15 to 20 years old because then the costly conversion is worth it," Niffka says. Simply removing the seats in order to pile packages in the cabin is neither efficient nor permissible. Jets that are approved for passenger transport are generally not allowed to switch overnight to transporting freight in their cabin. In addition, the structural resilience of a passenger aircraft is lower than that of a freighter. Not to mention that bulky pieces of freight will not fit through doors that were designed to admit passengers. Large loading doors must be retrofitted.

Special service for maintenance

In freight operations, for which older series are preferred, the advantages of modern jets often don't count for much. "It pays to use older models on some routes and new aircraft on others," Niffka says. This depends on a variety of factors, such as the operator and their business model, freight type, fuel prices, obtainable freight rates and usage. "Freighters tend to spend more time on the ground, often fly only at night and spend less time overall in the air than passenger aircraft," Niffka says.

From passenger jet to freighter — *This year, Amazon Air purchased four Boeing 767-300 aircraft from WestJet that are currently being converted to transport freight instead of passengers.*

No freight overnight — *If passenger jets are to start a new life as freighters, they must first undergo a complex and costly conversion.*

But when it comes to maintenance, owners of older aircraft with proven propulsion technology don't have to compromise at all on quality, reliability or safety—the same high standards apply in the freight business as in passenger air travel. The new dynamics that are shaping the cargo market mean that cargo customers have additional requirements and expectations. MTU Maintenance is also well aware of those requirements, and it can offer the right service solutions both for traditional freighter engines and for converted narrow- and widebody jets. In this way, it ensures that everything from medical technology to fresh fish and trendy sneakers can continue to be shipped quickly and safely by air.

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.

MORE INFORMATION ON THE TOPIC "FREIGHT BUSINESS":

Two of MTU's MRO experts discuss service requirements in the freight business
www.aeroreport.de/en

Digitalization for a high-tech world ——— *MTU aims to take its development, manufacturing and maintenance to the next level by harnessing big data, AI and automation. MTU CIO Dr. Lutz Seidenfaden and his team are paving the way for this.*

New worlds through binoculars

For the engine business in particular, digitalization offers a broad range of opportunities–and MTU is seizing them.

Text: *Thorsten Rienth*

Dr. Seidenfaden, what was the moment in your life when you truly realized that digitalization is the next big thing?

Dr. Lutz Seidenfaden: A key moment was certainly my first day in Singapore, where I had moved a few years before joining MTU. At that time, "apps" were something completely new in Europe. But in this Southeast Asian city-state, people were already managing their entire lives with the applications on their smartphones. Taxis, banking, government services–practically all of everyday life was organized digitally.

Now you're back in Germany, and as Chief Information Officer (CIO) you're responsible for digitalization at MTU Aero Engines.

Seidenfaden: It's incredibly exciting work! I'm utterly fascinated by where the virtual world meets the physical, and that's exactly what happens at MTU in the development and production of engines. It's a huge challenge for me to make digitalization visible in this high-tech world.

Dr. Lutz Seidenfaden ——
As an IT expert, he is convinced that by feeding expert knowledge into algorithms and combining them with data analysis methods, MTU can make considerable progress.

Dr. Lutz Seidenfaden studied business informatics at Georg-August-Universität Göttingen, where he also received his doctorate. For 12 years, he held various management positions at automation specialist Festo, most recently as head of information management IT services. Lutz Seidenfaden has been Senior Vice President Information Systems (CIO) at MTU Aero Engines since June 2020.

How do you make it visible?

Seidenfaden: In the past, IT was primarily an infrastructure service. When screens needed to be replaced, IT took care of it. If networks needed to be provided, that was IT's job. Many paper-based processes have now been digitalized. We make phone calls on our laptops. Multiple people can work on the same documents at the same time from different locations and using different devices. In parallel, the company has invested enormously in computing power. This is necessary so that IT can become the company's business enabler.

What do you mean by that?

Seidenfaden: In our business, terms like big data, artificial intelligence or automation are not ends in themselves. For us, big data is like a pair of binoculars that lets us peer into a new world. Artificial intelligence is the means by which we can draw the right conclusions from what we see there. And we're using the new possibilities in automation to generate concrete added value in our manufacturing network from all this.

