AEROREPORT 01|23

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

ENGINE MAKERS

MTU's employees each bring their own important contribution to the product. AEROREPORT spent a day with ten of them.

INNOVATION
RoBokop borescope inspections: Inspecting without disassembly

AVIATION
The Queen of the Skies retires: Production of the Boeing 747 is shutting down

GOOD TO KNOW
The gravity of services to science: Parabolic flights

AEROREPORT

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MTU
Aero Engines
YOU CAN FIND OUR TECHNOLOGY IN 30% OF ALL PLANES AND YOU GAVE IT 100%.
THE MOMENT WHEN IT TAKES OFF: UNBEATABLE.
Wanted: team players (all genders) who aim high.
Any other desk job is just a strip of concrete. Turn it into a runway and be part of high-flying projects. With us. At MTU.
Over 11,000 people. 18 locations worldwide. One in three planes flies with our technology. The only thing missing: You.
www.mtu.de/careers
Our online job market:
#UPLIFTYOURFUTURE

Dear readers,

Today I have the pleasure of addressing you for the first time as CEO of MTU Aero Engines. Since the beginning of 2023, I have been tasked with continuing MTU's success story. I have the support of MTU's highly professional management team and a fully committed workforce. Together, we will continue to work to provide excellent products and services and to shape the future of aviation.

I know MTU very well from my previous role as Chief Technology Officer. Before that, I held various management positions at Airbus until I joined MTU in 2015. My professional roots are in aerospace engineering, mechanical engineering and business administration. Flying has fascinated me since my youth, although nothing came of my former dream of being a professional pilot.

Every day, MTU's more than 11,000 employees at 18 sites around the world strive to ensure that our partners and customers can rely on our top quality. As an aviation company, we're helping shape a massive transformation. And what's our vision? Emissions-free flight. To turn this vision into reality, we're looking to hire bold, knowledge-hungry people who want to be part of this transformation.

In this issue of **AERO**REPORT, we'll transport you to our site in Munich for a day, so you can take a look behind the scenes at the sheer variety of the work we do—including electroplating, logistics and structural mechanics. And you'll get to know MTU's "engine makers," who play a major part in the company's success every day.

Moreover, this issue once again showcases innovative MTU projects. For example, the GelSight mobile measuring system, which we now use in our engine assembly shop to carry out testing procedures more quickly and efficiently. Or the RoBokop continuum robot, which in the future will be able to assist in borescope inspections to detect hidden damage inside the engine.

I hope you enjoy reading this issue!

Yours,

Lars Wagner
Chief Executive Officer of MTU Aero Engines AG

COVER STORY

"Creative minds that make what seems impossible possible"

Lars Wagner, CEO of MTU Aero Engines, on aviation's emissions-free future and opportunities for the engine makers of today and tomorrow.

Page 8

COVER STORY

MTU's engine makers

Building an engine requires the skills of many specialists. MTU's engine makers each bring their own important contribution to the product. **AERO**REPORT spent a day with ten of them at the Munich site.

Page 12

COVER STORY

"Our broad technological spectrum is a springboard to the best career opportunities"

Dr. Silke Maurer, Chief Operating Officer at MTU Aero Engines, talks about precision in production and what the transformation of this industry steeped in tradition means for engine makers.

Page 24

CONTENTS

INNOVATION

Ultraprecise fault analysis

Tactile imaging in engine assembly enables MTU to quickly and reliably analyze a scratch or irregularity on a component and determine whether there is cause to halt assembly.

Page 36

AVIATION

The Queen of the Skies retires

Almost everyone recognizes the giant with the upperdeck hump: even today, the Boeing 747 reigns as “Queen of the Skies.” The legendary widebody jet has been built in Seattle for more than half a century—until now. Time for a look back.

Page 46

GOOD TO KNOW

Aerial refueling

Refueling a fighter jet in the air extends its range and prevents it from having to waste time making strategically inconvenient stopovers. But what is the technology that makes this possible, and how do the pilot and the Air Refueling Officer work together?

Page 50

www.aeroreport.de/en

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.

ANNIVERSARY

Forty years of IAE

Happy birthday to one of the most successful engine programs in history

International Aero Engines (IAE) recently celebrated its 40th anniversary in Hartford, Connecticut. IAE is the consortium responsible for the V2500, which entered into service in 1989. Since then, this engine has been built almost 8,000 times, undergoing continuous development, and has logged more than 255 million flight hours. Today, the consortium is led by Pratt & Whitney, together with MTU and Japanese Aero Engine Corporation.

Variants of the V2500 engine are currently in service in nearly 3,500 aircraft operating in 80 countries worldwide. For example, around 60 percent of the global A320ceo fleet is powered by V2500 engines. The latest version of this engine—the V2500-E5—powers the Embraer C-390 Millennium military transport aircraft.

Impressive figures ___ *Built 8,000 times, over 255 million flight hours logged, still in service in almost 3,500 aircraft worldwide—the success of the V2500 speaks for itself.*

MTU IS GROWING

Down under ___ *MTU's Perth site is now certified to carry out work on the CF34 engine series.*

MTU Maintenance Service Centre Australia has received Part 145 certification from CASA for engines in the CF34 series. After nine years of successful operation as a service center for LM™ industrial gas turbines, which are also used on naval vessels, the shop in Perth, Western Australia, is now servicing the aviation sector for the first time. This MTU location is the only on-site service provider for turbofan engines in the South Pacific region. The team in Perth has already completed its first on-site service job, which was on a CF34-10E engine.

MTU Maintenance do Brasil has now received FAA certification for the CFM56 engine series. The location already holds ANAC and EASA certification for the V2500, CFM56-3/-5/-7, CF34-10, CF6-80 and GE90 engines. This brings major benefits for MTU customers in Brazil, since engines operated outside the country generally require dual EASA and FAA approval.

MTU Maintenance Dallas is to relocate to a substantially larger site located at the nearby Fort Worth Alliance Airport, Texas. The new facility will be equipped with a test stand providing 100,000 pounds of thrust. Within the MTU Maintenance network, the Dallas location is the center for on-site services in North America.

MTU Maintenance do Brasil ___ *MTU's São Paulo site provides customers in Latin America with quick and convenient access to ON-SITE^Plus services.*

DID YOU KNOW?

Aviation authorities grant authorization to airlines, issue aircraft registration numbers, approve airfields, ensure the surveillance of airspace, train aviation personnel such as pilots and air traffic controllers, and draw up regulations governing safety and business in the aviation industry. Approval from these authorities is also required in order to develop, manufacture or maintain engine parts and engine modules for use in aviation.

EASA *The European Union Aviation Safety Agency is the European authority for flight safety*

FAA *The Federal Aviation Administration is the federal aviation authority of the United States*

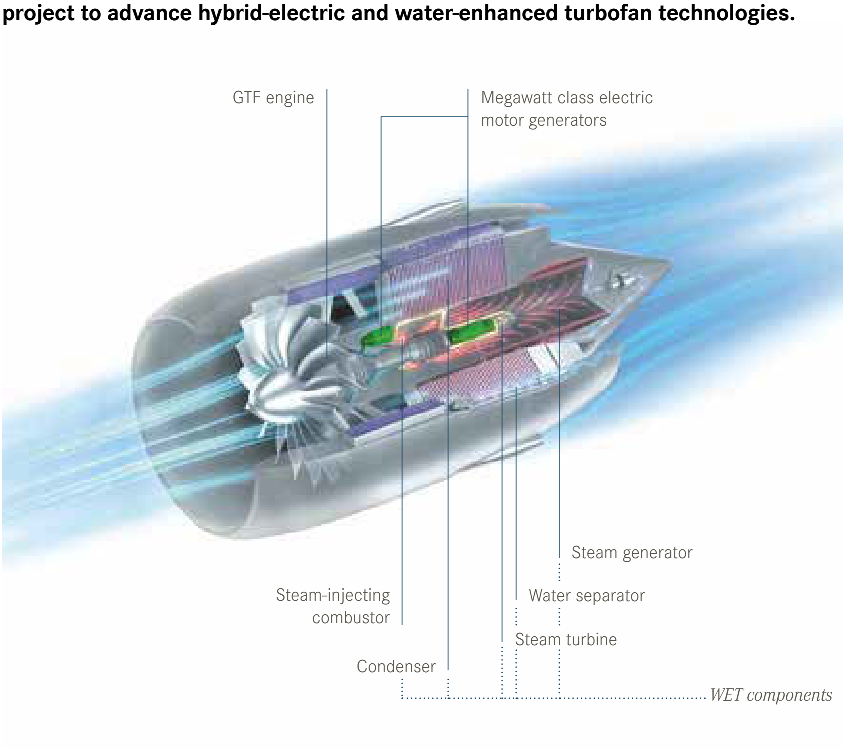
ANAC *Agência Nacional de Aviação Civil is the Brazilian civil aviation authority*

CASA *The Civil Aviation Safety Authority is the Australian aviation authority*

THE FUTURE OF AVIATION

Paving the way for emissions-free flight: the launch of the SWITCH project

SWITCH (Sustainable Water-Injecting Turbofan Comprising Hybrid-Electrics) project to advance hybrid-electric and water-enhanced turbofan technologies.



The project focuses on combining two revolutionary technologies: MTU's water-enhanced turbofan (WET) concept, and hybrid-electric propulsion system components. Work centers on Pratt & Whitney's Geared Turbofan™ engine. The SWITCH concept aims to significantly enhance efficiency and substantially reduce emissions across the full operating envelope of an aircraft. These new technologies are also suitable for operation with sustainable aviation fuels (SAFs). The future use of hydrogen as an energy source continues to be evaluated.

MTU FACTS & FIGURES

1,000

At the start of 2023, the 1,000th engine test was completed on the TP400-D6 test stand.

As a rule, engines for the Airbus A400M transport aircraft are put through their paces in Ludwigsfelde, where MTU Maintenance Berlin-Brandenburg is home to the world's only production test stand for TP400-D6 engines. A major milestone was reached at the beginning of the year, when the Ludwigsfelde site conducted its 1,000th test on this engine. Completed in 2005, the test stand has since logged a total run time of 5,340 hours.

TP400-D6 ___ *The TP400-D6 is the most powerful turboprop engine in the Western world. MTU makes the intermediate-pressure compressor, the intermediate-pressure turbine and the intermediate-pressure shaft for the engine and also has a stake in the engine control unit. Final assembly takes place at MTU in Munich.*

Immensely versatile ___ *Transport aircraft, refueler or flying intensive care unit (ICU).*

FACTS

Since entering into service in 2016, GTF™ engines have avoided more than
10 million
metric tons of CO_2

MTU is currently running
300
technology projects focused on sustainable flight

Over
11,000
employees working at 18 locations worldwide

Lars Wagner
Interview with the CEO of MTU Aero Engines

“Creative minds that make what seems impossible possible”

Lars Wagner, CEO of MTU Aero Engines, on aviation’s emissions-free future and opportunities for the engine makers of today and tomorrow.

Text: *Nicole Geffert*

"Change is sweeping through our offices and shops: we're becoming more digital, more diverse and more agile. Everyone who works here experiences trust, team spirit and camaraderie. At MTU, people are at the heart of everything we do."

Lars Wagner, *Chief Executive Officer of MTU Aero Engines AG*

AEROREPORT: ***Mr. Wagner, when we look up in the sky ten years from now, will we still see the same aircraft we do today?***

Lars Wagner: It's entirely possible that we'll glimpse one or two battery-electric air taxis. But when we consider the aviation industry's long production cycles and long-lasting products, ten years isn't all that much. So some passenger aircraft will still be powered by conventional gas turbine engines. But thanks to the evolutionary development of our highly efficient gas turbine based on the geared turbofan, and our revolutionary water-enhanced turbofan propulsion concept, we can drastically reduce emissions—and that's without having to redesign the aircraft.

AEROREPORT: ***In the future, will we see a mix of different technologies?***

Wagner: Yes we will. We'll implement new technologies where they are most efficient. Today, all passenger aircraft are powered by kerosene, but the future will widen the options considerably. Our aim for the Flying Fuel Cell™ is to create a hydrogen-powered propulsion system for aircraft that carry up to 100 passengers. For 150- to 200-seater aircraft, it'll be gas turbines running on synthetic fuels or hydrogen that will provide thrust. And we expect that gas turbines running on sustainable fuels will also be powering long-haul widebody aircraft with 250 seats and over.

AEROREPORT: ***Aviation remains under pressure due to its contribution to global warming. Is the dream of flight soon to be over?***

Wagner: No, mobility without aviation is out of the question, and people's desire to travel is as strong as ever. Remember that aircraft carry not just passengers but also goods around the world. But there's no getting around the fact that we must drastically cut emissions. That we develop increasingly efficient engines isn't news; MTU has being doing it for decades. And it's a path we're continuing along, only it's going to take everything we've got if we want to make flying climate-neutral and then emissions-free. The next ten to twenty years are going to be incredibly demanding, but we have a responsibility to the next generation to succeed. I have children and I want them to be able to shape their own future on this planet.

AEROREPORT: ***The industry is currently dominated by topics such as artificial intelligence, digitalization and the smart factory. What opportunities do these open up for engine makers?***

Wagner: For MTU and myself, these are much more than buzzwords—they are both our present and our future. We offer engine makers the chance to participate in exciting innovation projects that allow them to achieve entirely new developments. Together with our research partners and with companies specializing in, say, robotics, we're enhancing our production

by developing everything from ever more efficient processes to entirely new production lines. Digitalization is helping us become even more efficient and productive. Smart automation is already essential for the geared turbofan. What's special here is that these plants and processes tend not to be found in any other industry, which puts MTU at the cutting edge of innovation.

AEROREPORT: ***MTU is known the world over for its innovative technologies. How do you foster creativity among your employees?***

Wagner: For decades, we've been involved in close and interdisciplinary collaborations with research partners to drive innovation forward. We also maintain in-depth dialogues with think tanks, start-ups and other future-oriented teams—always on the lookout for the next technological leap forward. And in addition to their regular duties, we provide our experts with the freedom to brainstorm and experiment, for example in MTU's Digitalization Lab and Inno Lab, where they can try out digital technologies and unconventional ideas, but also scout global trends.

