

AEROREPORT 01|17

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

Preserving assets

Customized aircraft engine maintenance for a growing and changing worldwide market



TECHNOLOGY

Minor repair job—
major effect for V2500
compressor drums

TECHNOLOGY

Protection covered
Coatings for better
engine performance

PARTNERS

Researching together
with Leibniz
Universität Hannover



Value testing — Overhauled engines have to undergo ground tests to ensure that their performance is up to standard before they can be returned to the customer, such as this V2500 undergoing tests at MTU Maintenance Hannover. One of the crucial parameters is the exhaust temperature.

Dear readers,

Aircraft engines are extremely valuable capital assets. They retain their value over a long period of time, despite wear and tear in flight operations. An entire sector of the aviation industry is devoted to the maintenance, repair and overhaul of aircraft engines—and that sector of course includes MTU Maintenance. The market is currently undergoing change: new engines increasingly come packaged with a fly-by-hour-agreement. For OEMs and their partners, the advantage of such an agreement is that they start earning from the first flight hour rather than only when spare parts are sold. Airlines benefit from having cost control from the outset.

However, fly-by-hour-agreements don't make economic sense for every airline and engine. Billing actual expenses or lower-cost repairs can be more profitable solutions for older engines. One of our strengths at MTU Aero Engines is that our broad portfolio has a suitable offer for every operational scenario. In fact, recent data corroborates this: in 2016 MTU's commercial engine maintenance business once again achieved year-on-year growth of over 20 percent. Employees at our MRO locations handled 980 shop visits and a further 300 smaller orders.

In this issue of **AEROREPORT**, we highlight MTU's expertise in this area and, as always, take a look at the bigger picture. We also talk to IATA CEO Alexandre de Juniac about technology and politics in civil aviation, introduce the Institute of Turbomachinery and Fluid Dynamics at Leibniz Universität Hannover and present technologies and techniques that help preserve the value of engines.



I hope you enjoy reading this issue!

A handwritten signature in blue ink that reads "Reiner Winkler". The signature is fluid and cursive, written in a professional style.

Reiner Winkler
CEO



COVER STORY

Preserving assets

Aircraft engines are significant investment assets, in which billions of dollars are spent to assure their maintenance. From a technological point of view, they have no age limit, but each engine age and application requires and is given the optimum level of service in terms of cost efficiency.

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PARTNERS

Viva la Evolución

MTU Maintenance customer AeroMexico is the leading airline in Latin America's most prosperous economy. Like the country itself, it has been making great strides on the path to modernization, and has improved its profits through fleet renewal programs and a more reliable service.

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PARTNERS

Researching the supreme discipline together

Leibniz Universität Hannover is one of MTU's research partners. Its MRO Center of Competence, part of scientific alliance with MTU Aero Engines, develops new methods and tools for future engine maintenance strategies.

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**EXPERTISE**

“We need strong partnerships”

Alexandre de Juniac, Director General and CEO of the International Air Transport Association IATA, is convinced that the aviation industry has sufficient innovative capacity to find solutions to the growing demand for air travel—but only if everyone pulls together, as he said in an interview with **AEROREPORT**.

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**TECHNOLOGY**

We’ve got protection covered

More than half of the components in an aircraft engine are treated with special coatings. Millimeter-thin layers of metallic or ceramic materials provide protection against heat, erosion by sand or dust, and chemical agents. In the quest to design more efficient propulsion systems with higher combustion temperatures, thermal coatings have become a key technology.

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**TECHNOLOGY**

Minor repair job – major effect

Sometimes a seemingly insignificant component can have a considerable impact. In the case of the high-pressure compressor for the V2500 engine, thin vibration damping rings were reducing the service life of the entire housing. The problem was solved by introducing tongue-and-groove joints to connect the wire ends and applying a coating in a spark-free manner to the walls of the enclosure.

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TECHNOLOGY

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All articles from the print edition are also available online at www.aeroreport.de, optimized for smartphone and tablet. There you find informative videos, photo galleries, zoomable images and other interactive specials too.

GTF collaboration



Signing _____ MTU Chief Program Officer Michael Schreyögg (left) and Johannes Bußmann, CEO, Lufthansa Technik.

MTU Aero Engines and Lufthansa Technik to set up maintenance company. MTU Aero Engines and Lufthansa Technik plan to set up a joint maintenance company for Geared Turbofan™ engines. Each partner will hold 50 percent of the shares. Both companies signed an agreement to this effect on February 20 in Berlin, with the joint venture company expected to be set up in the second half of 2017. The new location is to start operations in 2020 with over 500 employees and a planned capacity of over 300 maintenance jobs per year.

Rapid support from Brandenburg

Pratt & Whitney Canada Customer Service Centre Europe (CSC) celebrates its 25th anniversary. MTU Maintenance Berlin-Brandenburg and Pratt & Whitney Canada founded their joint venture to provide customer support for P&WC engines in Europe, the Middle East and Africa (the EMEA region) on March 21, 1992. “Our launch customer was LeaseCo; Wideroes, Norsk Luftambulance and Jet Aviation were among the first companies to take advantage of our services,” reports CSC general manager Carsten Behrens. Customers range from business executives and commercial airlines to air rescue services such as

ADAC and Tyrol Air Ambulance. The number of employees has grown from 35 in the first year of operation to nearly 60 today, spread over five locations in Germany, France, England, Poland and South Africa. Since its creation in 1992, CSC has performed maintenance, repair and overhaul work on more than 12,500 engines and components. “Our intake for shop visits averages between 600 and 650 per year, plus approximately 200 on-site interventions by our mobile repair team,” says Behrens. The provision of lease engines and the sale of new and previously owned engines round off the current service portfolio.



Ahead of schedule

Embraer commences flight tests of E195-E2. Brazilian airframe manufacturer Embraer has not only rolled out its new E195-E2 six months earlier than originally announced but also carried out the first flight test at the end of March. During the two-hour flight, the test pilot retracted the landing gear and tested the fly-by-wire system in manual mode. According to Embraer COO Luis Carlos

Affonso, the pilots reported that the 120- to 142-seater aircraft's performance was just as good as the smaller E190-E2, which made its maiden flight in May 2016. "By the end of the two-year flight test campaign in 2019, we will be able to deliver a technically mature and fully reliable aircraft to our launch customer, the Brazilian low-cost carrier Azul," says Affonso. A second E195-E2-prototype is

scheduled to perform its first flight before the end of the year. Compared with the standard E195-E1 version, the E2 evolution offers three more rows of seats and an extended range of up to 2,450 nautical miles. Embraer claims that the E2 also reduces fuel consumption per seat by up to 24 percent. Both the E195-E2 and the E190-E2 are powered exclusively by PW1900G Geared Turbofan™ engines.

Nonstop from Cheapside to Wall Street

Bombardier demonstrates CS100's capability to fly nonstop between the two financial centers.

Until now, the banker shuttle between London City Airport (LCY) and New York (JFK), so-called because it links the airports closest to the world's two major financial centers, has been operated by British Airways using an A318. But the aircraft is obliged to make a refueling stop at Shannon Airport in Ireland because LCY's short runway restricts the payload at takeoff. Bombardier has now demonstrated that its CS100 is capable of flying this transatlantic route nonstop, at least in a 40-seat, all-business-class configuration.



London City Airport's downtown location demands fuel-efficient, low-noise engines and specially trained pilots. After a series of steep-approach trials, the CS100 with registration C-GWYD rose into the cloudy spring sky above London shortly before midday and landed in New York a little after seven p.m. after

flying nonstop across the Atlantic. Bombardier expects to obtain steep-approach certification for the CS100 very soon, after which it can enter service with Swiss on its proposed route to and from LCY. The C Series family is powered exclusively by PW1500G engines. MTU holds a 17 percent share in this engine program.

Renewed growth

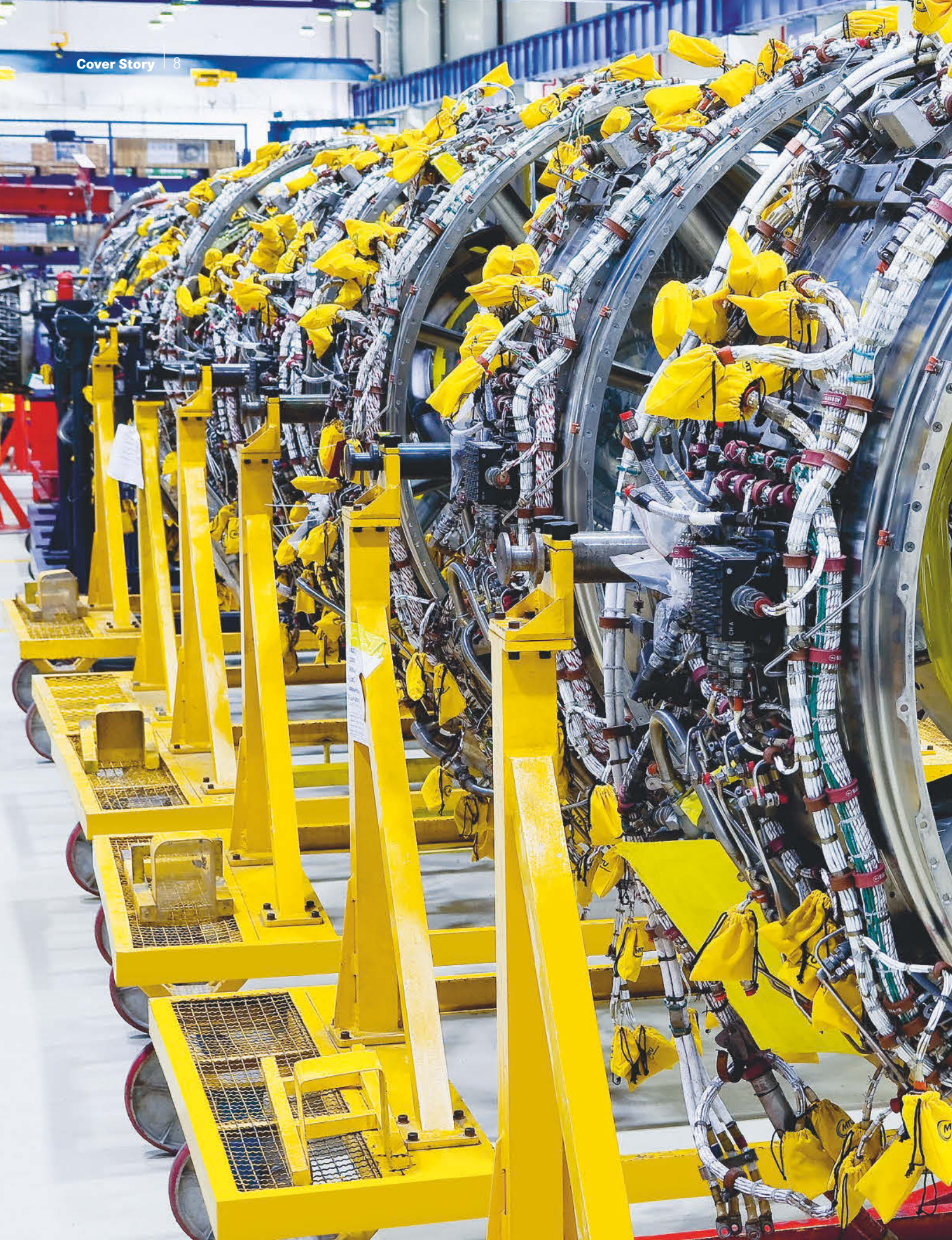
MTU Maintenance performance in 2016

Revenue from MTU's commercial maintenance business saw a year-on-year increase of over **20** percent in 2016, making it the second time in a row that such a high growth rate was recorded.