Could you explain in more detail?

Seidenfaden: Our production lines generate a large amount of machine data. We want to collect and evaluate this data and feed it back into the planning process. This involves, say, detecting patterns and interdependencies in the data that may be reflected in substandard component quality, which doesn't become apparent until later in the manufacturing process. If we can extract the trends in a reliable way, manufacturing engineers will have a sound basis for taking action early on. In addition, we aim to achieve complete data transparency in the supply chain. For example, which supplier delivers the best quality most reliably? What orders do we trigger, and at which volume and when, now that we can work backward based on reliable calculations of our machines' processing times? How can we apply new tools so that we can forecast customer call-offs with even more certainty? Can we predict unplanned downtime in our machinery based on machine data and avoid it through preventive maintenance? In finding the answers to these questions, digitalization is the key lever.

MTU offers customized maintenance and repair services. Its business model also includes integrated engine leasing with asset management. What does the digitalization strategy mean for the MRO business?

Seidenfaden: Actually, we currently see great potential for digital business enablement there. For example, at the moment we're in the process of setting up a status report system for engines that works much the way a package tracking system does. The airline will be able to check online which maintenance stage its engine is currently at, which work steps are still pending, and when it can expect delivery. This makes planning much easier! The next step is to intelligently combine this service with other MTU services, such as our engine leasing program. It's a way to help tide our customers over the repair times with a leased engine.

You already make extensive use of operational engine data with MTU's engine trend monitoring solution.

Seidenfaden: That doesn't mean that we can't improve the service. Using big data and AI, we could take it to the next level: away from individual engines and toward intelligent fleet management. When air traffic is humming, aircraft availability is the defining target. In times of crisis, the focus would be on cost optimization across the entire fleet. The larger the fleet, the more important support from artificial intelligence becomes, because the sheer volume of data simply pushes conventional tools to their limits. We can guarantee data security with state-of-the-art IT architectures.

Regardless of whether you're talking about the OEM business or the MRO business, more data does not automatically mean more benefits. How do you keep track of it all?

Seidenfaden: By approaching the matter in a structured way and not getting tangled up in the little things. In a kind of basic version, a lot of things already work via exploratory data analysis: you run algorithms on data sets in the hope that the computer will find connections that people wouldn't pick up on. But when a company like MTU has decades of expertise in the engine business, we can deploy these algorithms in a very targeted way. All the same, our engineers always take a close look to analyze and verify the results.

I'm convinced that by feeding expert knowledge into algorithms and combining them with data analysis methods, we can make considerable progress—especially in conventional engine development, for example in aerodynamics and structural mechanics.

Aren't you afraid that digitalization will one day make MTU's core business superfluous?

Seidenfaden: No. The trend toward flying is intact, and airlines will continue to require engines and the associated services. There will always be a need for people to further develop these engines and services and to maintain the engines. In this respect, digital services complement our core business with physical engines.

TEXT:

Thorsten Rienth writes as a freelance journalist for **AERO**REPORT.
In addition to the aerospace industry, his technical writing focuses on rail traffic and the transportation industry.

To-do lists – safety first

The goal of all scheduled flight preparations is the safety of all passengers and crew on board. Using checklists brings optimum reliability to this task.

Text: *Markus Kemminer*

Ready for takeoff ——— *Before an aircraft is ready to take off, there is a whole list of checks to work through. This goes beyond technical checks of the aircraft and sees the crew prepare for the flight together.*

What are pre-flight checklists?

The name says it all, really: a pre-flight checklist is a list of control inspections that a pilot or a crew member has to carry out on or in an aircraft before it can be reported as ready for takeoff.

The goal of all pre-flight checks is to inspect all functional and safety-relevant factors in the cockpit, cabin and exteriors.