AEROREPORT: ***You studied aerospace engineering. What is it that still fascinates you about this field?***

Wagner: In actual fact, I wanted to become a pilot. (laughs) I'm sure a lot of engineers who dreamt of sitting in the cockpit but ended up studying aerospace engineering say the same. I fell in love with flying when I was a child and that love has never waned. What motivates me are the goosebumps I get every time I see an aircraft fly. This enthusiasm and the unbridled enjoyment I have in my job are what drives me.

AEROREPORT: ***What message would you like to give the engine makers of today and tomorrow?***

Wagner: First, I'd like to congratulate them on choosing the right industry. We're delighted to have creative minds who channel their drive and passion into using technology to make what seems to be impossible possible. Even when we're immersed in our work, we're always thinking about our customers and their requirements. Yes, we work in an industry that is steeped in tradition, but that doesn't make us old school. Change is sweeping through our offices and shops: We're becoming more digital, more diverse and more agile. Everyone who works here experiences trust, team spirit and camaraderie. At MTU, people are at the heart of everything we do.

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.

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MTU's engine makers

Keeping everything running smoothly: ten MTU specialists talk about their job, what they particularly enjoy about it and their role in making an engine.

Text: *Nicole Geffert*

24:00
24 HOURS AT MTU: A BEHIND-THE-SCENES LOOK AT THE ENGINE MAKERS

Experience augmented reality on these two pages of the article and over its next ten pages. It's as simple as 1-2-3:

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3. Hold the smartphone over the page to learn more.

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On these two and the next 10 pages, there is more information as well as animations and videos of the protagonists and their activities. To see content on a particular page, scan the QR code there and then allow access to your camera. Hold the activated camera over the page and you will be able to view the additional content.

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What could be more exciting than working for a technology leader? For the expert when it comes to innovative propulsion systems and revolutionary engine concepts for commercial and military aircraft? For one of the world's major players in aviation, driven by the vision of emissions-free flight? MTU Aero Engines' more than 11,000 employees would clearly say, "There's nothing more exciting than working for MTU."

MTU can rely on their experience, expertise and innovative strength—every day. Because in addition to highly complex technology and innovative production, the focus here is on people. Few companies work at such an exacting level as MTU. So enthusiastic, so focused, so successful. These are all qualities that distinguish MTU employees. Qualities that show their attitude: they identify with the company and their job on an extremely profound level.

Building a product that's as highly complex as an engine requires teamwork and the skills of many top professionals. MTU's engine makers each play their own important role in engine production. The much-cited dream of flying is palpable everywhere here: in the offices of the development departments, at the ultra-modern workstations in production, in the boardroom. No matter what field our people work in, they all seize their opportunity as members of the global MTU family to always lead the way.

AEROREPORT spent a day at the company's Munich site with ten MTU engine makers who work in everything from logistics and development to production and quality assurance. Here, they talk about their job, what they particularly enjoy about it and their individual role in making an engine.

Help us raise digitalization at MTU to a whole new level as an **IT expert.**

Manage and monitor our finances and play a role making strategic corporate decisions as a **controller.**

Ensure that our products and processes meet the most stringent standards as a **quality controller.**

Help us assemble or maintain our extensive engine portfolio as an **aircraft maintenance engineer.**

And that's just the tip of the iceberg:

Whether your talents lie in design, purchasing, human resources, electroplating, or testing, and whether you're looking to enter as a **trainee, dual-track student, graduate, seasoned professional, or manager**—MTU has something to offer.

Our strong team ensures that our partners and customers around the world can always count on MTU quality. As an aviation company, we're helping shape a massive transformation. Our vision is emissions-free flight.

And turning this vision into reality hinges on developing revolutionary new engine concepts. That's why we're looking for bold, knowledge-hungry **engineers** who want to be part of this transformation.

And did you know? We don't just manufacture aircraft engines, we also train **cooks** in the company restaurant at our Munich site. So our job market is definitely worth a visit.

Apply now to join our extensive MTU family here:
www.mtu.de/careers/online-job-market

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02:00 A.M.

During deburring, the component is milled and cleaned up by means of an air grinder.

"Since we work on so many different components, I have a very varied daily routine–that's what makes my job so exciting."

Manfred Glas, *Machinist in the manufacture of static components*

It's 2 a.m. and Manfred Glas is wide awake. The machinist is holding a vane ring belonging to a low-pressure compressor for the Eurofighter's EJ200 engine. This component needs to be deburred, which involves filing material off at the edge of the

workpiece. Glas lays out the processing sheet for the component. "The drawings tell me where I have to deburr," he says. Glas has plenty of experience doing this particular job. "Regulations say that I have to consult the sheet, even if I already know what I have to do. Safety and regulatory oversight are paramount."

He mounts the fixture that holds the component on the deburring stand–a kind of small hoist that Glas can tilt by up to 180 degrees for optimal processing. Once the vane ring is clamped, Glas selects the correct milling cutter and begins–naturally wearing protective goggles and hearing protection. "MTU doesn't cut any corners and that's also true for occupational safety, which I think is both right and important. When we're working on components, we also have an exhaust extraction system running the whole time."

Glas works with strong focus, a steady hand and a trained eye. "I'm required to pass an eye test every year," he says. While some components have a processing time of five or six hours, the vane ring can be deburred in two. Glas then sends it on to the next department. "Every day is packed with new challenges. I work on a broad range of commercial and military components, so I never get bored."

Glas deburrs the components after they have been turned or milled and sends them on to be cleaned, inspected and finally installed. From time to time, he is also involved in installation. He particularly enjoys working the night shift, when MTU is quieter. "I like to focus on my work and that's when it's easiest to shut out what's going on around me." Nevertheless, he is in regular touch with his colleagues. "We process the components with a great deal of precision, following the regulations to the letter. This is essential, not least because our engines will go on to power aircraft that carry thousands of passengers."

AR

Manfred Glas
Machinist

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07:00 A.M.

MTU's blade production facility manufactures, among other things, high-pressure turbine airfoils for military and commercial engines.

"I take care of processes and HR planning and make sure that everyone on my team has an optimum work environment."

Florian Wutz, *Team Leader in airfoil production*

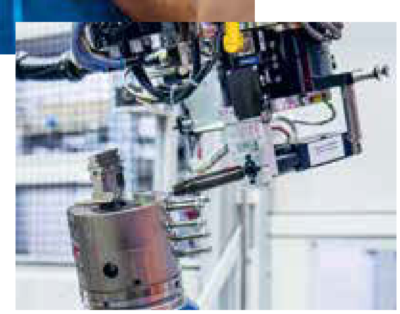
Florian Wutz
Team Leader in
airfoil production

There are appointments that no one gets to reschedule. It's 7 a.m., and that's always when Florian Wutz, Team Leader in airfoil production, meets with his team on the shop floor. "We use this meeting to discuss how we can best plan, implement and optimize our production processes," Wutz says as he welcomes his colleagues from manufacturing, operations scheduling and logistics. The eight team members are standing in front of the shop-floor board, where they have posted all the relevant data and KPIs from their department for all to see.

This daily briefing lasts no more than ten minutes. Everyone keeps their contributions short because there's a lot to do. Wutz manages processes and HR planning for airfoil production and is really enthusiastic about this particular product. "Working on this highly complex component made of high-strength alloys is the highlight of our job," he says. Having qualified as an industrial and mechanical engineer, Wutz knows how important such components are: "An engine can't fly without airfoils, and we look after these key components from start to finish."

Today, the team is discussing a deburring issue concerning airfoils for high-pressure turbines. "These airfoils are installed in the hot gas section of the engine, where they are subjected to temperatures of more than 1,000 degrees Celsius," Wutz says. The quality must be first rate. Immediately after the team meeting, he inspects the airfoils right there on the production line.

"Whenever we have an issue like this, seeing firsthand what's going on helps me come up with ideas for how to resolve it," Wutz says. He adds that there's no substitute for exchanging information directly with the manufacturing experts. "In airfoil production, we work together as one big team." Wutz knows what he's talking about. To achieve an optimum result, he makes sure that each member of his team is performing the tasks that best match their qualifications, thus preventing bottlenecks. After all, they have to manufacture airfoils in large numbers: every year, MTU produces some 70,000.



Automated manufacturing
MTU manufactures some of its high-pressure turbine airfoils fully automatically.

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09:00 A.M.

Process specialists are responsible for the technology related to one or more thematically linked special processes.

"As a process specialist, I work on a wide variety of component groups. What's particularly exciting for me is that I get to constantly alternate between office work and production support."

Lea Mainberger, *Process Specialist for Work Hardening Processes*

Under the magnifying glass ___ *Visual inspection of components is also part of the job of process specialists.*

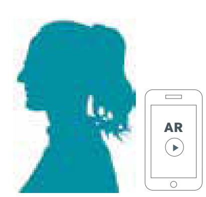
In the testing room this morning, everything revolves around compressor rotors. It's 9 a.m. and experts from production, operations scheduling, quality control and structural mechanics are inspecting a component. One of them is Lea Mainberger, Process Specialist for Work Hardening Processes. Together, they will clarify how a special cover for blisks—high-tech components that integrate blade and disk—can be optimized in the production process.

"I work at an interface to several technical departments," Mainberger says. "We coordinate across disciplines and jointly develop solutions that keep our manufacturing processes running smoothly." An industrial engineer specializing in materials technologies, she joined MTU's department of chemical and nonconventional technologies in 2019.

Here she has developed into a process specialist for shot peening as well as abrasive blasting. "Shot peening extends the life of a component by introducing a compressive residual stress layer. To do this, we either blast very small steel spheres directly onto the component via a nozzle or use ultrasound to excite them so that the spheres achieve a similar effect," she explains. "We put all rotating and highly stressed components such as disks, blades and blisks through this treatment." Abrasive blasting is used to clean or roughen the surfaces of housing parts, for example.

Mainberger's expertise is in demand when it comes to, say, process changes and testing, evaluating new methods for work hardening, and obtaining supplier approval for the processes. "Every day is different and I split my time between my desk and the manufacturing building," she says. She also revels in the team spirit and in knowing she can rely on her colleagues one hundred percent.

"Before I took on my current role at MTU, I was trained by a senior expert who retired shortly afterward," she says. MTU has also given her the opportunity to take external courses to gain additional qualifications. That, too, makes her job exciting: "Because the work we do is so specialized, there's always something new to learn."



Lea Mainberger
Process Specialist for Work Hardening Processes

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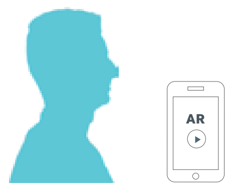
10:00 A.M.

At the electroplating shop they apply and strip galvanic as well as thermal coatings.



Michael Blümel
Electroplating Process Improver

"We get everything from small components just a few centimeters in size to components with a diameter of over a meter. They can be brand-new, without scratches or stains, or they may already have logged several thousand flight hours."

Michael Blümel, *Electroplating Process Improver*

"You can't miss us, considering the amount of space we take up here," Michael Blümel says, pointing to twenty large baths lined up in the electroplating shop. It's 10 a.m. and Blümel is in his element. A newly designed fixture for the first stage of the intermediate-pressure compressor for the TP400-D6, which powers the Airbus A400M military transporter, is being tested.

"In this component, we coat only a tiny groove with nickel to protect it from wear. This means we have to cover most of it with the fixture," Blümel says. After training as a surface coater, he first became a team coordinator and then advanced to become a process improver in electroplating.

MTU has mastered a wide range of electroplating processes for new and repair parts. "Every rotating disk has to go through the electrochemical processes in the electroplating bath to check the base material for defects," Blümel explains. Electrolysis is used to apply metallic layers to the components, which protects them from external influences such as heat and wear.

Wide range of processes —— *MTU's electroplating shop fills two buildings and features 150 baths with acids, alkalis and cyanides.*

The fixture covers the areas that are not supposed to be coated. Blümel expertly checks whether the component fits perfectly into the new fixture. Is the tightness right for submersion into the electroplating bath? What about the fixture's chemical resistance? It's 85 centimeters in diameter. Large components have their own hoists to ensure safe handling of both the component and the fixture.

"We can recoat worn areas over and over again, giving the components a second, third or fourth life. This helps the customer save costs and also conserves resources," Blümel says. However, there's no skimping on quality. "We check everything meticulously. The material must be flawless. That's how we ensure that every component is perfectly coated and meets the high requirements for flight safety."

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12:00 NOON

At the Munich site, more than 5,000 employees are served a variety of meals in the company restaurant every day.

It's midday and the coriander is almost gone. Claude Fini places a bowl of the freshly chopped herb next to the wok. As head chef at MTU's company restaurant, he always knows what's going on—even when thousands of hungry employees are pouring into the new section of MTU's Munich site. Fini greets them with a sparkling smile. "I always make myself available to our guests," he says. In the kitchen, his team hits the gas, but only metaphorically: all the sizzling, sautéing and steaming is done on electric and induction cooktops.

Claude Fini
Head Chef at the company restaurant

All the kitchen equipment at the recently completed site addition is top of the line. Food is served at four counters: "Local & traditional," "Salads & grill," "Pizza & pasta" and "Wok at work". "We expect to serve 1,500 to 1,700 meals a day and plan accordingly," Fini says as he organizes the refills at the "Local" counter. Today, his team has seasoned, breaded and cooked 900 schnitzels.

"We cook virtually everything from scratch—convenience food is a nonstarter at MTU," Fini says. "We do our part to keep employees fit and motivated as they do their jobs." Fini believes that sharing a meal promotes communication and strengthens group identity. This kind of team spirit is also important in the kitchen. "A restaurant kitchen is a stressful place to work," he says, which makes good organization and planning all the more important. "I also aim to create a sense of fun around the work we do."