Over **250** new contracts and individual orders accounted for an order value of **2.2 billion** U.S. dollars.

In 2016, employees at the MRO locations handled **980** repair and overhaul shop visits as well as around **300** smaller orders.

MTU Maintenance won **26** new customers in 2016. These include Sky Regional Airlines, BH Air, Garuda Indonesia, VivaAerobus and Kenya Airways.



Preserving assets

Engines are valuable capital assets. That's why billions of U.S. dollars are invested in maintenance and repairs every year. And this figure continues to rise: engine maintenance is becoming a growth market thanks to the increase in air traffic and new digital technologies.

Text: *Monika Weiner*

Market leader in Asia — V2500
fan housings at MTU Maintenance Zhuhai.



Inside view

Two employees at MTU Maintenance Hannover carry out a borescope inspection of a V2500 engine.

“From a technological point of view there is no age limit. We see it with the V2500. Some of these engines are almost 30 years old now and still fully functional.”

Leo Koppers

Senior Vice President Marketing and Sales, MTU Maintenance

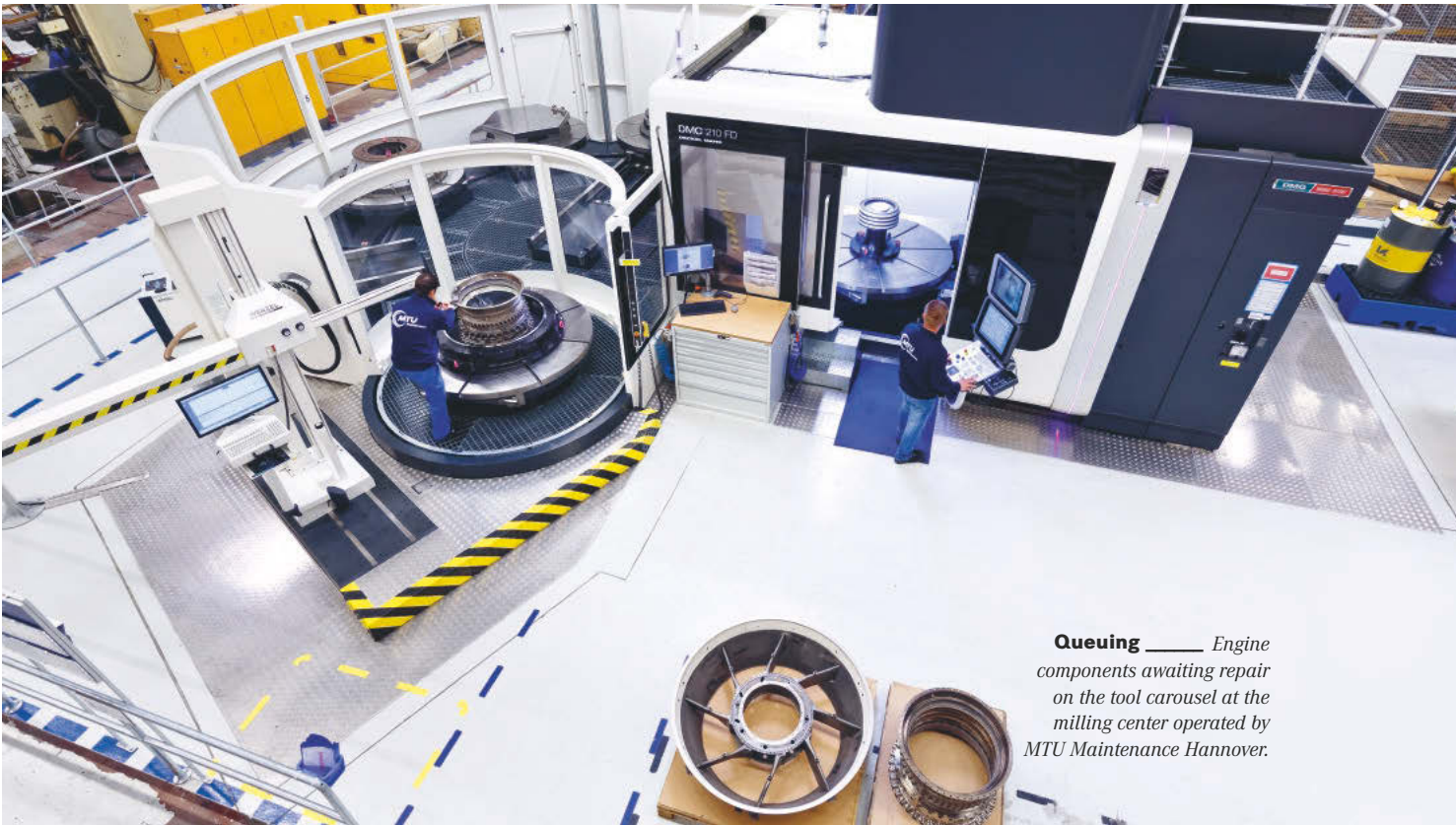
Too old to fly? Engines only get older. “From a technological point of view there is no age limit,” says Leo Koppers, Senior Vice President Marketing and Sales at MTU. “We see it with the V2500. Some of these engines are almost 30 years old now and still fully functional.”

However this requires some work, as engines are, of course, subject to wear and tear in flight. Maintenance intervals are dictated by strict safety regulations, and the components also wear more quickly depending on where the engine is used: in 2015 almost 30 billion U.S. dollars were spent worldwide on engine maintenance, repair and overhaul, or MRO for short. For 2025, the forecast is 46 billion U.S. dollars. That is a lot of money for airlines feeling the cost pressure from intense competition. The question as to why it is still worth their while investing increasingly high sums to make their engines last forever, or at least for a long time, is one that Dr. Andreas Sizmann, Future Technologies and

Ecology of Aviation expert at Bauhaus Luftfahrt, has the answer to. “First and foremost, airlines want to secure the availability of their fleets, because any downtime is associated with high losses. At the same time, they’re pursuing the goal of keeping maintenance costs as low as possible.”

All aircraft owners have different requirements

The amount an aircraft owner is willing to spend depends on many factors. First there are external constraints, such as maintenance intervals that are required by law and must be complied with. However another important factor is the age of the engines, and whether the aircraft are the property of the airline and are set to remain so over the long term, or whether they are leased. With owned aircraft, the airline itself can determine the time-scales for flight operations. Leasing companies that are interested in retaining the value of their aircraft may demand specific maintenance work and closer maintenance intervals. The conclu-



Queuing — Engine components awaiting repair on the tool carousel at the milling center operated by MTU Maintenance Hannover.

sion to be drawn from this is that the market is huge, but every customer is different.

And there are considerable differences among MRO service providers, too: on the one hand there are the original equipment manufacturers (OEMs), including e.g. GE Aviation, Rolls-Royce and Pratt & Whitney. The original parts they offer are expensive, but these improve value retention. This is an important criterion for owners who want to resell their aircraft ten to fifteen years down the line. Yet a range of comprehensive services is also offered by independent suppliers such as MTU Maintenance, who are able to install original parts but do not necessarily have to. However, all MRO service providers have things in common: they are continuously developing new technologies that allow maintenance work to be optimized and—for jobs that cannot be avoided—completed in the quickest possible time.

“One promising approach is electronic engine monitoring,” explains Koppers. “There are dozens of sensors taking in-flight measurements of exhaust gas and engine temperature, fuel and oil consumption, vibrations, and the pressure in the compressor, combustion chamber and turbines. The data can be read out after the flight or sent via satellite from the on-board computer to the ground station and instantly evaluated there. This allows us to detect technical problems early on, plus it enables us to better plan any necessary maintenance work.” In this way, the shop visits can be adapted to actual requirements. If an engine is mainly

BIG DATA IN ENGINE MRO

On average, an aircraft engine produces

one terabyte of data
during a single flight.

A Geared Turbofan™ engine collects data on more than

5,000 parameters
during a single flight.

When extrapolating this to the entire fleet of Geared Turbofan™ engines, the data collected in one year amounts to

two petabytes (one petabyte equals 1,000 terabytes or 10 to the power of 15 bytes). However, this is still lower than the storage capacity of the human brain, which neuroscientists estimate at 2.5 petabytes.

used in desert regions, for instance, where there is a lot of sand and dust in the air, it has to be sent to the engine shop sooner than an engine operating in northern Europe or North America.



Inside view
Borescope examination of an engine at MTU Maintenance Hannover.



Preparations
A V2500 high-pressure compressor before high-speed grinding.

NARROWBODY ENGINES: NUMBER OF SHOP VISITS IN 2016

Engine	In-service fleet	Number of shop visits*
V2500	5,850	800
CFM56-3	1,716	245
CFM56-5B/5C	7,070	600
CFM56-7	11,750	810
PW2000	562	110
JT8D-200	760	160

*estimate, source: Flightglobal Fleet Analyzer, March 2017

Increasingly long on-wing times

“Overall the trend is moving towards ever longer maintenance cycles,” emphasizes Koppers. “This is down to both improved monitoring and increasingly reliable technology. While the V2500 required up to five shop visits over its lifecycle, new NextGeneration engines like the PW1100G-JM or the LEAP will be able to make do with three, based on current trends.” And fewer shop visits mean less downtime and lower costs: for a full service, the engine has to be removed and a replacement engine installed, which takes at least eight hours. In the meantime the engine to be overhauled is brought by aircraft to the engine shop. Mechanics are on hand to clean, test and, if necessary, replace the components (see infographic, p. 16). That can take weeks and costs millions in high-quality materials and spare parts. What’s more, much of this complex work is not only technologically challenging, it is pure manual work. So any shop visit saved or postponed is a win.

Of course, such visits cannot be delayed arbitrarily: because single components like blades and sealing

“We also help the customer ensure that the engine is ready for operation whenever it’s needed, and that it can be sold at the best possible price in the end.”

Leo Koppers
SVP Marketing and Sales, MTU Maintenance

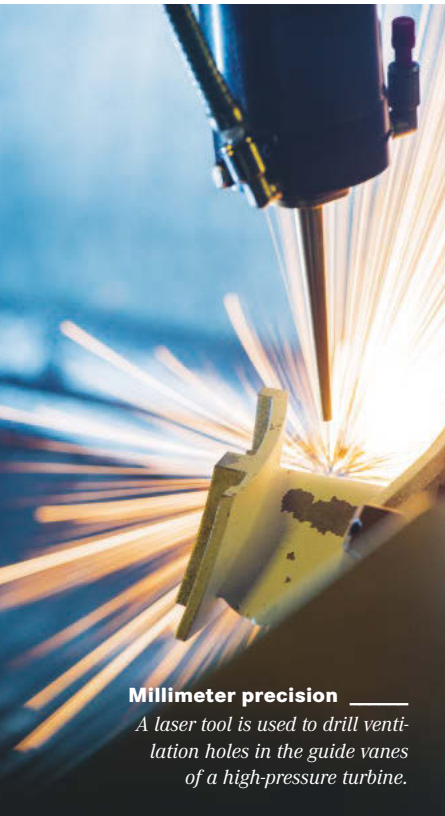
segments are subject to extreme loads, the engine’s performance decreases over the course of time. As its level of efficiency drops, the combustion temperature and fuel consumption increase, which is noticeable by the higher exhaust gas temperature (EGT). The drop in the difference between the permitted maximum temperature and the temperature in flight, the EGT margin, demonstrates the need for and success of maintenance work. In order to bring the EGT margin—and with it the engine’s efficiency—back up, a shop visit must reduce the clearance between the blade and the abradable lining in the high-pressure turbine, for example. To achieve this, linings are fitted to the inside of the casing, or a layer of hardfacing material is soldered onto the blade tips.