However …

… anyone looking for the checklist or the checklists to tick off during flight preparations will soon find themselves lost in a blizzard of options. The reason for this proliferation is the wide variety of different aircraft types and models, each with their own individual technical features, plus the (often historical) differences in the requirements of airlines and airport operators, which are effectively resistant to standardization. We can, however, distinguish two basic types of checklists:

- The “pre-flight check” (also known as an “external check” or “walkaround tour”), during which the externally visible components of the aircraft are inspected.
- The “pre-takeoff check” (or “before taxi check”), which basically encompasses all the inspections to be carried out in preparation for imminent takeoff.

Why are pre-flight checklists used?

For all the experience and routine that professionals bring to bear on their serious responsibilities, we know that human

Flight preparation ——— *The pilots brief the cabin crew about all important aspects of the flight, in particular the weather forecast and any turbulence this might indicate.*

Cabin crew ——— *Before takeoff, the crew checks whether all passengers have their seat belts fastened.*

memory is fallible and that people's ability to concentrate is always vulnerable to internal or external influences that can distract it. Checklists support the functions of memory, focus attention on a specific aspect, and structure the technical and functional inspection of an overall system into a defined sequence and routine.

Since when have pre-flight checklists been around?

For a surprisingly long time! The creation of pre-flight checklists was pioneered by the aircraft manufacturer Boeing in the middle of the 1930s. Boeing realized that pilots of its aircraft needed a memory aid—particularly when inspecting their aircraft during the preparation and takeoff phase—in order to avoid potential dangers and risks that can arise from inattentive or incomplete checks.

In what phase of flight preparation are the checks carried out?

The pre-flight check generally begins following the crew briefing, in which the members of the crew exchange flight, aircraft and weather information and discuss any potential special circumstances surrounding the flight. Above all, this meeting is about determining the amount of fuel that needs to be carried. Once the information has been exchanged, the pilots start the pre-flight check; that is, they inspect the key functional and safety-relevant factors in the cockpit, cabin and exteriors. The pre-takeoff check is then carried out, as the name indicates, in immediate preparation for takeoff.

What exactly does the pilot inspect on their walkaround?

The pre-flight check essentially comprises a technical inspection of the aircraft, which is conducted shortly before takeoff usually by the pilot him- or herself in a walk around the aircraft. First, they check for obvious issues: what is the condition of the tires, of the wings?

The lists that the person doing the inspection carries with them are always based on the particular characteristics of the specific aircraft model. The inspection tasks include:

- ✓ Checking the papers, inspecting the aircraft's logbooks, checking the correct settings on the aircraft and verifying the completeness of the equipment
- ✓ Checking the outside surfaces of the aircraft during the walkaround: are there noticeable cracks running along the fuselage, for example, or any dents or scratches?
- ✓ Checking the flight controls and the fuel and oil levels
- ✓ When temperatures are below a certain level: Checking whether the outer shell of the aircraft is free of snow and ice

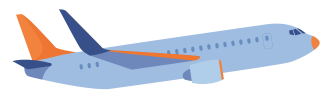
Based on this evaluation, the professional doing the inspection decides whether the aircraft is airworthy or not, in other words: go or no-go.

And what does the crew do during all this?

Following the meeting with the pilots in the crew room, there is generally an additional briefing on flight safety or first-aid topics.

During the actual flight preparation in the cabin, checking the emergency equipment using the Emergency Equipment Checklist (EECL) is one of the crew's most important tasks—and one that bears the heaviest load of responsibility. Among other things, it involves checking whether there are life jackets underneath all the seats and seeing to it that all other equipment (e.g. first-aid kits) is securely stowed and that oxygen cylinders are filled.

Pre-takeoff check _____ *The pilot and co-pilot check whether the individual items on the checklist have been carried out / set correctly.*



The actual pre-takeoff check itself …

… begins in the phase of flight preparations immediately before taking off. First, all important data for the flight is fed into the flight control computer. When all passengers are on board and their luggage stowed, the final weight of the aircraft can be determined; this is necessary for calculating the takeoff data (thrust, angle of climb, etc.). Only once this data has been registered by the control computer can the aircraft leave its parking position.