"Since we're in Bavaria, schnitzel and roast pork are always favorites, but vegetarian and healthy options are also among the popular items on the menu," Fini says. MTU's company restaurant serves pork sourced from "straw pigs"; these are pigs raised responsibly in straw-filled stalls. The vast majority of the chicken served comes from a free-range farm just outside Munich. Priority is given to regionally sourced ingredients. Just recently, Fini visited a farm that supplies the company restaurant with potatoes and vegetables to make sure the quality of the ingredients was up to standard and to show the supplier how MTU values their long-standing relationship.

The company restaurant closes at 1:45 p.m. Time for a break. Fini will be back at his desk later, though, to prepare the food orders for the next couple of days. Sweet pancakes (Kaiserschmarrn) and apple strudel are going to be on the menu. There's always room for dessert!

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01:00 P.M.

SAP in-house consultants are responsible for configuring and looking after the SAP system within MTU's IT system landscape.

"Life in MTU's IT department is extremely dynamic, so there's no chance of getting bored. On the contrary, every day brings new and exciting challenges."

Lisa Scheider, *SAP In-House Consultant for manufacturing*

It's 1 p.m. and Lisa Schneider is immersed in an IT concept for operations scheduling. "During my first job, I quickly realized that I had an aptitude for IT and SAP," says Schneider, whose main task at MTU is to look after the operations scheduling SAP module. "The SAP system extends into every corner of MTU. In my area, we tailor it to the specific requirements of manufacturing."

Schneider joined MTU at the beginning of 2022. "I actually got my start in process management for purchasing before switching to IT," she says. As an IT expert, she also belongs to a competence team that meets regularly. This has her working directly with her colleagues from the technical departments involved in production. "Being an IT planner doesn't mean you sit in front of a computer all day long," she says. "Quite the opposite: the close collaboration with the technical departments really makes this job about communication and teamwork."

Schneider draws extra motivation from having the autonomy to implement solutions on her own authority. "What I really like is getting to see orders through from concept to finished product." Some projects are so complex that they take months to complete. But sometimes, she can complete modifications to existing functions in just two weeks. "Not every technical manufacturing concept can be translated one to one into an IT concept. It takes creativity to come up with workable alternatives."

The pace of life in MTU's IT department is fast—especially considering the company's increasing use of intelligent digital connectivity for machines and processes, also known as Industry 4.0.

IT planning for manufacturing —— *Lisa Schneider adapts the SAP system to the specific requirements of manufacturing.*

"I'm always acquiring new knowledge, which is another reason why this job is so exciting," Schneider says. "By ensuring that current and future production requirements are implemented as successfully as possible in the system, I play my part in helping MTU manufacture top-quality engines."

Lisa Schneider
SAP In-House Consultant
for manufacturing

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02:00 P.M.

Quality controllers ensure that the products are made in accordance with the fundamental rules of quality and safety.

Always with an eye to quality ___ *Flight safety is MTU's top priority, which is why we have quality controllers working in all areas.*

Although the tiny deviation in the turbine blade is barely visible to the naked eye, the visual inspection was good enough to detect it. It's 2 p.m. and Marc Rehermann, Quality Controller for assembly, is notified immediately. There's no time to waste: "My office is only one floor away from the assembly line—a short distance for quick decisions."

The experts for this component work on-site. "That's a major advantage. We can contact our design and manufacturing specialists directly to agree on further actions. Product deviations are now always discussed as a team," Rehermann says.

Alongside improving processes, managing deviations is one of the quality controller's most important tasks. "We assess every anomaly, no matter how small," he says. "I help decide whether a component will be installed, reworked or rejected. That's quite a responsibility."

Rehermann, who is 26, studied aerospace engineering at FH Aachen and joined MTU in 2022. "During my studies, I completed an internship at MTU Maintenance Hannover," he says. "That experience was so fascinating, I realized that my idea of working as an engineer meant really getting my hands on the engines."

At MTU, Rehermann's theoretical knowledge is just as important as the real-world experience and expertise that his production and assembly colleagues have built up. "We examine the component from many different angles to ensure maximum quality," he says. "We make sure that any assembly stamped with the MTU logo has MTU quality underneath."

"Whether in assembly, production or development, we're there to ensure that our products are made in accordance with the fundamental rules of quality and safety."

Marc Rehermann, *Quality Controller for assembly*

Marc Rehermann
Quality Controller
for assembly

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03:00 P.M.

Outbound logistics is responsible for shipping and transport processing as well as shipping control and quality assurance.

Benedikt Buchner
Head of Outbound Logistics and Global Transport

It's 3 p.m. and the entire outbound logistics team knows what to do. Together, they work like a well-oiled machine. The truck that transports MTU components to Munich Airport once a day is standing by; it must be fully loaded by no later than 3:45 p.m. "Work gets more intense in the afternoons," says Benedikt Buchner, Head of Outbound Logistics and Quality Control, as he enters the hall. But everything's going according to plan, and Buchner knows that he can count on his team. "I value being able to work independently and so do the members of my team," he says.

Customs clearance is a complex business. Buchner has checked all the necessary documents, certificates and other paperwork. Everything has to be in order. Today, it's blisks that are being dispatched. "Blisks are transported in specially designed packaging," he says. "In addition to saving us time and money, this packaging is sustainable and doesn't need to be wrapped in plastic."

Buchner knows a lot about packaging and doesn't underestimate its importance. "We ship goods worth millions, so they have to be packed with great care. Flight safety is our top priority and we have a zero-tolerance policy for faults. Our partners want to receive their goods undamaged—and on time!" And that's what Buchner and his team achieve day in, day out with zero customer complaints. "In terms of quality, we're the final link in the engine production chain. We make sure that each component is perfectly packaged and always reaches its destination."

To keep things running smoothly, Buchner is in direct contact with suppliers, logistics providers and customers around the world. He knows what each one's transport requirements are. Next morning, he receives an e-mail from a customer in the U.S. telling him that the components were delivered on time—proof that his team's processes are effective.

Buchner joined MTU back in 2001, and his enthusiasm for the job has been a constant source of motivation. After all, logistics is a dynamic business. Buchner even goes a step further: "My team has a real passion for logistics. We make sure that the quality requirements for engine production extend to delivery," he says with a glance into the hall. He gives a thumbs-up. The truck leaves the loading zone and sets off for the airport.

> *"To work efficiently, we aim for strong connections and seamless interfaces."*

Benedikt Buchner, *Head of Outbound Logistics and Global Transport*

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04:00 P.M.

Development for structural mechanics ensures the structural integrity of the components.

"It's our job to design components so that they satisfy all metrics, including efficiency, costs and process stability."

Dr. Saskia Lessig, *Development Engineer for Structural Mechanics*

Dr. Saskia Lessig
Development Engineer for Structural Mechanics

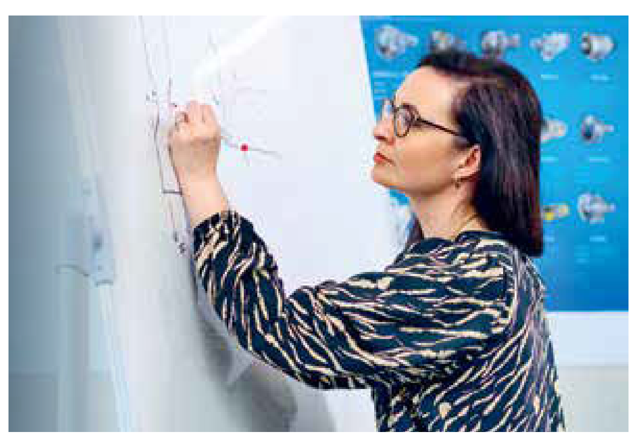
Dr. Saskia Lessig glances up at the clock. It's 4 p.m., which means she still has time to go through her notes from the previous meeting. The components team responsible for the blades of the TP400-D6 engine's intermediate-pressure turbine meets once a week. "We follow an interdisciplinary approach," Lessig says. These meetings bring together experts from different areas—such as engineering, manufacturing, quality assurance and program management—for discussion. "When we get to the structural integrity of the blades, everyone looks expectantly at me," she says with a chuckle. "I leave our meetings with a list of tasks and I look at these in my own time once I'm back at my desk."

The questions put to Lessig and her colleagues in structural mechanics are complex and highly technical. "We always works through such questions as a team," she says. "Together, we make sure that our surrogate models are error-free and fulfill the most stringent quality standards. Flight safety is our top priority." This is why all calculations are reviewed by at least two members of the team prior to approval. "We're specialists, yes, but we're also team players—our discipline is simply too broad for us not to be. Each of us has their particular niche, so together we find the answer."

As a mathematician, Lessig's expertise is in high demand when it comes to numerical analysis or stochastic problems. She did her PhD in contact mechanics, which "provided me with a bridge between theoretical mathematics and mechanical engineering," she says. It was her professor who first told her about MTU, which she calls a "happy coincidence." She came to the company through her PhD and has remained here. Lessig minored in IT, and she can also apply that knowledge at MTU—for instance, when integrating processes and procedures.

The challenges that come with the job are what she finds exciting about it. "The requirements that our engine programs need to meet are becoming more exacting all the time—especially when it comes to the innovative propulsion technologies that we're developing to ensure an emissions-free future for aircraft."

Highly technical —— *The development engineers define the quality requirements for each component.*



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10:00 P.M.

In the thermal spray shop they coat complex engine parts with materials to protect them against heat and wear and tear.

Last stop: thermal spraying ___ *Once the component has been coated, all that's left to do is the final inspection—then it's off to the customer.*

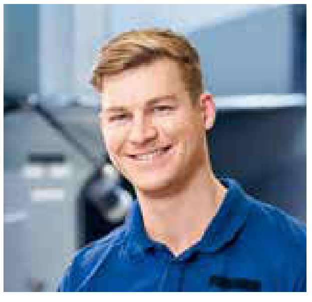
Highest precision ___ *To ensure that only the intended areas of the component are coated, the rest must be masked.*

It's 10 p.m. Half an hour ago, Maximilian Bayer started his night shift in the thermal spray shop without a trace of fatigue. The 27-year-old closely inspects a disk for the PW1100G-JM GTF engine. Where flying, and extremely safety-critical, parts are processed, careful scrutiny is the first duty. The visual inspection reveals no anomalies or deviations: the new component is perfect. Bayer covers it with heat-resistant silicone rings, explaining, "That way, only the areas that are supposed to be coated will be coated."

In 2010, Bayer started his career at MTU as an industrial mechanics apprentice. Now he is an expert in the thermal coating of engine components. He takes the disk to a blasting facility, where "the surface is roughened so that the adhesive layer sticks better." Next, he pushes the component into the coating line. There, the heat and wear protective layer is applied to the disk with the help of a robot and a plasma torch. Bayer deburrs the resulting edges with a brush and a file: "Even though we use state-of-the-art machinery here on the shop floor, my job requires craftsmanship."

"I machine about 25 different components. Every workday is different, and I like that," Bayer says. Independent work is key, but so is teamwork. "In any case, we apply the two-person principle, for example when it comes to measuring the coated component. The dimensions have to be right—we deliver nothing but first-class quality."

Bayer likes everything about his job, from the team, which includes many young people, to the development opportunities at MTU. And there's something else that excites him: the product. "Recently, I flew on an A320neo with the PW1100G-JM. A short time later, when I held a component of this engine type in my hands at my workplace, I thought: Cool, I just flew with that engine. It's possible that I even coated a component for it."



Maximilian Bayer
Thermal Spraying
Process Specialist

"As an engine maker, it's best to bring curiosity and a willingness to create and to change, because the aviation industry is on the cusp of a huge transformation. With us, you can play a major part every day in making aviation sustainable."

Dr. Silke Maurer, *Chief Operating Officer at MTU Aero Engines*

“Our broad technological spectrum is a springboard to the best career opportunities”

Dr. Silke Maurer, Chief Operating Officer at MTU Aero Engines, talks about precision in production and what the transformation of this industry steeped in tradition means for engine makers.

Text: *Nicole Geffert*

AEROREPORT: ***Dr. Maurer, you’ve been MTU’s Chief Operating Officer since the beginning of February. Before that, your career path hadn’t had any crossover with the aviation industry. Now it’s all about engines for you.***

Silke Maurer: Yes, my enthusiasm for engines as a product took root very quickly. Once you join MTU, it becomes a part of life. Sometimes I’ll meet employees in the factories and offices who have been working here for 30 years, and they’re still excited to talk about their job. This is thanks to their fascination with flying, the motivating work environment at MTU, but also our technically sophisticated product, which is durable but never dull.

AEROREPORT: ***What makes production at MTU so exceptional?***

Maurer: At MTU, we’re a state-of-the-art industrial company, but also a highly specialized manufacturer—so we combine the best of both worlds. We don’t have the kind of fast-paced, large-scale production setup found in the automotive industry. We manufacture extremely sophisticated components and assemble engines in very small quantities, sometimes even producing one-offs.

AEROREPORT: ***So the skills of well-qualified experts are in particular demand in highly specialized engine production?***

Maurer: Yes, especially since our products are very complex. Our parts and components must meet stringent requirements for safety, durability, accuracy and quality. This calls for a very high level of vertical integration compared to other industries. We manufacture in the micrometer range. It’s this precision work that’s one of our strengths, not mass production. And that is exactly why MTU depends on the excellent skills and know-how of every single specialist. We need their skill in handling precision tools, their expert eye for detail, their extremely intricate handiwork. The skills it takes to deliver that kind of perfect manual work are timeless. At the same time, we’ve built up highly automated, state-of-the-art production areas that offer exciting tasks for automation and programming specialists.