Cost optimization for older engines

The first shop visits may be expensive, but costs really jump once an aircraft reaches the end of its life after 25 to 30 years. That’s why MRO providers such as MTU Maintenance offer a whole range of mature engine service solutions to avoid the costs of maintenance that is no longer worthwhile: repairs, installation of new or used spare parts, disassembly and recycling, or the leasing of replacement engines. It is up to the customer.

“The really crucial factor here, though, is not how we make short-term savings but rather how we achieve long-term success,” stresses Koppers. “At MTU Maintenance we’ve developed a life-





Millimeter precision
A laser tool is used to drill ventilation holes in the guide vanes of a high-pressure turbine.



Meticulous testing
Visual inspection of repaired engine components at MTU.

“The cost pressure that airlines are facing will bring forward new testing and analysis procedures.”

Dr. Andreas Sizmann
Head of Future Technologies and Ecology of Aviation, Bauhaus Luftfahrt

cycle optimization concept that encompasses maintenance economy, value retention and customer satisfaction. We try to find the best solution in each individual case.” So for an engine that has a planned time on wing of ten years, the recommendation would be to install original parts, whereas for an engine that still has a few thousand take-offs and landings ahead of it, used and repaired spare parts may well be sufficient. “The advantage we have as an independent provider is that we can offer original spare parts, but we’re not obliged to. At the same time we also help the customer ensure that the engine is ready for operation whenever it’s needed, and that it can be sold at the best possible price in the end.”

Future trends


Yet in spite of all the optimization strategies being implemented, billions are still being plowed into maintenance; in recent years, the costs of shop visits have even gone up because engines are becoming more and more complex. According to the International Air Transport Association (IATA), engine maintenance costs made up 42 percent of total maintenance costs in 2007, but in 2016 this figure had already reached the 50 percent mark.

One thing Bauhaus Luftfahrt researcher Sizmann is sure of: “The cost pressure that airlines are facing will bring forward

new testing and analysis procedures. And these will help ensure that engines have a longer time on wing in future, and that a lot of the work can be done directly at the airport during normal downtimes.” The engine OEMs are already adjusting to this change, says Koppers: “The avoidance of maintenance costs is already built into the engine development process, for example by using modular designs that allow entire units to be replaced, thus simplifying repair work.”

“Virtual technologies will also help save time and cut costs in the future,” Sizmann predicts. “For example, we are currently exploring the potential that big data analysis offers. Improving the recording and evaluating of the condition of an engine during normal opera-

tion with the help of a deeply integrated network of sensors, without having to remove and dismantle it, could reduce costs. Augmented reality, meaning computer aided extension of reality perception, also offers interesting options. Computer-generated additional information on displays or smart glasses is already employed in some areas of construction or maintenance. There is yet potential to exploit.” He also believes that additive manufacturing with 3D printers which could help manufacture spare parts near-wing, without complex storing and logistics, is another field that shows promise.

A lot of this is still pie in the sky, but who knows: maybe the maintenance, repair and overhaul of engines really will be so easy, quick and flexible that it can be done at any airport. 

Fly-by-hour or time-and-material agreement?



Shop visits are expensive. Engine maintenance and repairs are a significant cost factor for airlines. That's why maintenance companies offer a variety of service models to help customers keep track of costs.

Fly-by-hour agreement

With conventional fly-by-hour services, customers pay a fixed price from day one for every hour flown, and in return they are offered a comprehensive range of services—engine removal, repair and installation, and the supply of a replacement engine to keep the aircraft flying. These flat rates are particularly popular with owners of newly developed aircraft and engines because they cover unscheduled shop visits and the replacement of parts, known as early removals. Fly-by-hour packages are offered by OEMs—Rolls-Royce, GE Aviation or Pratt & Whitney—who have the work carried out in their network shops. Independent MRO providers like MTU Maintenance also offer fly-by-hour agreements.

Time-and-material agreement

One alternative that is used primarily by airlines with older aircraft fleets is time-and-material agreements. They guarantee a contractually agreed maximum price for maintenance work. Labor and materials are included. Traditionally, this type of agreement is offered mainly by independent MROs who are not dependent on the use of expensive original parts. However, customers can now also sign agreements with OEMs who cooperate with external suppliers.



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



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Text:
Monika Weiner has been working as a science journalist since 1985. A geology graduate, she is especially interested in new developments in research and technology, and in their impact on society.

MRO diary of an engine

The “résumé” of a V2500 engine from a maintenance perspective.

Text: Monika Weiner
Graphics: Peter Diehl



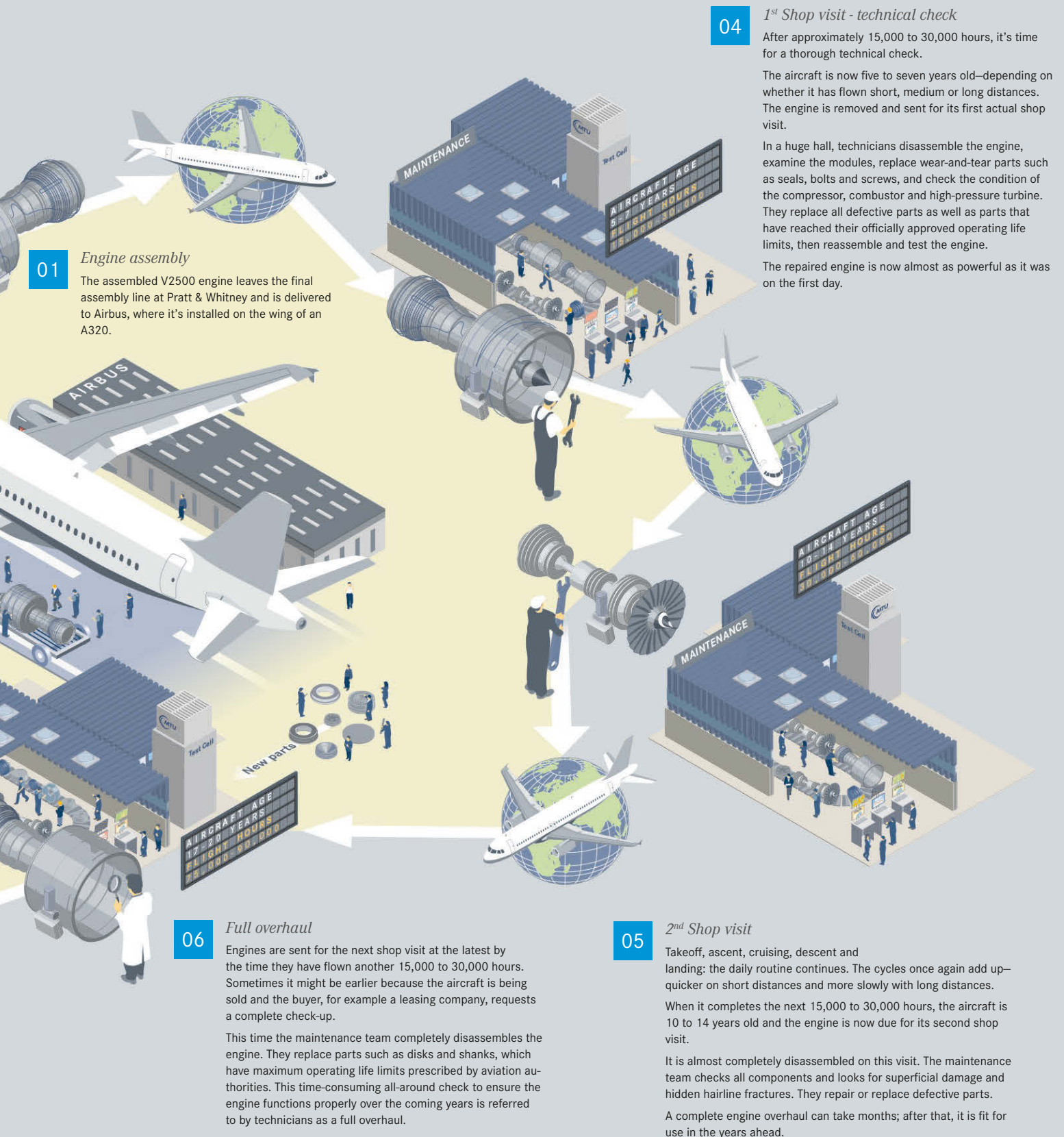
After 30 years in the sky, what better candidate than the V2500 family to present an “engine’s maintenance résumé?” While the oldest variant, the A1, is nearing the end of its service life, the fleet of V2500 A5 engines—the most common variant—is relatively young, with an average age of just over eight years. These engines are either yet to experience their first complete shop visit, or have only recently completed it.

Approximately every 15,000 to 30,000 flight hours, the engine is thoroughly checked and overhauled. Due to legal requirements, certain parts are completely replaced while others are examined in detail and repaired. In each case, the bottom line is to ensure compliance with strict safety regulations for aircraft engines at all times and to restore their performance. The older the engine, the greater the repair depth—the degree to which it is disassembled, inspected, repaired and reassembled. At the end of its “résumé,” owners and maintenance engineers can together decide on how best to continue preserving the engine’s value.



V2500

Around 96 percent of the active V2500 fleet is made up of the A5 variant, which powers the Airbus A320 family. The remaining engines are split between the D5 (Boeing MD-90) and E5 (Embraer KC-390). In 2014 there were roughly 760 V2500 shop visits worldwide; by 2016 this number had increased to about 800. Aviation Week, the industry magazine, expects up to 1,200 shop visits in 2019.