Among other things, this involves making sure that:

- ✓ The fuel volume actually tallies with the calculations made in advance
- ✓ Instruments, radio communications and flight control functions are working perfectly
- ✓ All relevant takeoff and pre-takeoff settings (on/off or specific settings) are in the correct position
- ✓ Doors and hatches are properly locked
- ✓ Crew members and passengers are wearing their seat belts

The pre-takeoff check is generally carried out by the pilot and the co-pilot in tandem. While one of them reads out the individual items on the list, the other one checks whether it has been carried out / set correctly.

In the meantime, the cabin crew welcomes the passengers on board. Their smiles are always friendly, but …

… their watchful eyes appraise the boarding passengers: What does their hand luggage look like? What languages are they speaking? What is their physical (or mental) state? Are they perhaps drunk or is their behavior notably aggressive?

With a “Cabin ready!” …

… the purser lets the cockpit know that all safety-relevant details have been checked in the cabin, work equipment has been stowed and all passengers have their seat belts fastened. It’s time to go!

TEXT:

Markus Kemminer is executive editor of the content agency TextVersion. He writes about a wide range of technology topics, with aviation up at the top of the list.

MASTHEAD

AEROREPORT 02|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
Dongyun Yang

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Layout
SPARKS CONSULTING GmbH, Munich

Photo credits
Cover MTU Aero Engines
3 MTU Aero Engines
6_7 MTU Aero Engines, Airbus
8_13 MTU Aero Engines, Airbus, Matthias Geiger
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60_63 Shutterstock
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Printed by
Eberl & Koesel, Altusried-Krugzell

Online
ADVERMA
Advertising und Marketing GmbH, Rohrbach

Translation
Klein Wolf Peters GmbH, Munich

IN A NUTSHELL

Sustainable aviation fuels

Sustainable aviation fuels (SAFs) have the potential to greatly reduce aviation's climate impact. They can already be used as "drop-in" fuels to power the existing fleet sustainably. Five questions about SAFs.

What are sustainable aviation fuels (SAFs)?

SAFs are sustainable fuels that greatly reduce aviation's climate impact. They can be divided into two categories:

- fuels that are produced using biomass.
- synthetic fuels produced using renewable energy and CO_2.

Several SAF manufacturing processes have already been certified. Power-to-liquid is considered a promising manufacturing process for synthetic SAFs.

What is the benefit of SAFs?

Because SAF production uses CO_2 as a raw material, it significantly reduces the fuel's carbon footprint—by 80 percent or more, depending on the process used. SAFs can already be "dropped in" to the existing fleet through admixtures of up to 50 percent, with no need to adapt the infrastructure, the aircraft or the engine. In initial trials, SAFs have additionally shown great potential for reducing contrails and their climate impact: this makes SAFs the technology for directly improving the climate impact of the existing fleet.

What role does hydrogen play?

Hydrogen forms the basis of several SAF production processes. That means aviation can make complementary use of hydrogen and SAFs. Over long distances, SAFs may have advantages over hydrogen, but over shorter distances, fuel cells show great potential: this concept is virtually emissions-free.

MTU is working with the German Aerospace Center (DLR) to develop the flying fuel cell demonstrator, which will take off in the next few years.

What is the demand for SAFs in aviation?

If aviation is to become climate-neutral, sustainable aviation fuels will need to be in use across the board by 2050. Total demand amounts to some 600 million metric tons. To meet that demand, it will be essential to provide large amounts of renewable energy and CO_2 for synthetic SAFs. Demand will initially have to be met using today's biogenic manufacturing processes. Advanced biogenic and synthetic processes that are highly sustainable must follow. A blend of biogenic and synthetic manufacturing processes maximizes the available volume.

Are SAFs already in use today?

Synthetic fuels are not yet produced on an industrial scale; demonstration plants are currently in the pipeline. Smaller amounts of biofuels are already in use, corresponding to about 0.1 percent of global kerosene consumption, which was 300 million metric tons in 2019.

MTU is supporting several projects to set up power-to-liquid production facilities.


MTU Aero Engines
IT HAS 80,000 POUNDS OF THRUST – AND YOU DEVELOPED IT.
THE MOMENT WHEN IT TAKES OFF: UNBEATABLE.
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