AEROREPORT: ***Do advanced production methods open up entirely new career opportunities?***

Maurer: Definitely. Anyone who joins our production team will find out that we supply many components that are one hundred percent made by MTU across all production steps and all along the value chain. We develop many pioneering processes in-house; one example is precise electrochemical machining: a patented high-precision, high-tech manufacturing process. Our broad technological spectrum is a springboard to the best career opportunities. People making a lateral move into aviation also have very good prospects with us. I recently met someone who used to work as a dental technician before coming to us. His precision work is also appreciated at MTU, which is why we provided him with training to apply those talents to new tasks.

AEROREPORT: ***What should future engine makers ideally bring along with them?***

Maurer: As an engine maker, it’s best to bring curiosity and a willingness to create and to change, because the aviation industry is on the cusp of a huge transformation. With us, you can play a major part every day in making aviation sustainable. We’re also keen to get more women interested in careers in technical fields. I’m an engineer myself, and I’d especially like to encourage girls who are interested but still undecided: talk to women in those kinds of professions, and hear them tell you how fascinating their jobs are and what great development opportunities they offer.

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.

RoBokop borescope inspections

Inspecting without disassembly: In the future, a flexible miniature robot will make it possible to use a borescope even in areas of an engine that were previously difficult to access.

Text: *Nicole Geffert*

With a steady hand and a trained eye—that's the only way to inspect the inside of an engine using a borescope in order to check the quality of components or the wear and tear on them. This visual inspection of cavities that are difficult to access is called borescopy, from the word "bore" meaning "to drill into." The procedure is very complicated and requires experienced inspectors.

One of them is André Laukart, a borescope inspection expert at MTU Maintenance Hannover. "Before disassembling an engine, we use a borescope to identify any hidden damage inside, so we can more precisely estimate how much of the engine we have to take apart and how much effort the repairs will entail," he says. "This allows us to clarify the scope of work with the customer at an early stage before disassembly starts."

But the experts are reaching their limits. "The borescope is a flexible instrument, but the probe head with the camera can move in only four directions. That's not flexible enough to get the camera into all the positions we need," Laukart says. It's also not possible for the stiffened tube to make several turns inside the engine, although this is precisely what would be needed to access the deeper components in the more highly compact engines.

Laukart gives an example: "The borescope lets us get to rotating components such as rotor blades, but we can reach the stator of a high-pressure compressor only with difficulty, if at all." But to inspect any damage there, the probe has to get as close to the component as possible. In addition—despite all the care and expertise—there's always the risk the borescope will get hung up on a component in a narrow space as it's being retracted.

Multi-jointed segments instead of conventional joints

Scientists Tim-David Job and Martin Bensch from the Institute of Mechatronic Systems at Leibniz University Hannover are also interested in this topic. The two robotics specialists learned from Laukart's firsthand experience and from viewing the engine themselves where the borescope technique is reaching its limits. "For us, these insights and direct discussions with the expert are enormously important," Job says. That's because they believe their research can provide a remedy.

In cooperation with MTU, the scientists are developing a robot-assisted borescope nicknamed "RoBokop." Dr. Manuel Voit and Jörg Windprechtinger, experts in automation and production processes at MTU Aero Engines, and their team are in close contact with the scientists. "The first prototype of the miniature robot was created after a year and a half," Voit says.

What distinguishes the RoBokop from a conventional borescope? "The miniature robot has bionic structures that let it move like a snake. Instead of conventional joints, it has multi-jointed segments that allow continuous movement. That's why it's

The future of engine repair — *A novel continuum robot opens up completely new possibilities in maintenance for detecting hidden damage inside an engine.*

Research on a laboratory scale *Running experiments with the RoBokop on a stage of a high-pressure compressor. The model has been scaled up by a factor of 2.5 to make conducting the experiments easier.*

Small and flexible *Cables and leads for the camera and measurement system run through the interior of the miniature robot. The RoBokop will be miniaturized down to a diameter of just six millimeters.*

also called a continuum robot," Windprechtinger explains. As a result, the RoBokop is much more flexible than the rigid borescope. "That means we can reach components deep inside the engine and have the camera capture areas that were previously inaccessible."

But before the RoBokop can go into operation for the first time, this innovative process will be researched on a much larger scale in the lab. The model that Job and Bensch built themselves has been scaled up by a factor of 2.5, making it easier for the scientists to conduct their experiments. Miniaturizing the RoBokop is the next step. "The challenge is the dimensions required," Bensch says. "The RoBokop is supposed to have a diameter of only 6 millimeters and a length of up to 1.80 meters."

Skeleton structure with wire ropes

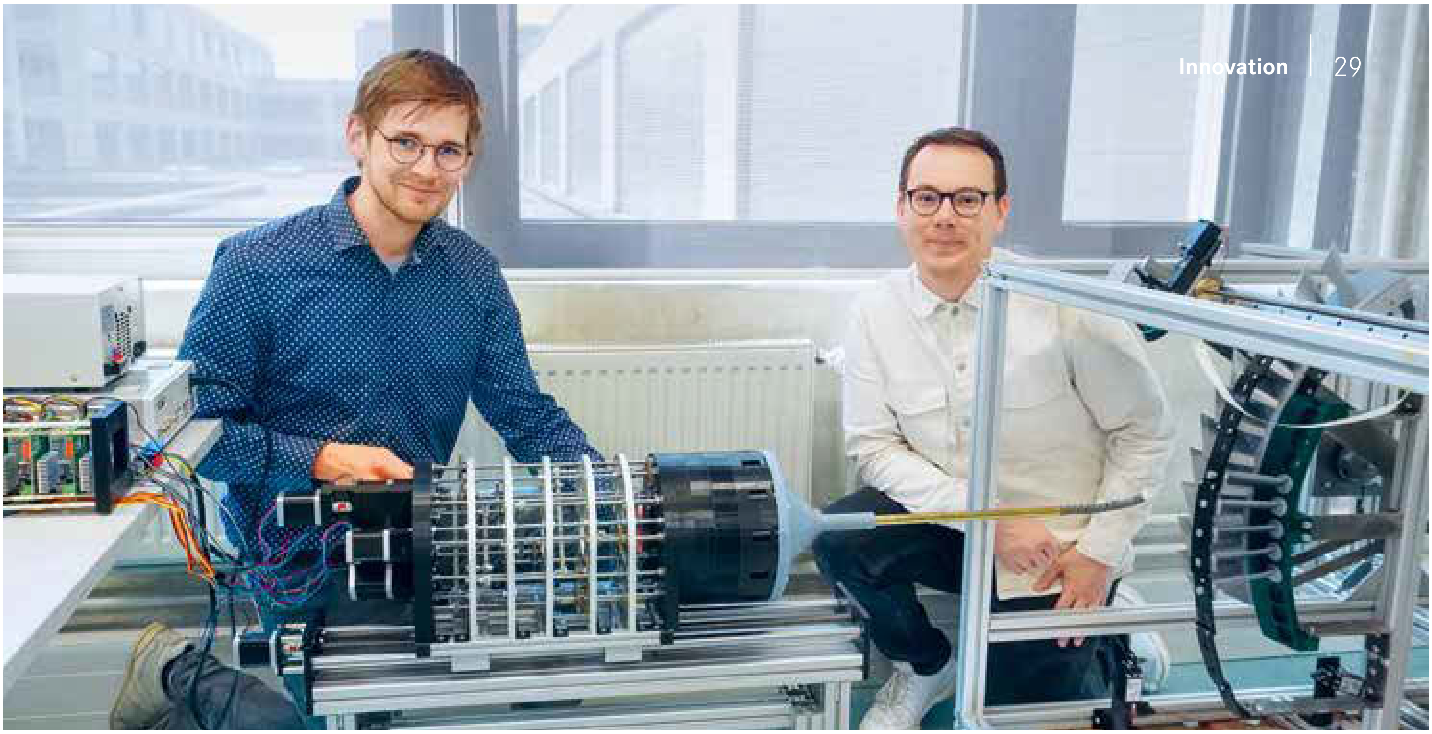
The required dimensions also influenced the decision on how to build the continuum robot's skeleton. "There are a few different concepts to choose from, such as micromotors or fluids," Job says. The scientists settled on wire ropes as actuators because they are easy to miniaturize. Guided by disks, these wire ropes are used to exert a force on the metal rods that form the backbone of the RoBokop. On the inside, the miniature robot is hollow to provide space for the camera cables and leads plus the measurement system.

In the future, the RoBokop could provide valuable services not only in the maintenance shop but in on-site operations as well. Whenever possible, MTU Maintenance's mobile teams perform borescope inspections and engine repairs directly on the wing. Since this avoids unexpected costs, it is particularly attractive for customers.

Another major advantage of the RoBokop is that it lets components such as blades be examined in a reproducible manner. In other words, the miniature robot can be used to target specific points on a blade multiple times. This is much more difficult with the stiff tube of the conventional borescope. Bensch explains it like this: "Anyone who's ever tried to pull a long cable out from under a sofa or cabinet and then push it back to exactly the same position knows how such a job ranges from tricky to impossible."

Automated inspection process

As soon as it's ready for use in engine maintenance, the RoBokop will be controlled by the borescope experts at MTU Maintenance. "We still have a classic human-machine interface here," Voit says. MTU Maintenance experts could operate the RoBokop using, say, a joystick or a tablet, while they concentrate on the monitor to assess the damage. "Evaluating an engine's condition and analyzing any damage are demanding tasks that will continue to be performed by our maintenance specialists," he says.



Robotics specialists ___ *Scientists Martin Bensch (left) and Tim-David Job from the Institute of Mechatronic Systems at Leibniz University Hannover are developing the robot-assisted borescope in cooperation with MTU.*

Agile as a snake ___ *Instead of conventional joints, the RoBokop has bionic structures: multi-jointed segments that allow continuous movement. That's why it's also called a continuum robot.*

But research teams are already targeting more distant goals. One is to completely automate the currently subjective inspection process, including damage analysis and damage repair. A prerequisite for this is also an advanced measurement method. Here, too, MTU is looking to its collaboration with Leibniz University Hannover, specifically with the Institute of Measurement and Automatic Control.

"3D Endoscopy and Damage Detection in Narrow Structural Spaces" is the name of the transfer project that launched in 2023. It is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) and originated from Collaborative Research Centre 871. MTU Maintenance Hannover is an industrial partner in this transfer project. "We make sure that the results from the basic research are fleshed out in more detail and transferred into industrial application," says Dr. Jörn Städing, who is responsible for MRO technology and digitalization management at the MTU Maintenance network.

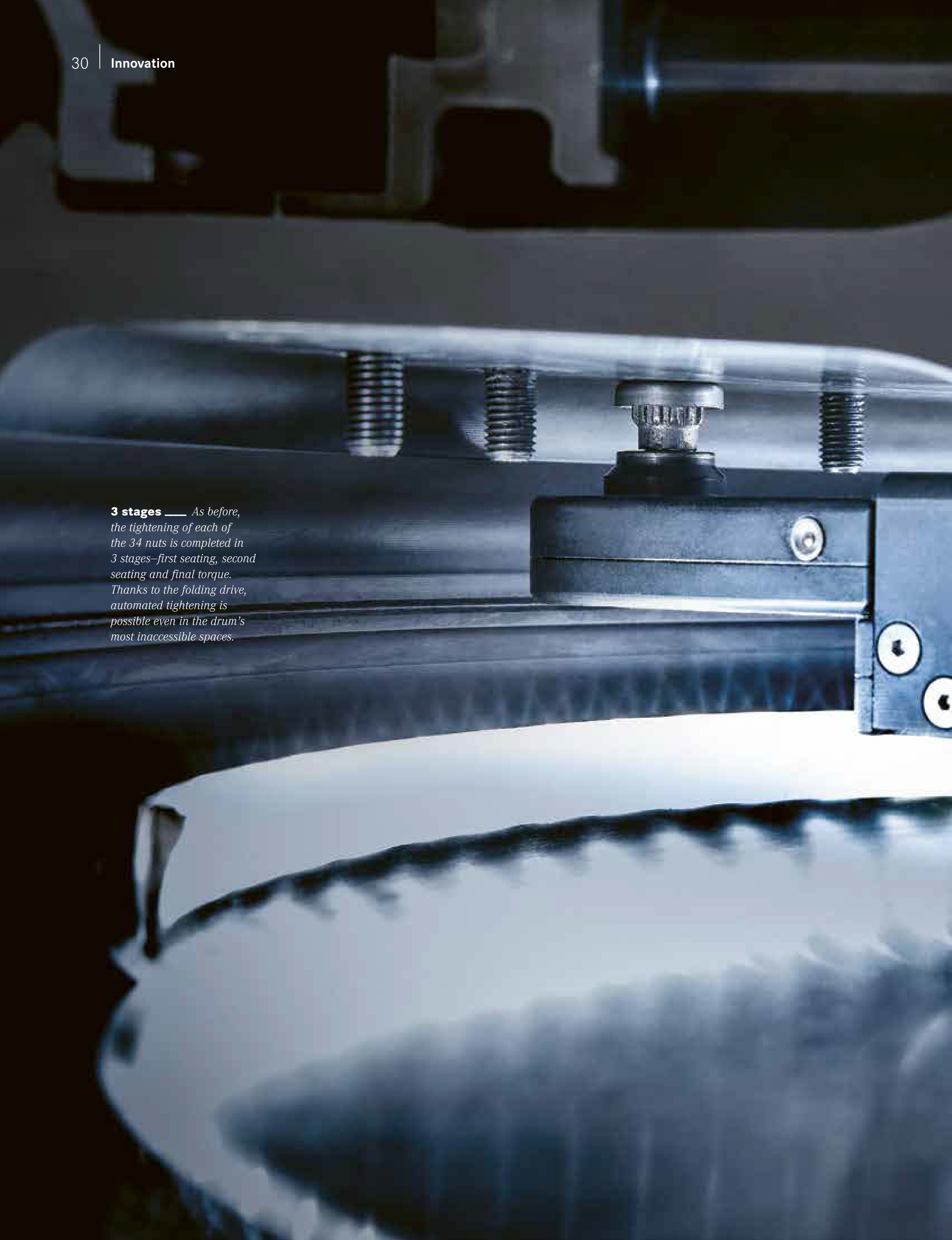
Technology development certainly isn't standing still in maintenance either, as Städing points out: "On the contrary, we're going to further optimize our overall process in the MRO sector and make it even more efficient. What's more, technological progress can also enable entirely new MRO offerings—for example, in the form of special maintenance services with RoBokop and an innovative measurement system."