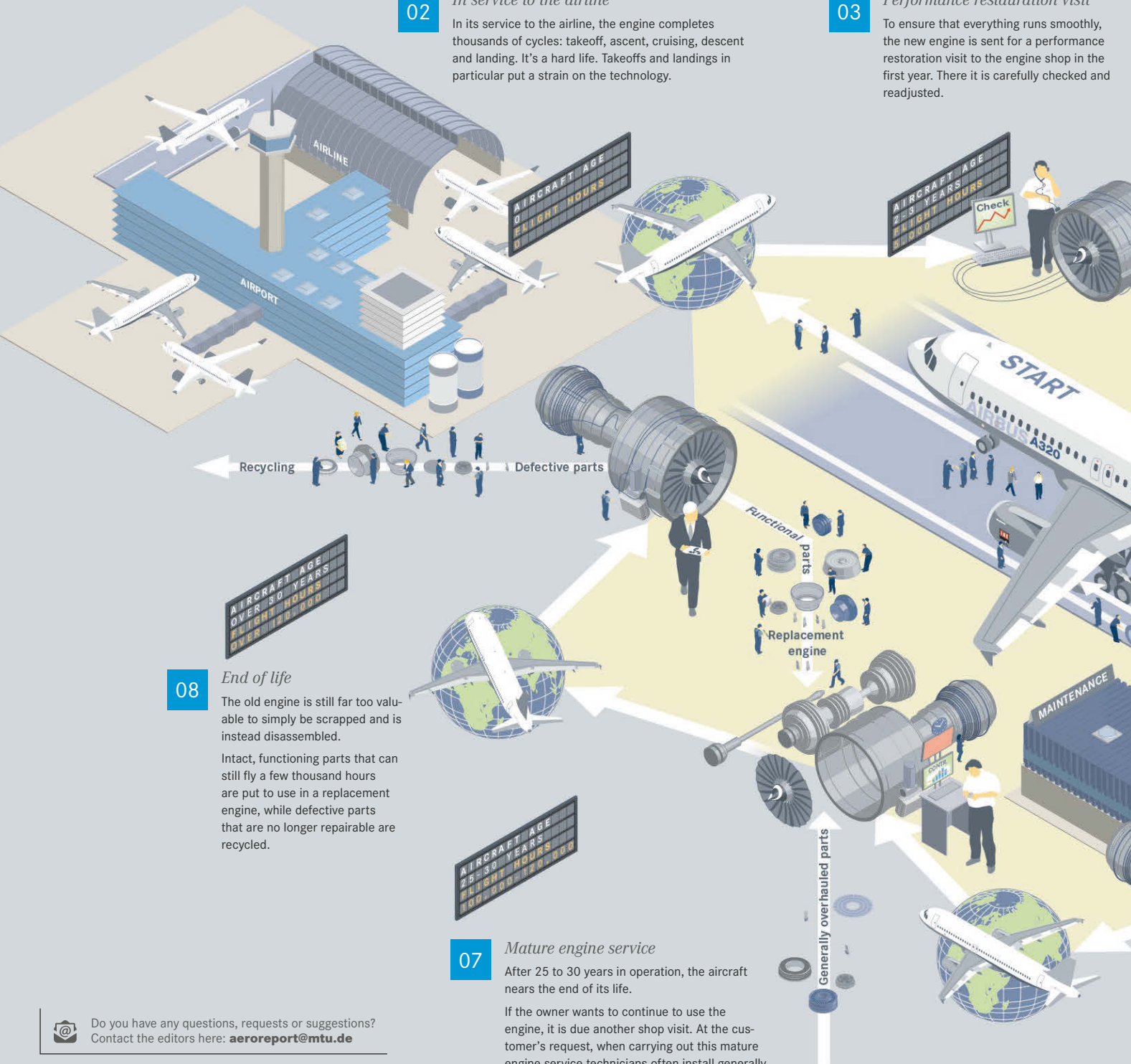


02 *In service to the airline*

In its service to the airline, the engine completes thousands of cycles: takeoff, ascent, cruising, descent and landing. It's a hard life. Takeoffs and landings in particular put a strain on the technology.

03 *Performance restoration visit*

To ensure that everything runs smoothly, the new engine is sent for a performance restoration visit to the engine shop in the first year. There it is carefully checked and readjusted.



08 *End of life*
 The old engine is still far too valuable to simply be scrapped and is instead disassembled. Intact, functioning parts that can still fly a few thousand hours are put to use in a replacement engine, while defective parts that are no longer repairable are recycled.

07 *Mature engine service*
 After 25 to 30 years in operation, the aircraft nears the end of its life.

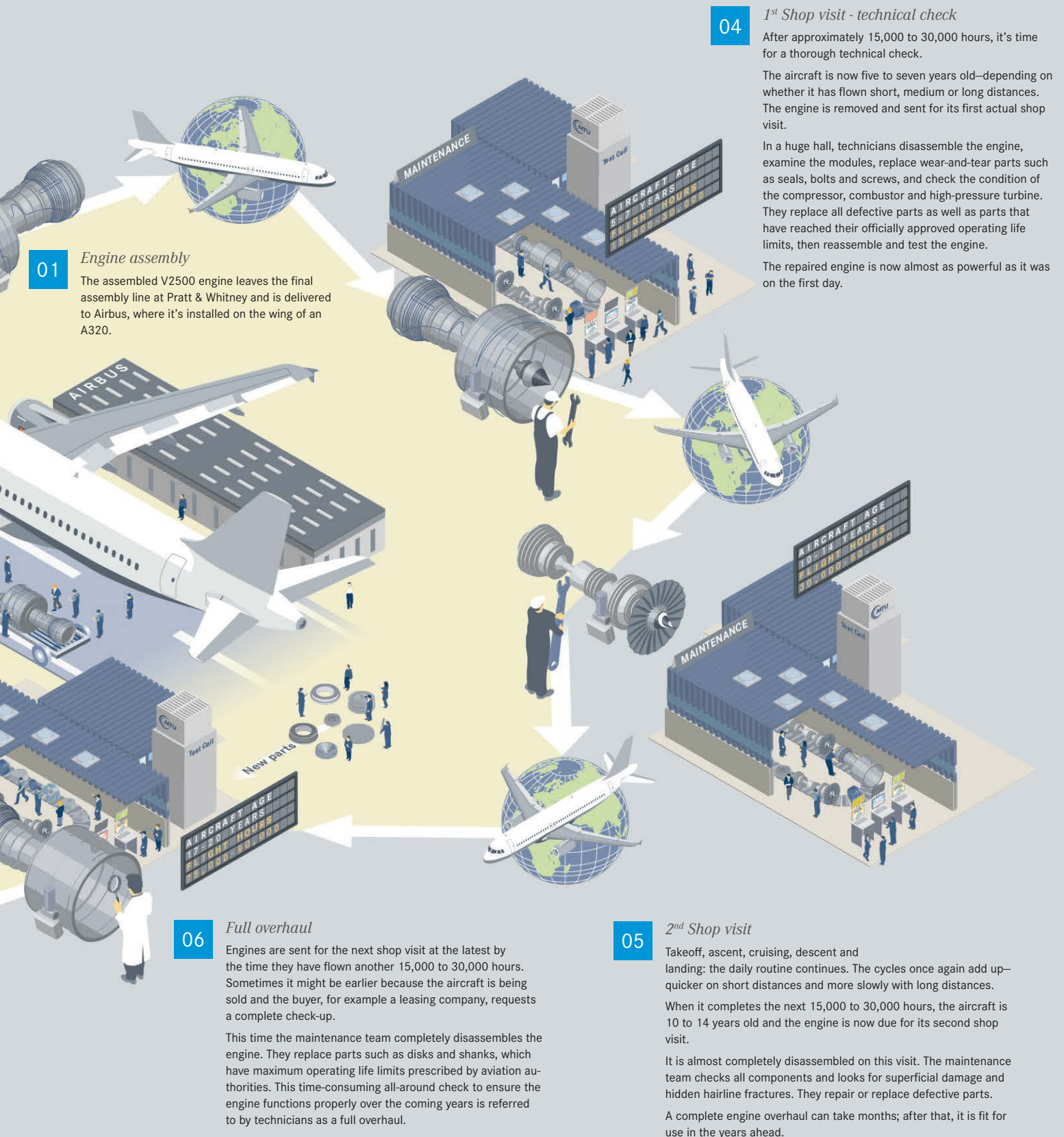
If the owner wants to continue to use the engine, it is due another shop visit. At the customer's request, when carrying out this mature engine service technicians often install generally overhauled used parts, which are significantly cheaper.

Alternatively, they swap a module for an old, but completely overhauled version that still has a limited flight time.

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

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Modern service to attract more business travelers _____
An Embraer E190LR operated by AeroMexico Connect at Mexico City Airport.



Viva la Evolución

Today AeroMexico is the market leader in Latin America's second largest economy. Like the country itself, since its privatization in 2007 Mexico's only full-service carrier has been making great strides on the path to modernization.

Text: Philipp Bruhns



Business travelers in particular value AeroMexico's good connections and comprehensive service. The airline has now also joined forces with U.S. heavy-weight Delta Air Lines to create a groundbreaking, cross-border joint venture.

Champagne corks may have popped a little louder last New Year's Eve in Mexico City and Atlanta. Just before Christmas, AeroMexico and Delta Air Lines agreed to the final competition law requirements for their proposed merger as part of a "joint cooperation agreement." This paves the way for the joint venture, which from April 2017 onwards sees both partners combine their strengths through closer collaboration. During the course of the year, Delta will increase its stake in Mexico's leading airline to as much as 49 percent. For AeroMexico's CEO Andrés Conesa, who spent the past few years working tirelessly with his team on the alliance between the longtime code-sharing partners, reaching this

agreement before year-end marks "the beginning of a new era in North American aviation." Shared networks will provide customers of both airlines more options for connectivity, products and services in the future. This is not the first joint venture between Delta and AeroMexico; since 2014 the two partners have jointly operated a maintenance facility in Querétaro, North-Central Mexico.

On the rise globally

This merger with Delta also shows how far the airline with the "Cauhtli" or Aztec eagle warrior logo has come in its quest to be a world leader in quality and performance. Established in 1934 and run by the state for over 50 years before being privatized again in 2007, today the airline will likely disappoint anyone looking for typical Mexican clichés. Of course, that's not counting the two-hour journey to reach the airport in the 20 million strong metropolitan region of Mexico City.



Vision of the future

The new airport for Mexico City, with a terminal building designed by star architect Norman Foster, is scheduled to open in 2020.



Good connections — An Embraer E190AR operated by AeroMexico Connect at Mexico City Airport.

A modern fleet, punctual and friendly service, internet access and plenty of onboard entertainment are the definition of modern “corporate Mexico” and clearly follow North American standards. Quality, comfort and good connections are key factors for business travelers, with whom AeroMexico achieves almost 80 percent of its profits. The high proportion of business flights is hardly surprising given how long Mexico—the second largest and, with a population of around 230 million, the second most populous country in Latin America—has been a global player. The G20 nation’s economy continues to grow, albeit not at the impressive rate of years gone by. Further economic reforms will ensure that the country depends less on automotive and oil production in the future. AeroMexico is the country’s only airline operating long-haul flights to trading partners in Asia, Europe and South America. It is now switching its widebody fleet from the Boeing 767 and 777 to the 787-8 and 787-9 Dreamliner versions. This will not only increase efficiency and comfort; the aircraft’s greater range also creates the potential to expand the airline’s inter-continental route network. For similar reasons, the medium-haul fleet serving the important U.S. and Central American business will be fully upgraded with 737-MAX jetliners from 2018. These investments are also interesting with regards to another future decision: the building of a new airport for Mexico City is set to propel this megacity, with its convenient location between the northern and southern hemisphere and the Atlantic and Pacific Oceans, to the position of leading global hub in Latin America. In 2020, the first phase with three runways and a terminal building designed by star architect Norman Foster will enter into service.

MEXICO – FACTS AND FIGURES



Official name:	United Mexican States (Estados Unidos Mexicanos)
Official language:	Spanish, in addition to 68 indigenous languages
Capital:	Mexico City, originally Mexico-Tenochtitlan, founded in 1325. Over 8.8 million inhabitants, or about 20 million including the metropolitan region, making it the third most populous city in the world.



Fifth largest
country in the Americas.

Around 2 million km²
of surface area, more than 3,000 km long and 200 to 2,000 km wide.

120 million
inhabitants, population density of 62 inhabitants per square kilometer.

Gross domestic product (GDP):
roughly **1.082 trillion**
U.S. dollars (2015); **8,698.59**
U.S. dollars per head.