MORE INFORMATION ON THE TOPIC:

Link to the video "A robot for borescope inspections"
www.aeroreport.de/en

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.



3 stages ___ *As before, the tightening of each of the 34 nuts is completed in 3 stages–first seating, second seating and final torque. Thanks to the folding drive, automated tightening is possible even in the drum's most inaccessible spaces.*

More precise than a mechanic's steady hand

Digitalizing a process that evolved over years of maintaining and repairing compressor rotors is a way to increase process reliability while reducing failure rates.

Text: *Tobias Weidemann*

"Instead, what we've achieved with the tightening robot is a stable, qualitatively better process and a workflow that enables us to reduce both the likelihood of errors and the failure rate. After all, it's in a robot's nature to perform the task more precisely and with less effort than a human."

Nico Vohse
Initiator of the project

Screwing together a compressor rotor demands considerable patience. This is a job that must not be rushed and that calls for a steady hand. Mechanics begin by aligning the two drums before placing 34 nuts and the corresponding washers, one by one, at the correct position. They fasten the nuts loosely and then tighten each one in turn in several stages and with precisely the right amount of torque. To ensure this doesn't warp the component, they tighten the nuts in opposite pairs. Before and after the tightening process, they use a calibration unit to measure the torque. At the final tighten, they check the self-retention of the oval nuts—these must not be too loose or too tight.

So this is a job that requires mechanics to have a very delicate touch. But in the future, at least at MTU Maintenance in Hannover, it will be performed by a robot. In addition to automating the process of screwing the rotor components together, this new method also uses the robot to digitally document everything at the same time. The robot's first assignment will be the high-pressure compressor rotor for the V2500 two-shaft turbofan engine, which powers the Airbus A320ceo series, among others.

"Our goal was to replace the established manual job because the sheer complexity of the tightening process meant that it was becoming increasingly prone to error," says Nico Vohse, who had the idea for the project and launched it. The project team set out to find an optimum, forward-thinking solution.

But instead of simply replacing one manual process with another, MTU decided to switch to an automated process based on industrial robots. This promises to be a sound investment in the future: as this new solution offers significantly greater precision and can be adapted to other models of rotor, other MTU sites also stand to benefit in the medium term.

Arduous and unergonomic manual labor eliminated

Together with 3D.aero—an automation solutions provider specializing in solving problems particular to the aviation industry—the Hannover team developed a solution that combines many of the benefits of digitalization and Industry 4.0. It also happens to make life much easier for the employees who have to get the job done.

It was advantageous that the project team comprised several employees who had performed the task manually many times before, which meant they were very familiar with the hand movements and the obstacles involved. "In the past, mechanics would work in a less than ergonomic position bent over the rotor, ultimately using a mirror and a light to check whether the nuts were in the correct position," says Ingo Scheele, the member of the project team responsible for first level support.

"So when we switched to the robotic solution, we took the opportunity to eliminate these unergonomic processes while also introducing a camera system to help chart and document the tightening process," Vohse says. Now, the camera system moves inside the rotor and documents whether everything there is up to scratch and if the nuts have been tightened correctly. The image data collected is then filed for future reference. This system's added bonus is that the whole process can now be monitored remotely.

Precise engine assembly with a low error tolerance

The process steps and sequence have, however, remained largely the same compared to the previous version: the first seating of the nuts and washers, tightening in opposite pairs, the second seating followed by self-retention check, and then the final torque. Now, though, the selection of the nuts and washers and their placement in the workpiece are fully automated, performed

Setup—part 1 ___ *First, the front compressor drum is positioned.*

Setup—part 2 ___ *Second, the rear compressor drum is prepared for the tightening process.*

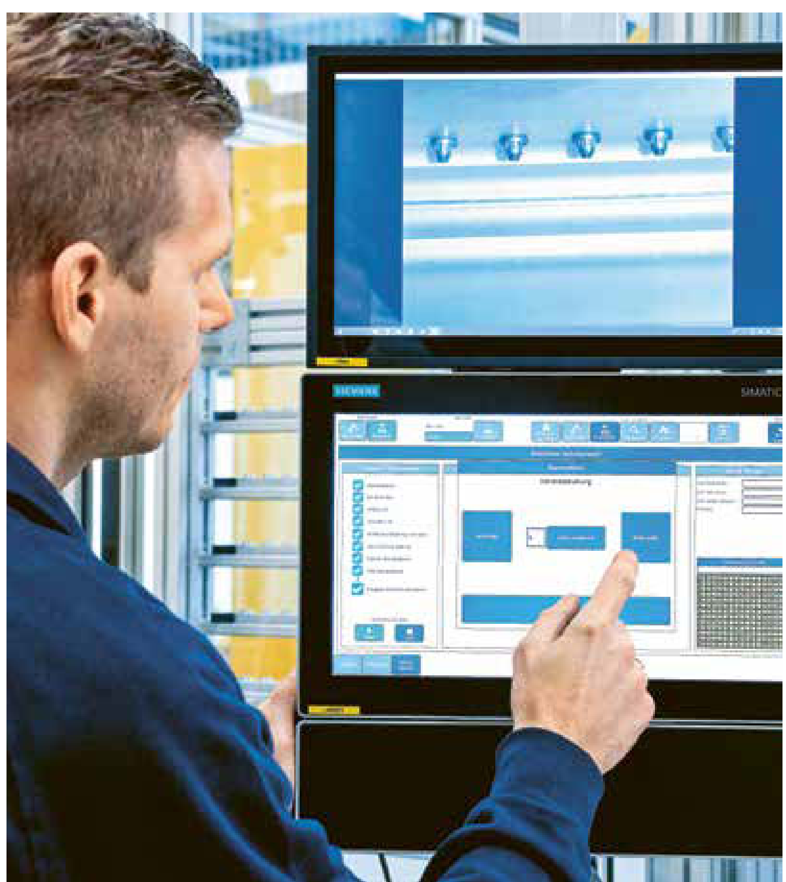
Setup on the clamping station ___ *The front and rear compressor drums are now aligned on the clamping station. While the rotor on the clamping station is being screwed together with the components prepared in one chamber, the neighboring chamber can be prepared for the next rotor.*

Precision tightening ___ *An industrial robot screws the two rotor drums together–fully automatic and more precise than is possible by human hands.*

Camera track ___ *The camera system moves inside the rotor and documents whether everything there is up to scratch and if the nuts have been tightened correctly.*

Fully automatic grab ___ *The robot uses a pneumatic grab arm to select the nuts and washers and position them in the flat folding drive.*

Camera documentation ___ *The image data collected is then filed for future reference. This means the process can also be monitored remotely.*



"At the end of the day, our greatest achievement with the tightening robot is that we've brought industrial systems and IT closer together and torn down some big barriers in everything from incorporating IT to helping realize MTU's Industry 4.0 strategy."

William Xu
Project team member

by a pneumatic grab arm via a grip-change station. Before and after the completed tightening process, a calibration unit is used to check that the torque on the mechanical components complies with the engine manufacturer's stringent specifications. A twin magazine system reduces unutilized assembly times: while the tightening process is taking place in one chamber, the setup for the next order is being prepared in the other.

Even with the new solution, it still takes around two hours to screw together a compressor rotor. But Vohse notes that a few minutes here or there would be of little consequence given how long it takes to assemble an entire engine. What's more important, he says, is to have a low error tolerance and a reliable, plannable process—which is why shaving a couple of minutes off the process time was never a high priority. "Instead, what we've achieved with the tightening robot is a stable, qualitatively better process and a workflow that enables us to reduce both the likelihood of errors and the failure rate. After all, it's in a robot's nature to perform the task more precisely and with less effort than a human."

Flexibly adaptable to other compressor rotors

The solution achieved in collaboration with 3D.aero is highly customized—there was no real blueprint to follow or any similar process. "This is MTU's first automated tightening robot in the field of assembly and disassembly to support such a specific maintenance area. But it won't remain the only application we could imagine for this technology," says Oliver Persuhn, who, together with Vohse, has been a part of developing the system from day one and is transferring it to standard operations.

Persuhn explains that MTU is striving to replicate the system's more precise tightening and the improved time planning in maintenance processes for larger rotor series. "The current system variant can accommodate rotors with a diameter of up to 1.10 meters. And since the robot is equipped with quick-lock couplings, we can change out the tightening tool relatively easily and inexpensively." What's more, the technology provides an ideal basis for an automated measuring and assembly system for larger rotors and other automation projects.

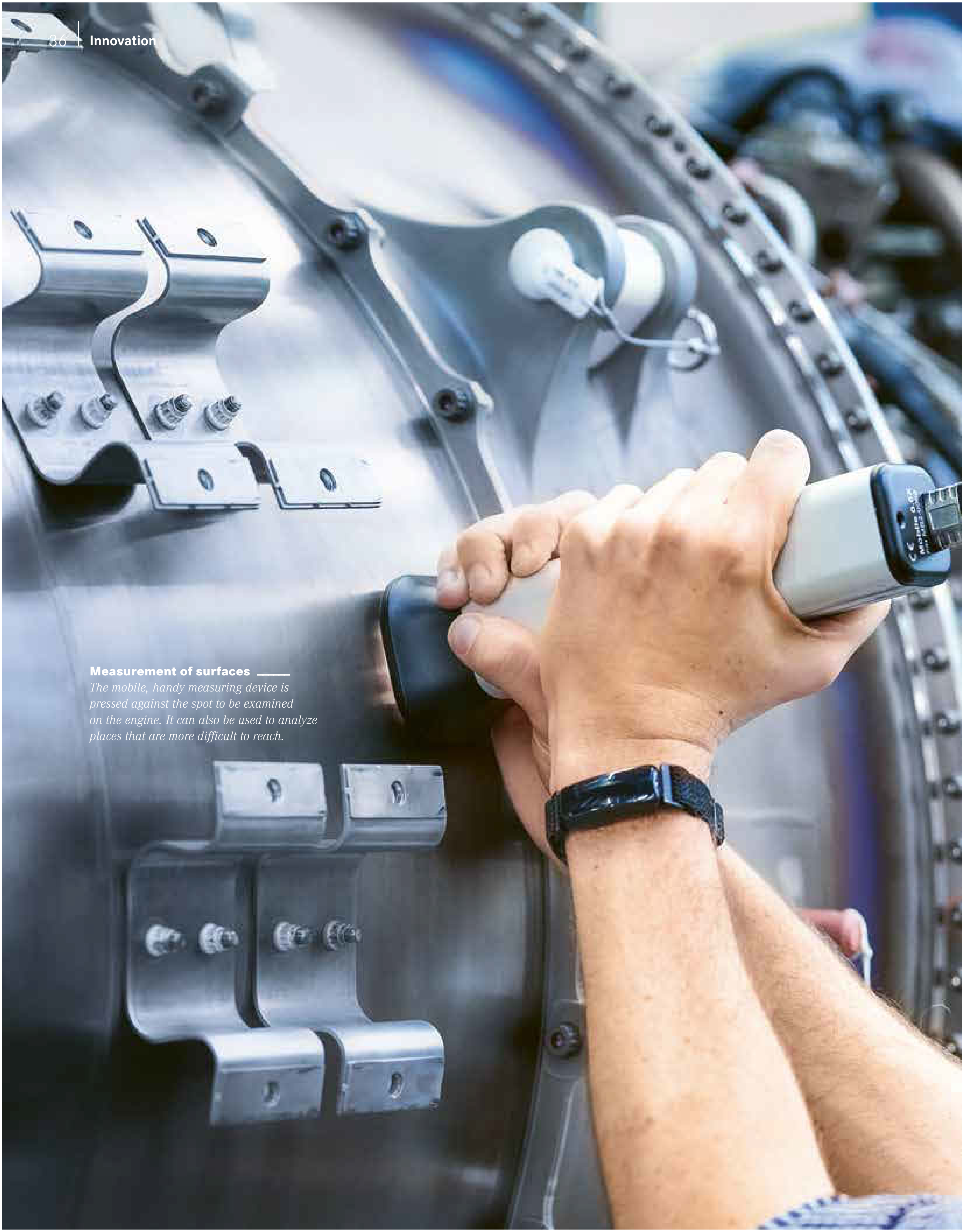
"At the end of the day," says project team member William Xu, "our greatest achievement with the tightening robot is that we've brought industrial systems and IT closer together and torn down some big barriers in everything from incorporating IT to helping realize MTU's Industry 4.0 strategy." He adds that it's now easier to integrate process data into the MTU ecosystem and to gather additional empirical data with a view to rolling out this lighthouse project at other sites further down the line.

MORE INFORMATIONEN ON THE TOPIC "INDUSTRY 4.0":

Automated airfoil
production paves way
to the smart factory
www.aeroreport.de/en

TEXT:

Tobias Weidemann has been working as a journalist and content consultant for more than 20 years. He writes about technology and business topics, often with a focus on business IT, digitalization and future technologies.



Measurement of surfaces
The mobile, handy measuring device is pressed against the spot to be examined on the engine. It can also be used to analyze places that are more difficult to reach.

Ultraprecise fault analysis

MTU uses the GelSight device to detect and document even small defects, ultimately accelerating engine assembly.

Text: *Tobias Weidemann*

The head of the surface-measuring device glides over a component during final engine assembly. There's a small scratch; it's visible to the naked eye but hard to describe—and especially difficult to evaluate. The experience and gut feeling of MTU's seasoned engine experts are a good indication, but these alone are not enough for a reliable assessment. Is it just a minor flaw, a tool mark on a component? Or could it impair functionality or cause damage later on? Going further, does the part need to be replaced? And if so, will this delay the assembly of the engine, which consists of several thousand components?

To answer these questions, in the past an MTU Aero Engines assembly mechanic would have had to make an impression of the component and then send it to the lab for analysis. There, the lab technicians would measure the anomaly and issue a damage report, which the technical department would use as a basis for making a decision. This report would also be kept for documentation. Alternatively, the component would be replaced as a precautionary measure, which was not in the best interests of costs nor sustainability.

Either way, this resulted in a significant assembly delay and required that a spare part be available for replacement in the first place. In addition, the engine may have already been on the test stand, so a swap would mean retesting. "All that often took a good deal of time. And if we were unlucky, the assembly of a complete engine would have to wait until the measurement results were available and we had clarity on whether the part could remain installed or not," explains Carmen Pomp from MTU in Munich. "Even just keeping the engine on 'hold' or making it possible to replace a component was a challenge for our assembly teams."

New device accurately measures surface structures

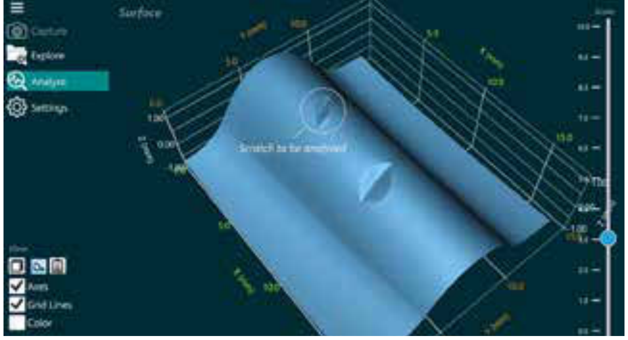
This is precisely where the 3D surface analysis device GelSight Mobile™, which Pomp together with colleagues from different departments helped introduce as an innovation in PW1100G-JM final assembly, comes to the rescue: the high-resolution device can measure the topology of structures in combination with a standard notebook or tablet and the appropriate software. It's easy to transport to modules consisting of larger parts and can even be operated outside the company network in the interests of data protection. In addition, the device makes it possible to document the degree of deviation from the standard with just a few clicks. This significantly accelerates decision-making processes and shortens timeframes.

The device has a wand like the kind used in medical ultrasounds. At the tip is a round elastomeric gel pad with a diameter of just under two centimeters. When pressed lightly to the component under inspection, this pad conforms to its surface topology and thus creates a precise impression of the area being measured. This works with a variety of materials ranging from reflective to matte, metal to plastic, and can capture and examine even detailed structures and textures. Compared to other optical measuring systems, GelSight allows MTU technicians to cover an area measuring several square centimeters very quickly.

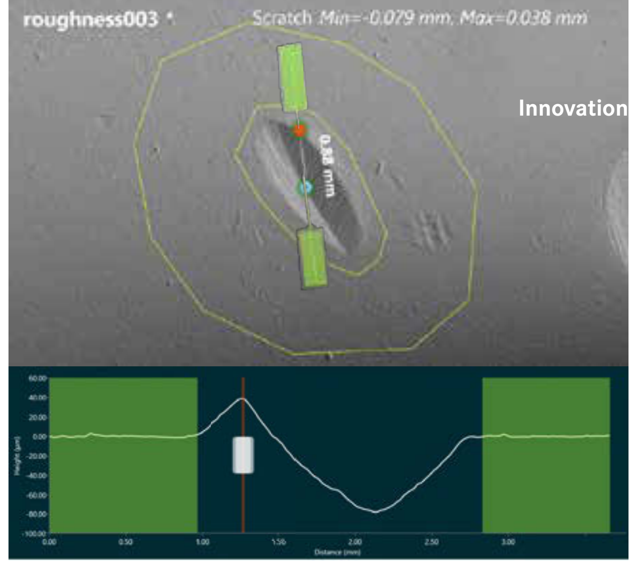
Six LEDs mounted in the wand light up one after the other, producing six individual images at different exposures and from different perspectives within just a few seconds. An algorithm factors out all colors and transparencies as well as reflections and glare, creating a 3D image of the structure. Distilled down to its pure form, this view offers significantly better insights than a conventional microscope. The image can also be rotated, tilted and examined from all perspectives with a manageable amount of graphic processing power. Data obtained this way can be standardized for further processing in other software programs.

If desired, it's also possible to define a specific target surface level in order to accurately measure a deviation or dent. "In the case of a scratch, for instance, the system measures the highest

No assembly delays ______ *With GelSight, Julian Mandel and Carmen Pomp found a measurement method that makes engine assembly considerably more efficient.*



Step 1 ——— *The image of the structure of an uneven spot can easily be measured with the help of the GelSight device. First, the gel pad is pressed onto the area to be examined. By pressing a button, the user can have a 3D model created from the six perspective photos. The location of the damage to be analyzed can now be defined on this model.*



Step 2 ——— *For the correct assessment of the elevation or indentation, a target surface level is defined for comparison with the area under inspection.*

and lowest points in a defined area," says Julian Mandel, who was also involved in launching the GelSight system at MTU. Measurement resolution is in the single-digit micrometer range and varies between just four (axial) and eight micrometers (lateral). In describing the order of magnitude, Mandel explains: "This is approximately the thickness of a human hair, which is perfectly sufficient for our requirements."

Extra calibration procedure put in place

One major hurdle to using GelSight was obtaining metrological approval for it from MTU. To meet the stringent requirements of engine production, the device had to undergo an extensive certification process in accordance with exacting international specifications laid down by the production partners. "The deciding factor was that GelSight reliably produces the same measurement results every time," says Stefan Necker, expert for geometric measurement technology at MTU. "In cooperation with MTU's calibration department, the measurement team has found an adequate solution. A particular challenge for the device manufacturer was the integration of a calibration procedure—a basic requirement for measurement systems in the engine world."

The young company from Boston was founded within the Massachusetts Institute of Technology (MIT) environment and is involved in tactile imaging as well as tactile sensor technology. The latter involves, for example, determining the optimal force for a robot to use when gripping or holding a component for processing.

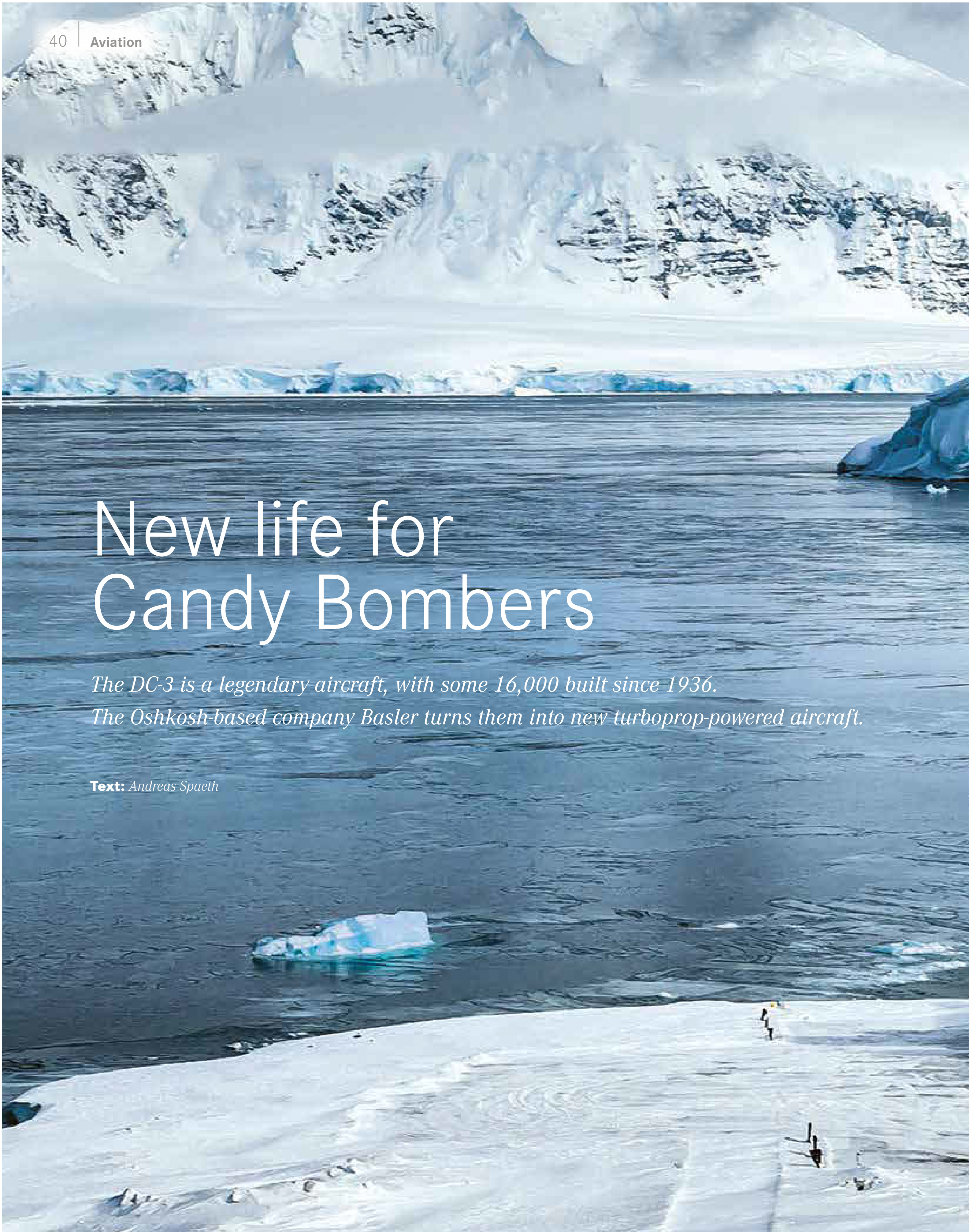
"To meet the high safety standards in aviation, engine experts have traditionally had to perform inspections and complex laboratory measurements that slow down processes and decision-making. With the portable GelSight Mobile system, the MTU team now has the ability to significantly simplify and speed up inspection procedures while arriving at the same robust results about the quality of engine parts," explains Youssef Benmokhtar, CEO at GelSight. "Through our collaboration with MTU, we have demonstrated that our tactile sensor technology can be used for aerospace quality assurance and quality control, helping to automate, standardize and significantly speed up these processes."

Wide range of applications

The GelSight device has been used on the final assembly lines for the PW1100G-JM engine for the A320neo and the TP400-D6 engine for the A400M since 2019. However, the engine manufacturer will soon be relying on GelSight technology in other areas as well. As Mandel says, "We're already getting visits from colleagues in other departments who want to inspect something quickly." In addition, the device is already in use in the MTU Maintenance network: at MTU Maintenance Berlin-Brandenburg and at MTU's Canadian site in Vancouver, GelSight provides support in repair and damage assessment.

TEXT:

Tobias Weidemann has been working as a journalist and content consultant for more than 20 years. He writes about technology and business topics, often with a focus on business IT, digitalization and future technologies.

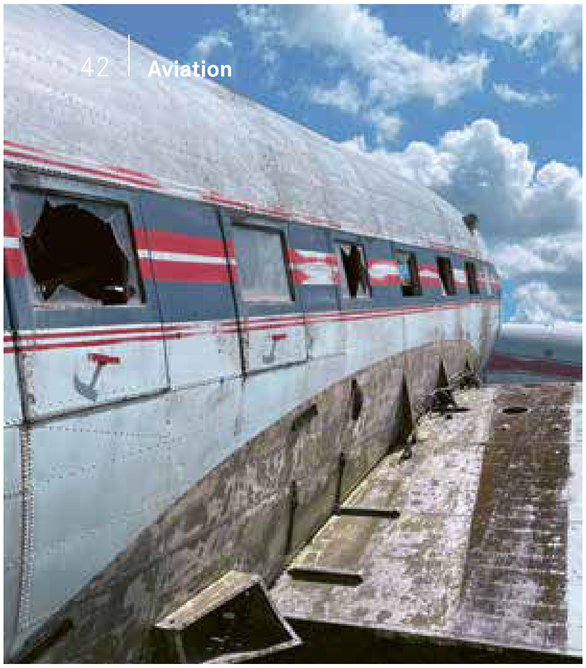


New life for Candy Bombers

The DC-3 is a legendary aircraft, with some 16,000 built since 1936. The Oshkosh-based company Basler turns them into new turboprop-powered aircraft.

Text: *Andreas Spaeth*

Research on the wing
Germany, Australia and China use the new BT-67 for research and for supplying Artic and Antarctic bases with the help of the wheel/ski modification option.



No wings, dents in the fuselage ___ *It's hard to believe that Basler is turning DC-3s that are essentially scrap, some of them 80 years old, back into brand-new aircraft.*

Aircraft cemetery in front of Basler's hangar ___ *In fact, these remnants of old DC-3s are an important basis for production in the years ahead.*

Unparalleled ___ *By 1942, 607 DC-3s had been built. Over 10,000 of its military version, the C-47, were built as well.*

In front of the hangar, it looks like an aircraft graveyard: a line of aged Douglas DC-3 Dakotas, their fuselages overgrown with weeds, some without wings, others with broken windows and clouded cockpit windshields. No one would guess that rather than standing at death's door, these wrecks are about to be given a new lease on life. These veteran aircraft, some of them 80 years old, are waiting to be pushed into the hangar. Around six months and 50,000 work hours later, each will reemerge as a brand-new Basler BT-67. These refurbished aircraft retain some of their original outward characteristics, but are in fact ultramodern and in mint condition. This is the essence of the astonishing business model implemented by Basler Turbo Conversions at Wittman Regional Airport in Oshkosh, Wisconsin.

And business is booming: "Our order books are already full through 2023," Basler President Joseph Varkoly tells mesmerized visitors as he shows them around the factory hangar, which at 7,000 square meters can accommodate up to four aircraft at a time for their regeneration. Basler is more of a custom contractor than an industrial producer, a specialist provider that used all of its ingenuity and expertise to turn the miraculous "making old new again" metamorphosis into a business model, with customers from all over the world desperate to get their hands on the finished product. Basler currently completes two conversions a year.