In the name of the eagle warrior — The aircraft of the AeroMexico fleet bear the stylized head of an Aztec eagle warrior on their tail fins. But this is the only remaining sign of this Central American country's past traditions: as a G20 nation, 49 percent of the shares in Mexico's flag carrier are now owned by U.S. operator Delta Air Lines, and the company is expanding its business thanks to more modern aircraft.

Strong regional presence

In the past few years, Mexico's domestic market has also come to life. Continuous economic development has seen a rise in the Mexican middle class, with disposable incomes rising steadily. More and more Mexicans are now opting to use aircraft for private journeys, too. The low-cost market in particular is thriving, with fierce competition on busy routes between the capital and metropolises such as Tijuana, Monterrey and Guadalajara or the tourism hotspot of Cancún. AeroMexico, which flies to all Mexican cities with a population of 500,000 or more, also operates on these routes. However, last summer, AeroMexico's CEO Conesa confirmed that the company will not launch its own low-cost airline for the time being, as its regular business is already beginning to benefit from these new target groups. The airline holds another trump card in the domestic market and for flights to neighboring countries: even routes with lower passenger volumes are profitable thanks to its regional subsidiary airline Aerolitoral, whose fleet of 65 smaller Embraer regional jets serves domestic and neighboring destinations under the "AeroMexico Connect" brand. Already young, this fleet will be further modernized when its 50-seater ERJ145 aircraft are be-

ing replaced by the bigger and newer E190 that comes with a business-class configuration. MTU Maintenance is also on board as it is exclusively in charge of the maintenance, repair and overhaul of the E190's CF34-10E engines (see Inside MTU).

Exciting prospects

AeroMexico's future seems to be heading in the right direction. However, a comparison with two neighboring countries reveals that Mexico is still a dormant air traffic giant. For example, per capita economic power is now slightly higher than in Brazil, long the Latin American leader. However, on average, middle-income Mexicans still fly 25 percent less often. That said, catching up with the United States would require a threefold increase in flight frequency. Silvan Brandt, who keenly observes the market's development as MTU's Director of Sales for the region, confirms that the fundamental data is correct. "Even though these days all eyes are on Washington and the new U.S. government, not much has changed when it comes to the major fundamentals." For Brandt, Mexico remains a market with enormous potential. It also holds true for other countries in the region where MTU Maintenance has a strong presence. 



Inside MTU — MRO cooperation

Since 2011, the AeroMexico Group has been MTU Maintenance's biggest exclusive customer for the maintenance, repair and overhaul of the engines for the bestselling Brazilian E190/195 regional jet. MTU Maintenance Berlin-Brandenburg currently manages a total of 64 CF34-10E engines manufactured by GE Aviation for AeroMexico Connect and will continue to do so until at least 2022.

The regional subsidiary of the Mexican market leader is one of the largest operators of this engine type in Latin America. For MTU, which is the world's first independent maintenance company to manage this fairly new engine, the partnership with AeroMexico has played an important role in opening doors for MTU in the region, as Thomas Needham, MTU's Programs & Sales Director in Berlin, explains: "The Embraer jets are a bestseller worldwide, but they have a particularly high market share in Latin America where they are manufactured. It makes us very proud that one of the region's leading airlines boasting such a large fleet has placed its trust in us."



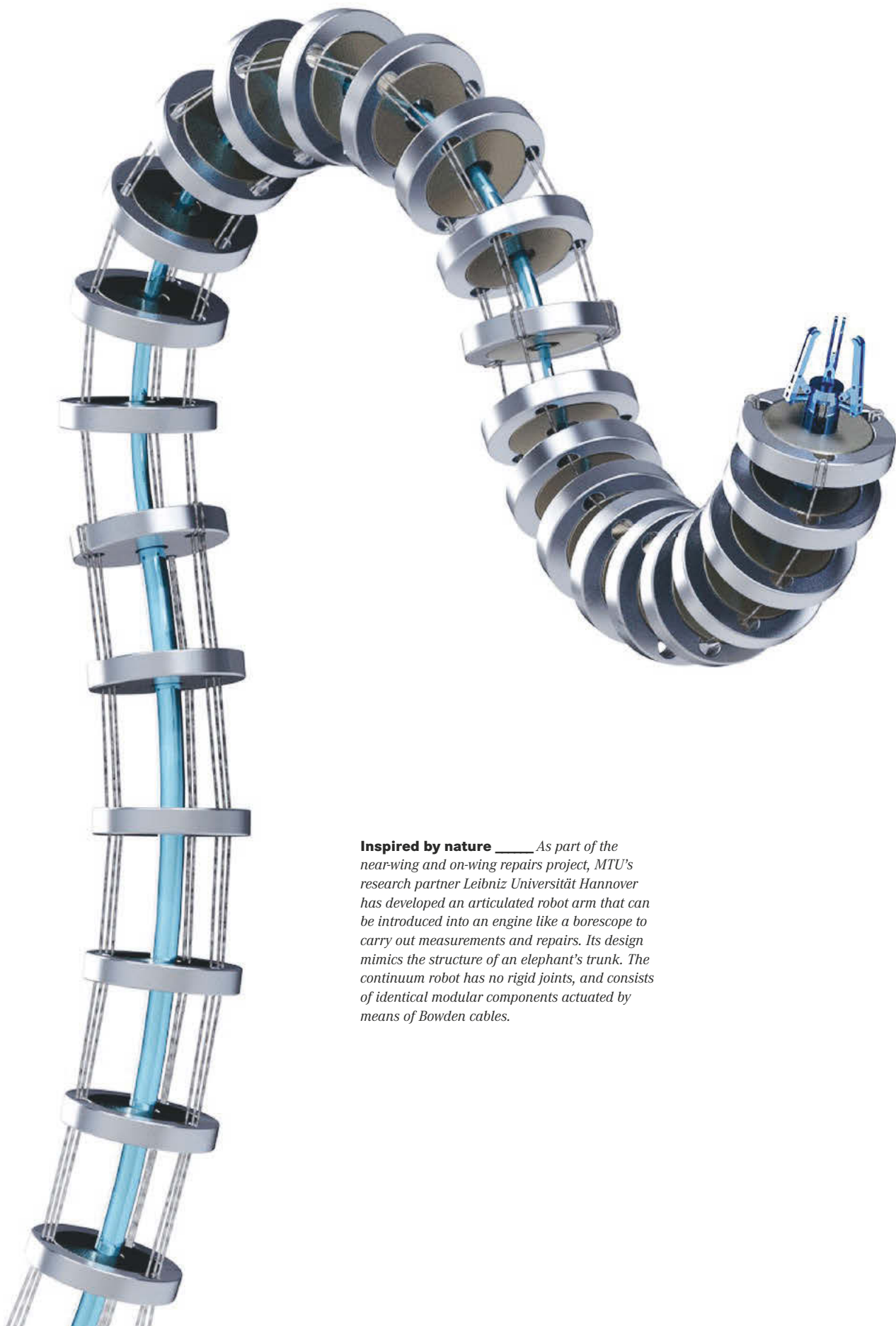
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Text:
Dr. Philipp Bruhns has been working in corporate communications for over 15 years, and has been self-employed since 2008. Based in Denmark, Bruhns has a doctoral degree in psycholinguistics and as an author specializes in maintenance topics and health and social issues.



Inspired by nature — As part of the near-wing and on-wing repairs project, MTU's research partner Leibniz Universität Hannover has developed an articulated robot arm that can be introduced into an engine like a borescope to carry out measurements and repairs. Its design mimics the structure of an elephant's trunk. The continuum robot has no rigid joints, and consists of identical modular components actuated by means of Bowden cables.

Researching the supreme discipline together

*The MRO Center of Competence
at Leibniz Universität Hannover.*

Text: *Silke Hansen*

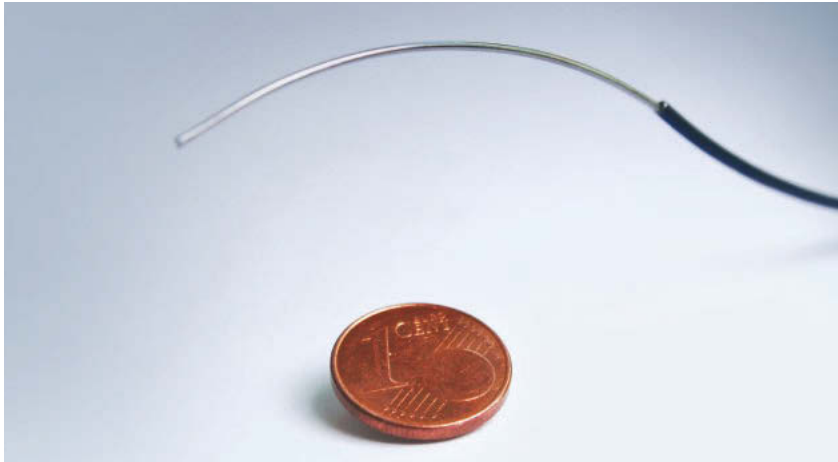
Like a thin snake or long earthworm, the robot skillfully slithers its way through the engine—from the front, in between the fan blades, and then deeper into the engine’s inner workings. Is this the future of engine repair?

Scientists at Gottfried Wilhelm Leibniz Universität Hannover believe it is. They are researching this completely new method at the Center of Competence for turbines and Maintenance, Repair & Overhaul (MRO), which was founded as part of a scientific alliance with MTU Aero Engines. The miniature robot has a bionic structure inspired by nature—elephant trunks, snakes and tentacles in particular, according to Professor Jessica Burgner-Kahrs.

The little helpers that she and her team developed are called continuum robots in the technical jargon because of their ability to function without any joints. Not only do they have the potential to improve minimally invasive surgical procedures in the field of medicine, they also offer brand new possibilities for inspections and repairs in engine maintenance.

Dr. Bertram Kopperger, the head of manufacturing and MRO technology management at MTU, oversees this project: “In contrast to rigid borescopes, the ‘robot’ is much more flexible.” Plus: In conventional borescoping, engineers can access the engine only from certain borescope bosses on the side and the openings are not particularly large.

Scientists from Universität Hannover want to develop a first-generation robot with the necessary stability by 2020. Experts at MTU are working in parallel on three different tool attachments—for example, to polish blades or rework coatings. MTU Maintenance provides the modules for testing. “This project is a trailblazer,” says Kopperger. Fly-by-hour contracts, in which the airline pays fixed maintenance rates per flight hour for its engines, are becoming more popular in the aviation sector. Fast, flexible repair solutions are gaining in importance. The robot could do its job while the engine is still mounted on the wing or is at least standing near the aircraft.



Record performance _____ The record for the smallest continuum robot in the world is held by a device measuring between 0.8 and 2.5 millimeters in diameter that can be equipped with tiny pincers or miniature cameras. Several such robot arms can be introduced into an engine through a single borescope opening.



Repair without disassembly _____ The robot arm, shown here next to a one-cent coin to illustrate its size, can access the blades of all turbine stages and, depending on the instruments with which it is equipped, carry out measurements or clean and repair components without having to remove or disassemble the engine.