300 of 16,000 DC-3s still in service today

The main reason all this is possible is that the twin-engine DC-3s that began to emerge from the Douglas factory in California in 1936 demonstrated a level of resilience, robustness and durability that remains unparalleled to this day. Both the DC-3 (607 had been built by 1942) and especially the military version C-47 (of which more than 10,000 were made) would soon become pillars of aviation. Counting all license variants and subvariants, around 16,000 of these classics were built—and some 300 of them are still in service today. During the Second World War, as "Candy Bombers" during the Berlin Blockade of 1947–48 and later during the Vietnam War, this aircraft was regarded as basic equipment. After the Second World War, many C-47s were converted into passenger aircraft and were the backbone of the global boom in air travel.

It was back in 1980 that company founder Warren Basler (1926–1997) completed the first modern reincarnation of the DC-3/C-47. Brought to market as the Basler BT-67, it soon found buyers. The U.S. Federal Aviation Administration (FAA) recognizes the reincarnations as brand-new aircraft with zero flight hours. “In a typical BT-67, only around 10 percent of the metal from the original aircraft has been retained,” Varkoly says. While it’s sometimes possible to reuse up to 40 percent of the total material, the vast majority of the airframe is replaced, as is the skin. Since original spares for aircraft of this vintage are no longer available, Basler manufactures all the parts—6,800 different components in all—it needs in-house.

Powerhouses from Pratt & Whitney Canada provide new propulsion

A crucial modification is the incorporation of two new, highly efficient Pratt & Whitney Canada PT6A-67R turboprop engines in place of the old radial engines. Featuring five-blade metal propellors, each of the new engines delivers 1,062 kW (1,424 PS), whereas each engine on a DC-3/C-47 delivered just 895 kW (1,200 PS). As the new composite engine nacelles are much wider than the old housings, the fuselage has been extended behind the cockpit by 1.06 meters to ensure the crew sit further forward than the propellors. This also increases the volume of the cabin by 35 percent. And pilots now have a state-of-the-art glass cockpit featuring the latest avionics, digital instrument displays and even blind-landing and all-weather capabilities.

Veteran-based new builds are cheaper

At first it might seem an odd decision to laboriously convert old veteran fuselages instead of just building a new BT-67 from scratch. But there is a simple reason for this: cost. “Testing an entirely new aircraft and getting it certified is more expensive than our conversions that tend to use only the fully renovated original airframe,” Varkoly says. New parts are generally manufactured according to the original specifications of the DC-3, which has an outstanding safety record.

Modern turboprop engines, shiny fuselages ___ *Basler turns DC-3 scrap metal into ultramodern special-purpose BT-67 aircraft.*

01 ___ *This 1946 military veteran is being transformed at Basler into a new special-purpose aircraft for commercial use.*

02 ___ *The new composite engine nacelles are so much wider that the fuselage has to be extended.*

03 ___ *The vast majority of the airframe is replaced, as is the skin.*

04 ___ *Only around 10 percent of the metal from the DC-3 is retained in the new BT-67.*

A small company like Basler could never afford a new certification. The price of a new BT-67 starts at around 12 million U.S. dollars, with many custom builds likely to be much more expensive. Each BT-67 is customized to cater for the huge variety of requirements depending on the given use case, the range of which is virtually limitless. The 69th BT-67 was completed by the end of 2022 and the 70th is already in the works.

Germany, Australia and China use these aircraft for research purposes and for supplying Artic and Antarctic bases with the help of the wheel/ski modification option. Varkoly is aware that it's really the stamina of his BT-67s that is more sought-after than ever before: “They can fly for up to 11 hours, and with long-haul auxiliary tanks even over 13 hours. A Twin Otter turboprop can manage just three to four hours.”

MORE INFORMATIONEN ON THE TOPIC "AVIATION":

Germany as pioneer: The dream of vertical takeoff
www.aeroreport.de/en

TEXT:

Andreas Spaeth has been traveling the world as a freelance aviation journalist for over 25 years, visiting and writing about airlines and airports. He is frequently invited to appear on radio and TV programs to discuss current events in the sector.

PT6 – the all-around talent

Guarantee of success — *The PT6A engine family is the world's most popular engine in its class. The experience acquired with the PT6A played a part in the creation of many other Pratt & Whitney engine families.*

An aviation classic, the Pratt & Whitney Canada PT6 turboprop engine first flew in 1961. It is available in different sizes for applications ranging from single-engine sports aircraft to helicopters. The largest variant of the PT6A is for heavier twin-engine aircraft like the BT-67 or the Short 360 regional commuter airliner. Approximately 12,000 of these large PT6A engines are around today, and it is estimated that, counting all variants, some 55,000 PT6 engines have been built to date.

MTU Maintenance Berlin-Brandenburg in Ludwigsfelde offers maintenance services as part of the P&WC Customer Service Centre joint venture with Pratt & Whitney Canada (P&WC). “We work on between 60 and 80 PT6A engines

Maintenance professionals — *Maintenance of the PT6A is performed at MTU Maintenance Berlin-Brandenburg as part of the worldwide Pratt & Whitney Canada Customer Service Centre.*

a year,” says Jens Arend, Director of Pratt & Whitney Canada programs at MTU Maintenance Berlin-Brandenburg. “Up to 50 percent of these are the large variant.” Ludwigsfelde has also serviced a pair of PT6A-67R engines, which power the Basler BT-67, but these particular examples were on the wings of a Short 360.

The Queen of the Skies retires

The iconic jumbo jet first took off in 1969, and now the 1,574th and last Boeing 747 has been produced. This is just one of the many extraordinary achievements of this special aircraft.

Text: *Andreas Spaeth*

A glorious era came to an end at the start of 2023: after 56 years, production of the Boeing 747 is shutting down. The last of its kind is also the 1,574th one built, a 747-8F freighter that Atlas Air will operate for the logistics group Kuehne & Nagel. The Boeing 747 achieved the greatest quantum leap in the history of passenger aviation: its predecessor, the Boeing 707, could hold only up to 189 passengers, but the jumbo jet was initially certified for up to 550 passengers and later could carry as many as 660.

It all started on a fishing trip

The creation of the 747 is the stuff of myth and legend. In 1965, Boeing CEO William Allen and Pan Am founder Juan Trippe, the two most influential men in aviation at the time, were on their annual salmon fishing trip when they made a gentleman's agreement to build the world's largest passenger jet. They sealed the deal with a handshake and without signing any official documents. Today, it's hard to believe that a project that risked the future of both companies and would cost billions of dollars came about in such an informal way. "Basically, Tripp said, 'You build it, I'll buy it.' And Allen replied: 'I'll build it if you buy it.' They didn't sign a contract, but that was the start of the program," recalled chief engineer Joe Sutter, the "father of the 747," who died in 2016.

In today's digital age of computer design and virtual 3D models that can be created with a few mouse clicks, it's hard to imagine the challenge that the Boeing 747 engineers faced in the mid-1960s. It was clear that the airlines, especially Pan Am, wanted a much larger aircraft than had ever been built before—in other words, completely uncharted territory. For Trippe, the 707 was the benchmark, so he held on to the original idea of a double-decker aircraft for a long time. The plan was to mount two slightly enlarged 707 fuselages on top of each other. Initially, there were more than 200 design drafts for the 747, many of which came from a tender for a new military transport aircraft that Lockheed had won with the C-5A. About 50 designs were looked at more closely, almost all of them double-decker. By mid-1965, however, Boeing had abandoned the idea of using the 707 as a base, whether stretched or double-decker.

BOEING 747

Maiden flight in
1969

1,574
aircraft built

Capacity for up to
660
passengers

The dawn of an era — *Held in Everett in 1968, the unveiling ceremony for the Boeing 747 prototype was attended by cabin crews from all customer airlines.*

Production facility in Everett ___ *Workers stand in the cockpit area of the full-size 747 mock-up three floors above the ground.*

Just bridging the gap until the supersonic era

The 747 was initially intended to be merely a transitional aircraft, biding time until most intercontinental passengers would fly at supersonic speeds in either the Concorde or the Boeing SST, which were being developed at the same time. After that, she was to remain in operation as a freighter. The cockpit was therefore moved above the main deck to make space for a fuselage nose that could be opened upward, allowing for easy loading. This configuration left a small area behind the cockpit, the 747's famous "hump." Instead of building two narrower decks on top of each other as initially considered, the 747 was equipped with just the one main deck. However, it offered the widest cabin ever seen in a passenger aircraft, measuring over six meters across; seats could be removed to accommodate two cargo containers side by side. On April 13, 1966, Pan Am announced an order for 25 Boeing 747s, valued at 525 million U.S. dollars (about 4.8 billion U.S. dollars today), thus officially launching the 747 program.

Wooden mockup of the JT9D ___ *The Pratt & Whitney engine was the first jet engine with a high bypass ratio to power a widebody aircraft.*

The contract with Pan Am called for an aircraft that could carry 370 passengers and their luggage, with a range of at least 8,263 kilometers at a speed of Mach 0.877—nearly 88 percent the speed of sound. To build the 747 production facility, in June 1966 Boeing purchased about 780 acres of wooded marshland near the Paine Field airport in Everett, a city north of Seattle, Washington. Today, it is still the largest building in the world by volume. By comparison, the fourth largest is currently the former Cargolifter airship hangar in Brandenburg, and Berlin's Tropical Islands resort would fit inside the 747 production halls two and a half times over. Building the production facility was a merciless race given the purely analog tools of the time. The factory was being built while work on the 747 design was still in progress.

Wooden models of the aircraft were essential

Under this intense time pressure, the engineers built wooden models of individual parts and of the entire aircraft in order to see how they worked and to test the production processes. Everything was meticulously planned—the prototype was to fly within two years, and the rollout for the Boeing 747 was set for September 30, 1968. All this less than three years after Pan Am signed the letter of intent to order and only two and a half years after the widebody design was agreed upon. The team was able to keep to this extremely ambitious plan: the new Queen of the Skies appeared precisely on time.

The "Spacious Age," as the 747 era was called, officially began with the aircraft's maiden flight on February 9, 1969. It lasted an hour and 16 minutes and went unusually smoothly. However, the huge Pratt & Whitney JT9D engines, in their still unimagined dimensions, became one of the biggest problems of the 747 flight tests. It was also the engines that delayed the 747's debut passenger flight for first operator Pan Am on the route from New York to London on January 21, 1970. Nevertheless, the 747 quickly made a name for itself, entering regular service with airlines around the world at incredible speed.

By 1975, the global 747 fleet had carried 100 million passengers. Probably the most important decision for the 747's long career was made in 1985 with the launch of the 747-400. This was the twelfth version of the jumbo jet, but by far its most successful. Boeing sold nearly 400 units of the 747-200, but the upgraded 747-400—featuring a glass cockpit, longer upper deck, improved turbofan engines (Pratt & Whitney's PW4000 or GE's CF6) and winglets—managed to tally nearly 700 orders over the next two decades. It first entered commercial service in 1989. In October 1993, Boeing reached another important milestone with delivery of the 1,000th 747, which went to Singapore Airlines.

Boeing and Lufthansa launched the refurbished 747-8 in 2005

The original concept from the 1960s has certainly proven its staying power. One illustration of this is that Boeing, together with launch customer Lufthansa, decided in 2005 to issue another 747 generation—even though there was now a competitor with a full two decks in the form of the Airbus A380. The Boeing 747-8 was created with the active participation of the still sprightly 747 legend Joe Sutter. Four decades after the first 747 was produced, Boeing was now stretching the fuselage for the first time, making the 747-8 the longest aircraft in the world. The Boeing 777-9 will break that record when it enters commercial service in the next few years.

The 747-8 received new wings and engines, both taken from the successful Dreamliner, the Boeing 787. But then it was precisely this new generation of ultra-efficient twinjets that put an end to the production of all four-engine long-haul widebody jets. However, the Boeing 747 will continue to play a major role once the U.S. Air Force's two new presidential aircraft are ready. They are expected to take off starting in 2027.

TEXT:

Andreas Spaeth has been traveling the world as a freelance aviation journalist for over 25 years, visiting and writing about airlines and airports. He is frequently invited to appear on radio and TV programs to discuss current events in the sector.

Fast facts about the Boeing 747

75,000 technical drawings by engineers and **15,000** hours in the wind tunnel were needed to build the first Boeing 747.

A Boeing 747-400 consists of **six million** parts, **half of** which are **rivets**.

With a **volume of 876 cubic meters**, the Boeing 747-400 offered the largest interior space at the time (later surpassed by the 747-8 and the Airbus A380). That's the equivalent of **more than three houses with 135 cubic meters of living space each**.

274 kilometers of cable run through a Boeing 747-400.

The **wingspan** of a Boeing 747-8 is equal to **the length of two Boeing 737-700s** placed end to end.

At 19.5 meters, the tail **assembly** of a Boeing 747 is **as high as a six-story building**.

The wings of a Boeing 747-400 cover an area of **524.9 square meters**—enough space to park **45 midsize cars**.

The engine noise of the Boeing 747-400 in 1989 was only **half as loud** as that of the first 747-100 in 1969.

By 2017, **over 5.6 billion people** had flown in a Boeing 747—over 80 percent of the global population at that time.

As of 2017, the global 747 fleet had traveled more than **78 billion kilometers, equivalent to 101,500 trips to the moon and back**.

The cockpit of the Boeing 747-400 has only **365 switches**, **dials and lights**, compared with **971** in the Boeing 747-100.

Aerial refueling

Even with state-of-the-art technology, refueling a fighter jet during flight remains an adventure that calls for maximum aeronautical skill and experience.

Text: *Tobias Weidemann*

Fascinating maneuvers *Refueling a fighter jet in the air extends its range and prevents it from having to waste time making strategically inconvenient stopovers.*

Oversized shuttlecock
In this refueling method, the probe of the aircraft requiring fuel is guided into the drogue.

Aerial refueling is still one of the most fascinating maneuvers in aviation: A specially equipped transport aircraft, such as an Airbus A330 MRTT, carrying fuel proceeds to a prescribed position in restricted airspace—in Germany, this risky maneuver is permitted only in a few sparsely populated areas. The fighter approaches from the rear until it is just 20 meters away. As soon as both aircraft are in position and are connected, the refueling process begins and lasts for approximately ten minutes. Depending on the refueling procedure in question, the transporter delivers up to 1,590 kilograms of fuel every minute—at an altitude of between 1,500 and 10,000 meters and while flying at a speed of around 500 kilometers an hour.

The whole process is monitored by an Air Refueling Officer (ARO), who has the controls to adjust the volume of fuel to be delivered and—based on the weather and other local conditions—the speed of the refueling process. To help manage the process, the ARO has access to video and infrared camera systems mounted to the side of the fuselage, which also facilitate reliable docking during hours of darkness. The job of maintaining the short distance between the aircraft and gently making any course corrections falls to the autopilot. Ideally, however, aerial refueling is performed in fair weather with clear skies, good visibility and steady wind conditions. And despite today's technical possibilities, it still calls for maximum aeronautical precision and experience.

Such operations often involve refueling multiple aircraft, one after another in an intricately planned schedule, before the flying fuel pump returns to the military base. It is also not uncommon to refuel two aircraft simultaneously, provided the weather and airspace conditions permit.

The MRTT—which stands for multi-role tanker transport—version of the Airbus A330 is a versatile transporter. In addition to its uses as a freighter or passenger aircraft, it can also be converted into a flying intensive care unit or, indeed, serve as a flying fuel pump capable of carrying up to 111 metric tons of fuel. To date, this military version of the A330-200 commercial model is in service with four air forces (including the Bundeswehr) and on order for seven countries and NATO. Incidentally, the practice of aerial refueling is exclusive to the military; in commercial aviation, the need to comply with safety requirements means it would be effectively uneconomical and impracticable.

Boom systems vs. probe-and-drogue solutions

There are essentially two established methods of aerial refueling. If a boom system is used, the refueler positions itself in front of the receiving aircraft. The rear of the refueler is equipped with a boom that has limited maneuverability, which allows it to dock with the receiving aircraft's fuel tank. Locking the boom and nozzles in place completes an electrical circuit that starts the pressurized pumping of the fuel. During refueling, the receiving aircraft flies in formation either behind or below the tanker aircraft. At the end of the refueling process, the valves are sealed and the telescopic boom is retracted.

An alternative method is to use a probe and a drogue, which resembles an oversized shuttlecock. This is attached to a flexible hose that trails behind the refueler. To refuel, the refueler flies in front of the fighter, whose pilot guides the probe into the drogue. The force of the air flow on the drogue establishes a connection between the fuel probe tip and the valve. Once locked, the pressurized refueling process begins.

Automatic air-to-air refueling (A3R) —— *The air-to-air refueling system reduces the ARO's workload with the help of automation.*

This method requires the pilot of the receiver aircraft to fly with greater precision; with the boom solution, it is more a question of how well the ARO can maneuver the rigid boom within its limited scope of movement. While the boom's larger diameter makes it the faster refueling method, the probe-and-drogue method's 22-meter hose allows the two aircraft to be farther away from one another and thus reduces the risk of collision.

All popular refuelers, including the Airbus A330 MRTT, are suitable for either of these methods. Which one is used depends on the refueling certification given to the aircraft type in question. In addition to these two main concepts, there are also combination solutions that feature both a boom and one or several drogue systems.

Refueling aircraft will soon be largely autonomous

Although the first forays into aerial refueling were made back in the 1920s, and the various concepts have been refined over the decades, the next few years will also see technical innovations that will trigger further enhancements. For instance, the Airbus A330 MRTT is the first tanker to be certified for automated aerial refueling during daylight.

To gain certification, Airbus developed its automatic air-to-air refueling (A3R) system, which uses automation to potentially reduce the ARO's workload to simply monitoring the process. Using automated and IT-driven image recognition and processing, the video and infrared camera systems make it easier to align the boom tip with the receiving aircraft's intake to within a few centimeters. The correct alignment and the stability of the receiving aircraft can be verified in real time.

The system requires no conversion of the receiver aircraft and can make performing refueling operations safer in weather conditions that are less than ideal. In the medium term, this type of refueling process will run largely autonomously and prove reliable even under adverse visibility and atmospheric conditions. One of the goals of the follow-up project, A4R, will be to automate the tasks carried out by the receiving aircraft.

Even if this technology were to relieve some of the burden on the crew, planning these operations will still call for extensive experience and aeronautical skill. But it should make it possible to perform aerial refueling under more difficult conditions than the ones pilots are able to tackle today.

TEXT:

Tobias Weidemann has been working as a journalist and content consultant for more than 20 years. He writes about technology and business topics, often with a focus on business IT, digitalization and future technologies.

The gravity of services to sciences

Parabolic flights in an Airbus A310 let astronauts and researchers achieve weightlessness without going into space.

Text: *Andreas Spaeth*


E3
6
E11
7

22 seconds of weightlessness
To achieve weightlessness outside of space, special aircraft perform parabolic flights.

Special missions
Space agencies such as the German Aerospace Center (DLR) or France's CNES use parabolic flights for scientific purposes.

Parabolic aircraft
Most of the cabin is empty, with mats and padding all around.

What is parabolic flight?

These are special missions where the aircraft flies along the line of a parabola up to a maximum of 31 times in a row. This creates weightlessness on board for up to 22 seconds each time, as if in space. The principle is based on physical laws: An object is weightless when it is in free fall. If you throw a ball into the air, it is weightless and will follow a parabolic trajectory. An aircraft performing a parabolic flight achieves free fall while it is on this trajectory much as the ball does.

What are parabolic flights used for? By whom?

For scientific experiments to be performed on or by humans in zero gravity, the only option (aside from traveling to outer space) is parabolic flights. That makes these flights especially important for the preparation of space missions and experiments planned for them, but also for research in general. Many substances as well as biological, physical or medical processes can be produced or studied particularly well under zero-gravity conditions. Astronauts and scientists use parabolic flights to acclimate their bodies to space and to familiarize themselves with experiments to be conducted there. However, most providers also let members of the general public fly on certain flights for prices of around 6,000 to 8,000 euros per person.

What is a typical parabolic flight like?

From a normal cruising altitude of about 6,000 meters, the aircraft goes into a steep climb. After 20 seconds, it reaches a pitch angle of about 50 degrees, compared to the 18 degrees that are usual during takeoff. This subjects the aircraft to “hypergravity,” a force equal to 1.8 times the Earth’s gravity (1.8 g). During this phase, which is the most strenuous for the body, the aircraft’s occupants are usually lying on the cabin floor. At this point, the pilot cuts back on the power, setting the engines almost to idle. Even without forward thrust, the aircraft gains almost another 1,000 meters of altitude thanks to the physics of momentum alone before entering free fall along a trajectory shaped like a downward-opening parabola (hence the term “parabolic”). By the time it reaches the apex of the parabola at roughly 8,500 meters, the aircraft’s velocity is only about 380 km/h. During the last phase of its climb, at its highest point and while the aircraft heads downward at a steep pitch angle of 42 degrees, there is a total of 20 to 22 seconds of zero gravity on board. Then the pilot steps back in, applying

01

02

03

04

04 *Novespace is Europe's only operator of parabolic flights.*

01 *The Spacebike experiment investigates the extent to which weightlessness changes the control the human brain has over muscles during "normal" movement.* **02** *Researchers discuss how to test a concept for filling and transferring liquid propellants in a weightless environment.*
03 *The "CoolFly" experiment investigates the effect of cooling clothing on human circulation.*

strong thrust to bring the aircraft back into level flight—1.8 g of hypergravity again prevails for about 20 seconds.

What's the history of parabolic flights?

In the 1950s, the U.S. and the Soviet Union used two-seater fighter and training jets for astronaut training in zero gravity. Then in the 1960s, NASA was the first to operate larger special-purpose aircraft such as converted KC-135 tankers (the military version of the Boeing 707) to fly parabolic flights. These aircraft were nicknamed "the vomit comet." In 1989, the French space agency CNES put a converted Caravelle into service as the first European parabolic flight vehicle, which flew missions until 1995. The Soviet Union converted a total of three large Ilyushin Il-76 MDK transport aircraft for this purpose. From 1996 to 2014, Europe's Novespace operated the oldest surviving Airbus A300 for zero-g missions. Built as the third prototype in 1973, today the aircraft is on exhibit at Cologne Bonn Airport.

What equipment do these aircraft carry?

Former commercial aircraft that are converted for parabolic flights are left with just a few seats, which are used during takeoff and landing. Most of the cabin is empty, with mats and padding all around as well as rails to which the experiments can be fixed. In the cockpit, there are additional accelerometers and screens showing the activity in the cabin. Only in the Ilyushin Il-76 MDK were structural changes made and the oil and fuel supply to the engines modified.

What aircraft can fly parabolic flights?

A handful at most. In the U.S., a Boeing 727-200 built for Braniff in 1976 continues to fly and has been performing zero-g flights for both NASA and enthusiasts since 2004. The Europeans have an Airbus A310-300 with a 33-meter cabin, which is the largest parabolic aircraft currently in service. It can carry as many as 40 passengers on board and is operated by Bordeaux-based Novespace under the name AirZero G. This aircraft has a special history: Initially, it was delivered to the East German airline Interflug in 1989. Then, in 1991, it became the VIP aircraft of the German Air Force's Special Air Mission Wing. Christened "Konrad Adenauer," it flew Chancellor Helmut Kohl and later Angela Merkel and their respective ministers around the world. In 2014, the A310 took up its new role at Novespace.

TEXT:

Andreas Spaeth has been traveling the world as a freelance aviation journalist for over 25 years, visiting and writing about airlines and airports. He is frequently invited to appear on radio and TV programs to discuss current events in the sector.

A BRIEF GUIDE:

The Future Combat Air System

As a system of systems consisting of various platforms and components, FCAS will be significantly more effective than previous air defense systems.

System of systems *FCAS is divided into seven pillars: New Generation Fighter, Next European Fighter Engine, Remote Carriers, Air Combat Cloud, Simulation, Sensors and Stealth.*

The Future Combat Air System (FCAS) is the European air defense system that is set to enter into service in 2040. Germany, France and Spain are working together on this. The development of FCAS is divided into several pillars, with each pillar involving companies from all three partner nations. The engine for Europe's next-generation fighter is one of these pillars.

FCAS will be far more than a network of conventional combat aircraft. While the centerpiece is the New Generation Fighter, a next-generation jet with a human pilot, this is supplemented by unmanned components known as remote carriers. Together, they form the Next Generation Weapon System. A combat cloud ensures that all information within the corresponding network is available in real time to all units involved in a mission. FCAS is referred to as a systems of systems because of its complex digital network.

NGF
The sixth-generation fighter jet is at the heart of FCAS.

NEFE
A powerful engine for a powerful fighter.

Overview of the pillars of the Future Combat Air System:

- **New Generation Fighter:** A sixth-generation fighter jet that enables connectivity between the fighter and unmanned components. It uses more advanced key technologies—particularly in the field of electronics and sensors.

- **Next European Fighter Engine:** Engine specialists MTU and Safran are developing the engine for the New Generation Fighter under the leadership of their EUMET (European Military Engine Team) joint venture and in collaboration with their main partner ITP Aero. MTU is responsible for its core competencies of high-pressure and low-pressure compressors and the compressor intermediate case as well as for parts of the control systems, and is the lead company for aspects of engine maintenance.

- **Remote Carriers:** Unmanned components that interact with the fighter jet and support it in reconnaissance, electronic warfare and effectiveness. The unmanned components reduce the mission risks to the combat aircraft and their pilots.

- **Air Combat Cloud:** A protected IT system that serves as a digital backbone connecting the combat aircraft and the unmanned components for the exchange of information. Its open system architecture also permits the integration of existing systems (such as the Eurofighter or A400M), new systems (such as the Eurodrone) and other dimensions (land, sea, space and cyber).

The remaining pillars deal with the topics of simulation, sensors and stealth.

Europe's most strategic defense program has now entered its next phase: on March 20, 2023, the contract between the industrial partners of the participating nations went into force. The demonstrator phase will extend through 2028/2029. FCAS is then scheduled to be available from 2040 onward.

HUMOR

At a recent factory visit:

Statements we know well

Today: Parabolic flight

"Oh no, here we go!"
"Ahhhhhhhhh!"
"Let me try doing a flip."
"Aww, is it over already?"
"PASS ME A BARF BAG, QUICK!"

Top tips

PARABOLIC FLIGHT

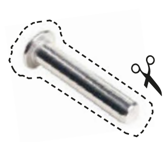
If you can't afford a parabolic flight, just throw a math textbook across the room and watch as it arcs through the air.

AERIAL REFUELING

People who reach their flight at the last minute, so there's no time for a drink on the ground, might want to consider aerial refueling instead.

READERS' MODEL MAKING

Today: Boeing 747



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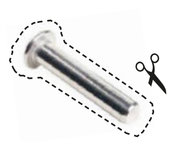

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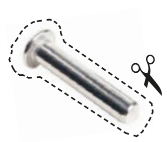
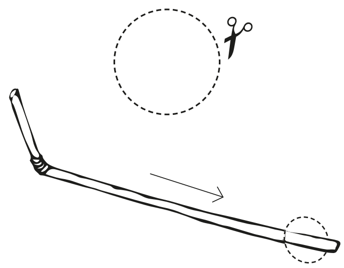


Part 3 of 6,000,000

Part 4 of 6,000,000

READERS' FLIGHT SCHOOL

Today: Aerial refueling



Try to get the end of the straw through the hole, ideally while you're running through the office making airplane noises.

MASTHEAD

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