Collaborative research into the “regeneration of complex capital goods”

Among other things, this project—which is a part of the Collaborative Research Centres (CRC) of the German Research Foundation DFG—is jointly funded. Assigned the CRC code 871, it deals with the “regeneration of complex capital goods.” “The close interdisciplinary cooperation between various institutions of Universität Hannover and the Technische Universität Braunschweig means several chairs are

pooling their expertise,” says Professor Jörg Seume, Head of the Institute of Turbomachinery and Fluid Dynamics (TFD) at Universität Hannover. His institute is responsible for this CRC and has been MTU’s university partner for about 20 years; joining the Center of Competence for turbines and MRO in 2008. Munich values the high level of professional competence in the field of continuous-flow machines offered in Hannover. Its proximity to the headquarters of MTU Maintenance at Hannover Airport was another reason to establish the



Leibniz Universität Hannover

Today there are more than 25,000 students enrolled at Gottfried Wilhelm Leibniz Universität Hannover (Leibniz Universität Hannover for short; formerly University of Hannover), pursuing studies in the natural sciences and engineering, the humanities and social sciences, law and economics. The university offers courses in around 90 different subjects, with a distinct leaning toward scientific and technological disciplines. Student numbers increased significantly in the 1970s, when urgently needed teacher training courses were added to the university’s curriculum.

Leibniz Universität Hannover is a member of TU9 German Institutes of Technology e.V., an alliance of Germany’s nine leading technical universities.

Center of Competence (CoC) for turbines and MRO here.

Scientists are also carrying out important fundamental research on turbines. A key strength is their thematic range, encompassing aerodynamics, aeroacoustics, aeroelastics and numerical methods for calculation and simulation. In addition, within the mechanical engineering faculty, there is a close research collaboration with the institutes for manufacturing and turbomachinery, according to Seume.



Lab work _____ Students at Leibniz Universität Hannover develop engine maintenance technologies in partnership with MTU.

The technical equipment is also very impressive: the TFD alone offers three test rigs for testing, one of which is a completely new turbine test cell. Companies including MTU, Siemens, MAN and Volkswagen rely on this scientific know-how. According to one of the scientists, the collaboration with MTU is very intensive and productive. Currently, the engine manufacturer has placed six ongoing projects at the CoC, with six more currently at the planning stage for 2017 and 2018.

From higher vocational school to a TU9 member


Leibniz Universität Hannover was founded in 1831 as a higher vocational school with 64 students and 14 subjects—and mechanical engineering was one of them from the very beginning. Today the university is a member of TU9, an alliance of leading Ger-

“We’re working with MTU on cutting-edge technologies.”

Prof. Dr.-Ing. Jörg Seume,
Head of the Institute of Turbomachinery and Fluid Dynamics (TFD) at Universität Hannover

man technical universities. Along with five other universities and research institutes in Germany as well as the materials and structural mechanics cluster, it is also a partner of MTU, who has founded a joint Center of Competence with each of them. “In this way, we can put selected universities and research institutes in a position to meet our needs and requirements,” ex-

plains Kopperger. “It ensures MTU’s ability to innovate, strengthens the networking between science and industry, and helps us attract young academic talent to the company.”

However, these collaborations are by no means a one-way street. Seume values them highly: “We can mutually exploit our skills and learn from each other.” There are numerous advantages to this reciprocal exchange of knowledge. “We’re working with MTU on cutting-edge technologies.” After all, for mechanical engineers, an aircraft engine is the supreme discipline: it is hot, under heavy load and constantly vibrating. It calls for the development of complex methods and long-term solutions. Or, as a scientist at the mechanical engineering faculty in Hannover puts it: “It takes a lot of brain power.” 



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Text:

Silke Hansen writes for **AEROREPORT** as a freelance journalist. For over ten years, she has covered the world of aviation focusing on technology, innovation and the market. Corporate responsibility reporting is another of her specialty areas.

Building bridges

Anita VanBarneveld is passionate about three things: engineering, sports and family. This 42-year-old Canadian is proof that these pursuits don't have to be mutually exclusive.

Text: Thorsten Rienth



Anita VanBarneveld has no more than ten seconds to pass the 175-gram plastic disk to the next player. She's not allowed to run, only pivot. Just like the ball in American football, the flying disk must make it to the opposing team's end zone through a series of skillful passes. VanBarneveld was good enough to make the German national ultimate frisbee squad.

That VanBarneveld competes in what would have to be counted as a fringe sport somehow fits with her career path. Never really one for taking the road most traveled, she was one of only a handful of women in her native Ottawa at the time to study aerospace engineering. After a few years working in the industry in Canada, she felt she was bound for bigger things. Fairchild-Dornier in Oberpfaffenhofen, Germany, was hiring. At first, this little place southwest of Munich took some finding on the map. "My boyfriend and I thought it looked like a pretty place and decided to go and spend a couple of years there." It's now been 15 years since leaving Canada, even though—or perhaps because—Fairchild Dornier filed for bankruptcy in 2002.



From aircraft to engine in 20 kilometers

VanBarneveld then heard from a friend that their company was looking for someone with precisely her credentials.

The company in question was MTU Aero

Engines, located in the northwest of Munich, just 20 kilometers from Oberpfaffenhofen—"perfect." It wasn't long before VanBarneveld was calculating the rigidity of blades for business jet engines at MTU. Then another piece of the puzzle fell into place: "MTU was manufacturing these engines in collaboration with Pratt & Whitney Canada—familiar territory for me."

From there on in, her work took on a whole new dimension. She helped develop the low-pressure turbine for the Airbus A380's GP7000 engine. Once that engine was up and running, she switched roles to and become the module team leader, for the team, which was developing the GENx turbine center frame for the Dreamliner and the 747-8. After that, she took up her present position as head of the low-pressure turbine module team



for the PW800 family. That appointment brought her full circle: the PW800 is the successor to precisely the business jet applications for which VanBarneveld calculated blade rigidities at the start of her MTU career.

Dream views and daycare

At Fairchild-Dornier, English was the company language. This had both advantages and disadvantages. “Back then, my German didn’t extend much beyond ‘ein Bier bitte!’” And since the move to MTU meant she wouldn’t be returning to Canada in the foreseeable future, VanBarneveld made a strict pact with her colleagues to speak only German. As is usual in such situations, it was a tough at first because her colleagues stuck to the plan. But over time, language skills become more assured; now VanBarneveld says that for her, speaking German is like slipping into a comfortable pair of shoes.

The VanBarnevelds’ quality of life in Munich has always had a lot to do with where the city lies. Like a great many people who choose to live in the area, they enjoy having the Alps at their front door. “We’re always up for a bit of climbing, hiking or biking at the weekend.” And now with two sons aged two and three, it’s fun for all the family. “But none of this would work without having every day planned out.” Dream views are one thing, but everyone needs support they can count on.


Take the “TurBienenchen”—a parents’ initiative that runs a daycare center not 50 meters from the front gates of MTU’s headquarters in Munich. In keeping with the German play on the words for turbine and bee, the mascot is a bee in a turbine costume.

“Apart from when it gets really cold in winter, twice a week I load the kids into the bike trailer in the morning and get to work that way.”

Building bridges becomes routine

The final leg of the commute is through the showers. A 10-kilometer ride pulling two kids is quite a workout, even for an accomplished sportswoman. Sometimes, the boys get a ride home in the car with their father, allowing their mother to work longer. “It’s rare that I have any appointments with Pratt & Whitney Canada before 2 p.m.” Our colleagues in Canada are six hours behind Germany. This means that VanBarneveld’s daily routine is one of building bridges—between Europe and North America, work and family, free time and planned time.

None of this would work without the support of management, which first had to consider if a young woman from Canada would make a good addition to the team. The first pregnancy was closely followed by a second. “Management found a way for me to come back to work for the four-month period between my maternity leaves so I could remain in the loop.” Where there’s a will, there’s a way. “At the end of the day, it’s a question of mindset—and MTU has the right one.”

It will be time for the next organizational reshuffle in another three or four years, when her older son starts school. Although this new family dynamic will not make things any less complicated, VanBarneveld has found a silver lining: “At least then I can look over his shoulder when he’s doing his homework and finally learn how German grammar really works.” 



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



“We need strong partnerships”

IATA CEO Alexandre de Juniac on new technologies, politics in civil aviation and the return of glamour to flying.

Text: *Andreas Spaeth*



Alexandre de Juniac —
 Director General and CEO of International Air Transport Association (IATA)

The experienced aviation manager Alexandre de Juniac took over leadership of the International Air Transport Association (IATA), the world’s leading representative body for civil aviation, in September 2016. Born in 1962, de Juniac was Chairman at Air France-KLM From 2013 to 2016; previously he headed up Air France. From 1995 to 2009, he held various management roles at Thales Group. He participated in French politics from 1988 to 1995 and again from 2009 to 2011, most recently as a member of Minister of Economics Christine Lagarde’s cabinet. De Juniac received degrees from École Polytechnique de Paris as well as École Nationale de l’Administration. He is a knight of the National Order of the Legion of Honour and currently president of the “Le Club des Juristes” think tank.

“We need a very strong partnership with airframe and engine manufacturers and system providers, to be able to demonstrate that these new technologies can work effectively in new aircraft.”

M. de Juniac, IATA has supported the fuel-less flight of Solar Impulse around the world. What does that tell us about the potential of aviation?

Alexandre de Juniac: It gives us several messages. First of all, it tells us that aviation is at the cutting edge of innovation. Historically that always has been the case. We are paving the way for clean energy in transportation, for preserving our planet by using no-fuel energy. Secondly, it represents a symbol of hope that mankind can do things better. Thirdly, Bertrand Piccard and André Borschberg have demonstrated that tenacity is absolutely key when pursuing an idea—or a dream. Remember: they started this project over twelve years ago.

What lessons do you extract from this for the airline industry?

de Juniac: The project Solar Impulse shows how we in this industry must be innovative, particularly to protect the environment and reduce CO₂ emissions. It shows that this goal is achievable and we will do it. It makes us optimistic that what we are doing for the environment within IATA and in cooperation with ICAO will be successful. That’s very important because it is an enormous program that we have, based on commitments of all the stakeholders in the industry. We recognize that translating this achievement into solar-powered or even all-electric commercial transports is a challenge on a wholly different scale. But Solar Impulse shows that his industry is serious; when we make commitments and set targets, we stick to them.

What kind of partners do the passenger airlines need in order to achieve the environmental goals IATA has set out?

de Juniac: We need a very strong partnership with airframe and engine manufacturers and system providers, to be able to demonstrate that these new technologies can work effectively in new aircraft. We need strong partnerships with airports, governments and air navigation service providers to show that we are able to manage the sky and the ground properly. And all that needs to be in accordance with our objective to reduce CO₂ emissions, for example, by having more direct trajectories and more direct approaches, or doing ‘green taxiing’ on the tarmac.

Can relationships between aircraft operators, the airlines, and the engine manufacturers be improved?

de Juniac: These relationships are very good already, it’s a multilateral partnership. You buy an aircraft and engine to last at least 20 years, you refurbish an aircraft two or three times during its lifetime, so you need a long-standing relationship including technical support and upgrading. In this is an industry you can’t work without close relations between the suppliers and the airlines.

How can the engine manufacturers contribute to achieve IATA’s climate goals, what do you need from them?

de Juniac: We are asking for a lot. Today’s engines are highly fuel efficient and remarkably reliable. Yet we need them to be even more efficient and reliable in the future to help us achieve our CO₂ goals, with greater use of recyclable technology. Noise is also a consideration. We need to continue to reduce noise levels. Of course there are difficult environmental trade-offs to consider. As I said, this is an innovative industry, and I’m confident that these challenges will be addressed.

What are your priorities in your new job heading IATA, what are currently the biggest challenges for passenger aviation?

de Juniac: I think we have three big challenges ahead of us. First of all, to maintain and improve our economic and financial health. Second, we have big security issues. And the third area is infrastructure. If we want to support the growth in demand for our product, we must have efficient and affordable infrastructure with sufficient capacity.

That aviation is a growth industry is a given, but apparently infrastructure is not growing at the same rate. What can you do to improve this?

de Juniac: We have to repeat this message to governments, to develop a long-term plan for aviation infrastructure to follow and cope with growth. We know that improving infrastructure means long-term planning. On top of that, there is some resistance from various sides, especially if you want to build a new airport or new runways.



IATA —The International Air Transport Association (IATA) is the international representative body for civil aviation, located in Montreal, Canada. Its goal is to encourage safe and economic air transport for passengers and freight. Currently, IATA has 265 member airlines, representing 83 percent of international air traffic. What is more, IATA has around 400 strategic partners from the aircraft and engine industry as well as some 100,000 accredited travel and freight companies.



ICAO —Based in Montreal, Canada, the International Civil Aviation Organization (ICAO) is a specialized agency of the United Nations (UN). Its aim is to plan and secure sustainable growth for air transportation. Its tasks include the preparation of recommendations and guidelines, the regulation of international air traffic rights and the development of binding standards for air transport. Currently, there are 191 ICAO member countries.



Aviation journalist Andreas Spaeth (left) in conversation with IATA CEO Alexandre de Juniac (right).

“With the environmental agenda, I am optimistic we will have made a lot of progress. Innovation will always be at the top of our agenda.”

Alexandre de Juniac

Director General and CEO of the International Air Transport Association (IATA)

Is it right that aviation still has no priority for many governments?

de Juniac: Aviation should be a top priority for any government. Some countries have decided to put aviation at the core of their national strategy, such as some of the Gulf states or Singapore, South Korea and the Netherlands. Unfortunately only a small proportion of states make aviation a priority. We urge other governments to work out a kind of aviation strategy and implement it. Especially as long-term planning is required here, you must have a strategic vision for the next ten or even twenty years. Otherwise it's a nightmare. How is it possible there are so many problems with the new airport in Berlin? Why have we been waiting for the third runway at London-Heathrow now

for 70 years? Or 35 years for a quick rail access from Charles de Gaulle airport to the center of Paris? We have to convince governments that aviation is a key element for prosperity. We are the business of freedom, one that means jobs, GDP growth, happiness and optimism.

Do you think that in ten years' time, the same issues as today will still be on IATA's agenda?

de Juniac: Some items will be similar. Probably the infrastructure constraints will not be solved totally. With the environmental agenda, I am optimistic we will have made a lot of progress. Innovation will always be at the top of our agenda.

IATA has a very diverse membership, from small island carriers to huge airline groups. Is it difficult to find a common path for all of these?

de Juniac: No, it's not. During my time as the CEO of Air France, we created the A4E lobby group, combining low cost and legacy airlines. That was considered impossible, because our common interests were supposed to be very limited. But that was totally wrong. The common interests between the two biggest low cost airlines and three legacy carriers were representing 80 or 90 percent of the subjects we were dealing with. And this is true in the same way for our IATA members. Of course there are specific items for small carriers in small island nations and others for big legacy carriers in industrial countries. But the common interests represent more than 60, 70 or even 80 percent of the subjects. That's the reason why IATA is expanding. This is by DNA a global business.

Besides IATA, the other global aviation body is the United Nations' ICAO. How do you get along with each other?

de Juniac: We need each other. ICAO is the regulatory, 'legislative' body, designing and creating rules that are applicable by states. We are the body that provides expertise, solutions and recommendations to feed these regulations and complement them with industry knowledge and experience. And the last session has been a perfect example of that, when ICAO adopted the carbon-offsetting scheme for aviation.


It's often said ICAO acts very slowly...

de Juniac: First of all, the aviation sector is not very fast in general. And as any intergovernmental organization, ICAO has its rhythm. One of our duties is to push ICAO to act quickly, and to provide them with enough expertise to enable them to act cleverly and efficiently.

But isn't it also IATA's task to create common procedures among airlines?

de Juniac: Yes, our job is to design and apply global standards that are recognized and applicable for all the industry. We are doing that with our 'ONE order' initiative for example. That creates one file and set of data for each passenger, and not two or five or seven sets of data, as has been the case so far, which is confusing and might lead to mistakes.

Almost four billion passengers are currently flying in a single year. Is there still any glamour in flying or can you bring it back somehow?

de Juniac: In fact, some glamour is returning to flying. Until the 1970s, flying was mostly dedicated to business travel and a higher-end part of the population. It was expensive, but also fast and comfortable. Then the big aircraft like the 747 arrived, flying became a mass transportation system, and, in conjunction with deregulation and liberalization, the comfort level dropped. At the time, the 'jet set' image of aviation slipped in many places. At the end of the 1990s many airlines—especially those with longer histories—rediscovered the fact that they needed to treat the high-yield passengers accordingly. Since then, investment in high-end products has been enormous. But Economy Class has not been ignored. You often have Wi-Fi there, a high-definition screen, or you can plug in your smartphone. For those passengers looking for a bit more, many airlines have introduced premium economy. And we see what all airlines have done on the ground. The lounges are a dream now. It's all much better than it was. 



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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.


Heat protection _____ *Few engine components can withstand elevated temperatures without special coatings. This picture shows the thermal barrier coating on a CF34 combustor ring.*



We've got protection covered

Coatings protect engine components against high temperatures, chemical attacks and rapid erosion caused by sand and dust. They have become a key technology on the path to more efficient aircraft engines with higher combustion temperatures and cost-effective operation.

Text: Denis Dilba



According to Frank Seidel, with the exception of aggressive volcano ash, “which planes should always fly around anyway,” there is only one thing that creates more problems for engines in everyday flight service than sand—and that is liquid sand. Hang on, sand can become liquid? “You bet,” says the Director Repair Engineering at MTU Maintenance Hannover. “At temperatures of around 1,500 degrees Celsius in the combustion chamber of a modern aircraft engine, sand just melts away.” And until recently, Seidel and his colleagues were regularly seeing close up the harm these grains cause while carrying out repairs. Gaping centimeter-wide holes in the combustion chamber were not uncommon. This happens when the hot molten sand reacts with the thermal protection coating and causes it to flake away. In these exposed areas, the intense heat then burns holes through the chamber wall. A similar fate is suffered by the blades of the high-pressure turbine that directly follows the combustion chamber.

CMAS-resistant thermal protection coating

When such damage is discovered in an engine, it often has to be replaced and at short notice. And because the engine then has to be laboriously dismantled for repairs, the costs shoot up even higher. Thanks to a new engineering development by MTU Aero Engines, customers will have to contend with these massive damage situations in sandy regions less frequently in the future. It's a thermal protection coating that is able to withstand liquid sand to a large extent. The CMAS-resistant thermal protection coating—CMAS stands for calcium-magnesium-aluminum silicates, the main components of sand—is just one example of the performance and variety of the coating systems used at MTU. Ordinary thermal barrier coatings consist of a metallic corrosion protection layer beneath a layer composed of yttria-stabilized zirconia (YSZ), a micro-porous ceramic.

“This oxide ceramic conducts heat very poorly and keeps the air-cooled components at lower temperatures,” explains Seidel. However, if YSZ comes into contact with molten sand, it absorbs it, becomes saturated, hardens and flakes off. The solution Seidel’s team came up with was to place a further layer over the YSZ layer. The new layer reacts with

the molten sand in such a way that the heat insulation is retained. “The tricky thing was to prove that the regular thermal coating beneath the additional CMAS layer also works flawlessly even when the aircraft is not flying over regions with a lot of sand. Without this proof, we wouldn’t have got certification for it,” says Seidel.



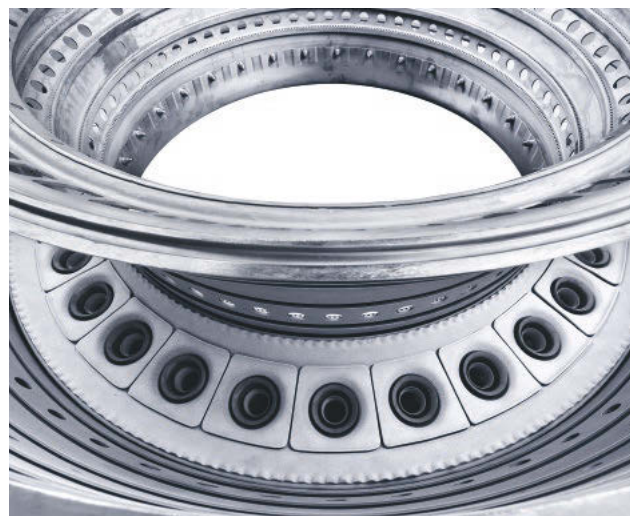
Delamination _____ Damage to the thermal barrier coating in the combustion chamber of a CF6-80C2.



Before repair _____ Inside a CF6-80C2 combustor.



Restored _____ CF6-80C2 combustion chamber with thermal barrier coating.



As good as new _____ Thermal barrier coating in the CF6-80C2 combustion chamber

“Most of the materials in use today couldn’t be used without high-tech coatings.”

Dr. Frank Seidel

Director Repair Engineering, MTU Maintenance Hannover

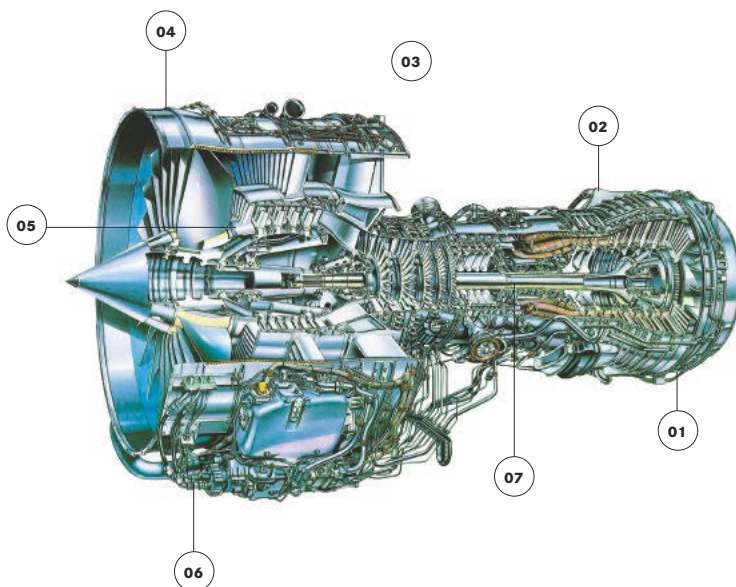
More than half of components in an engine are coated

“In today’s engines, it’s actually quite hard to find a component that isn’t coated,” says Dr. Jörg EBlinger, Director Materials Engineering and Componenttesting at MTU in Munich. “More than half of them are already coated in one way or another.” One large group of coatings is used primarily to protect against abrasion. A main source of abrasion is sand and dust that is sucked into the engine and that acts on the engine components like a sandblaster. Another source is components—for example, blades and casing parts—moving and rubbing against each other. The other large group of coatings has the job of protecting the engine

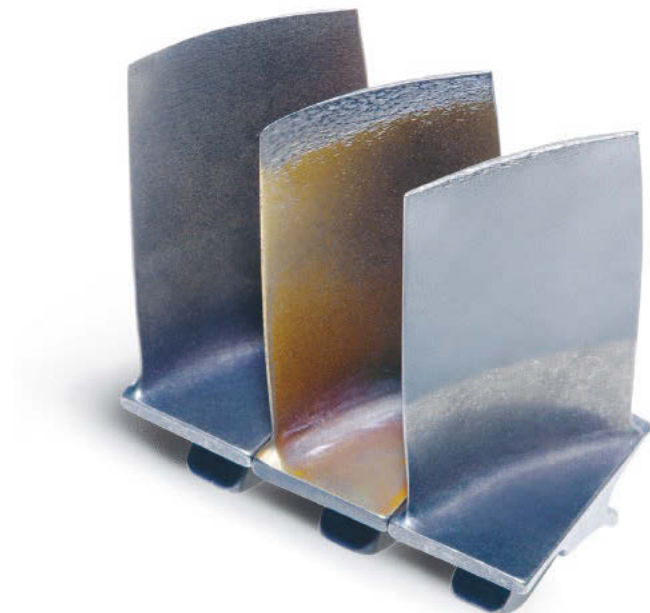
materials mainly against hot gas and chemical attacks, such as those caused by liquid sand. EBlinger is convinced that the proportion of coatings used in engines will grow even further in the future. After all, one of the few levers for increasing the efficiency of engines consists in making the combustion process even hotter. And this is a challenge that the engine materials cannot master without better, higher-performance coatings. According to Seidel, “most of the materials in use today couldn’t be used without high-tech coatings.”

Another aspect also comes into play, says Thomas Dautl, Head of Manufacturing Technologies at MTU: “With engines that

COATINGS IN AN ENGINE



- 01 — Corrosion/oxidation protection coatings**
Turbine blades
- 02 — Thermal insulation coatings**
Turbine blades, combustion chamber
- 03 — Dimensional adjustment coatings**
All components
- 04 — Titanium fire protection coatings**
Compressor casings
- 05 — Erosion protection coatings**
Compressor blades
- 06 — Abradable and sealing coatings**
Housings, blade tips, sealing rings
- 07 — Wear protection coatings**
Housings, blades, disks, shafts



Comparison of blade coatings _____

Uncoated and coated compressor blades after two years' operation. Far right: with MTU erosion protection.

require less maintenance overall, the fly-by-hour business model becomes more economical." Under this model, MTU customers pay a fee for the flight hours the engine has served, which covers both scheduled maintenance and unplanned repairs. "It's kind of like an insurance policy," observes Dautl. "The fewer cases of unplanned damage that arise, the better it is for the customer and the bigger our cost saving." But the system works only because MTU is prepared to invest up front, Dautl explains, "but the leverage it affords is huge, as it can double and even triple the service life of a component."

Vacuum-metalized elasticity

MTU's ERCoat^{nt}® erosion protection also plays its part. "The coating for high-pressure compressor rotor blades and guide vanes offers between six and ten times better resistance against erosion than untreated components," says Eßlinger. In regions with a lot of sand, dust and aerosols in the air, such as the Middle East or India, an erosion coating has to perform equally well: "Without coating, a few flight hours is all it takes in this environment for material abrasion to occur on the blades together with the corresponding loss of engine performance," says Eßlinger. To ensure that ERCoat^{nt}® is particularly well able to withstand the constant bombardment with particles, the MTU developers designed the abrasion protection as a multi-coat system. At a time, two coatings are applied to the blades in alternation to build up a total of around 15 layers, each a few micrometers thick and always in the same order: metal nitride

followed by metal. This resolves a dilemma that plagued conventional erosion protection before now: if you make the coating hard, it protects effectively against abrasion, but also increases the risk of germ formation in cracks; if you soften it up, you reduce this risk, but at the expense of the coating's service life.

In ERCoat^{nt}®, hard and soft coats alternate with each other. "This ensures that the erosion protection possesses a certain flexibility and is slower to tear when bombarded with sand and dust," says Dautl. And even if it does, the crack cannot grow unchecked, because the soft layer stops it. In the course of the component's lifetime, the individual layers are used up successively and still offer active protection down to the last few micrometers. "And then we simply re-apply the coating system from scratch," says Seidel. To do this, MTU uses physical vapor deposition (PVD), which involves evaporating the respective coating materials in a vacuum and then letting them rain down on the component. "The longer we leave a blade in the vapor, the thicker the coating deposited on it," explains Seidel.

Aluminum-chromium for low-pressure turbines

A new aluminum-chromium (AlCr) coating designed for all stages of the low-pressure turbine also promises significantly longer component service lives. It offers simultaneous protection against oxidation at temperatures above 900 degrees Celsius and against sulfidation at temperatures between 700 and 900

“The coating for high-pressure compressor rotor blades and guide vanes offers between six and ten times better resistance against erosion than untreated components.”


Dr. Jörg Eßlinger

Director Materials Engineering and Componenttesting, MTU Aero Engines

degrees Celsius. Sulfidation refers to chemical reactions that attack the material and where sulfur is the catalyst. As part of an MTU-patented process, both chromium and aluminum are applied in a defined manner to the surface of blades to provide targeted local protection as required—in other words as dictated by the component’s temperature profile—against oxidation and sulfidation. As Eßlinger explains: “That gives our customers flexibility where needed and at any rate four times as much protection against sulfidation than before.”

Coatings becoming increasingly specific

For Uwe Schulz from the German Aerospace Center’s (DLR) Institute of Materials Research in Cologne, this kind of adjustable AlCr coating is a sign of things to come. Head of the High Tem-

perature and Functional Coatings department, Schulz expects that not only will more components be coated in the future than ever before, but that they will be coated in much more bespoke ways. “This will happen first because of the greater possibilities afforded by a growing understanding of the mechanisms of action, which will allow us to improve existing coatings so that engines can work that bit more efficiently. Second, new materials will force us to make these changes,” says Schulz. For example, fiber-reinforced ceramics promise big improvement potential in terms of the cost-effectiveness, service lives and weight of the engines of tomorrow. “But these ceramic materials also need additional protective coatings,” notes Schulz. In short, these unimposing coatings that have such a big effect will be in high demand in the future, too. 



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Text:

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

Minor repair job – major effect

Sometimes a seemingly insignificant component can have a considerable impact. In the case of the high-pressure compressor for the V2500 engine, thin vibration damping rings were greatly reducing its service life. MTU Aero Engines has now come up with a simple, approved solution to tackle this issue.

Text: Achim Figgen, Thorsten Rienth



Tongue and groove — In this repair technique developed by MTU, the wire ends of the vibration damping system for the casing of the V2500 high-pressure compressor are connected using the tongue-and-groove principle, preventing friction between the wire and the locking groove in the compressor housing.

Installed in over half of the Airbus A320's globally operating aircraft, the V2500 engine—or the “V”, as it's called by the specialists at MTU Maintenance in Hannover—is a regular visitor to the shop. Its high-pressure compressor should ideally withstand 16,000 to 20,000 cycles, in other words that many takeoffs and landings. However, maintenance staff soon noted that they were replacing the front part of the compressor's rotor drum, which is a very valuable component, after roughly 8,000 cycles.

The problem was traced to relatively inconspicuous components, namely sealing wires made of a cobalt-based alloy and just millimeters wide. They serve as vibration dampers for the compressor blades in stages six to eight to ensure the stator blade ring and rotor do not wear each other out and the blades do not fracture. While in use, the wire ends were eating into the titanium alloy of the

retaining grooves directly in front of and behind the blade roots where the six damping rings sit. They would damage the groove to such an extent that the rotor could not operate after around 8,000 cycles.

Lock and key principle in the millimeter range

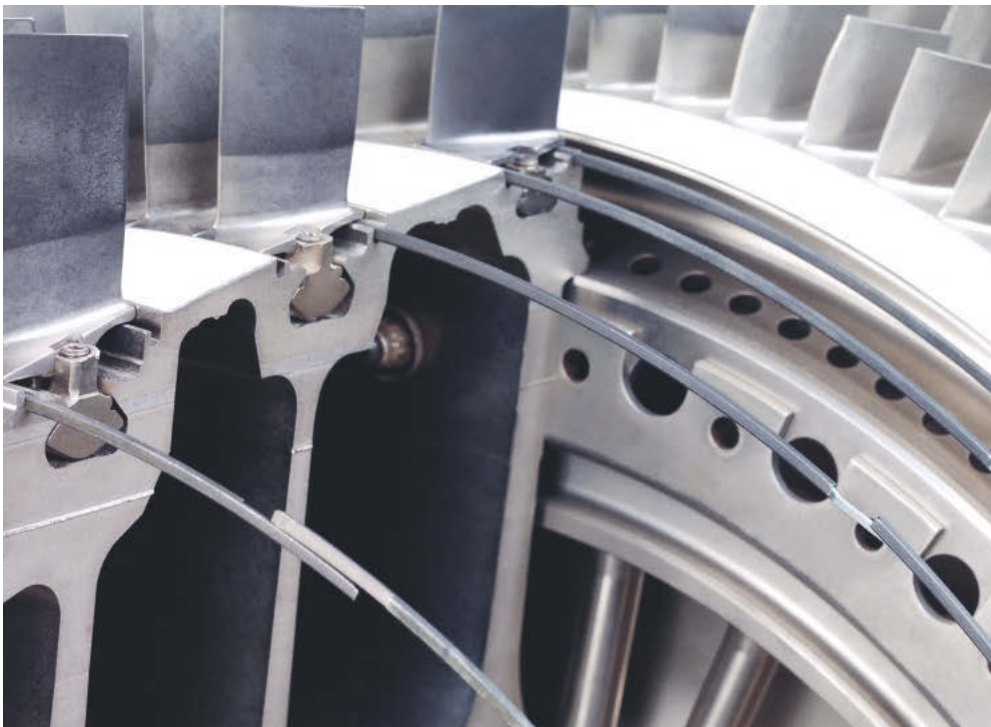
The OEMs itself carried out multiple changes to the wire, with engineers first rounding off the initially blunt ends and later trying to overlap them. MTU then came up with a tongue-and-groove solution so blunt ends were neither left exposed nor overlapping. In order to prove their effectiveness, the repair engineering teams from MTU in Hannover and Munich as well as several other analytics, materials and test engineers scrutinized the entire air circulation system including all load factors and examined samples of different materials under a scanning electron microscope.

“Simply put, this relies on a lock and key principle at a scale of fractions of a millimeter,” explains propulsion engineer Christian Heinzmaier. “The wire tapers at one end. Its counterpart at the other end is designed like a small tunnel for the tapered end to enter. With a length of six millimeters, the ends remain flexible so they can sustain thermal expansion and loads without breaking. However, the real advantage is that this interlocking prevents the wire ends from swinging freely and embedding themselves in the wall of the grooves. This in turn means there is no need to repair the groove walls by ablation until much later.” It's a relatively easy solution—“when you know how.”

Second issue: Outer wall of the groove

Because the outer wall of the groove is very thin, especially in the case of the eighth stage, after ablating away severe

Cross-section model comparing old and new _____ *Image on the left: In the foreground, the wires are overlapped, whereas in the background they are slipped inside one another. Image on the right: Detailed image of the interwoven wire ends, a technique that prevents them from working free and penetrating the grooves in the drum walls.*



damage there is hardly any material left. For this reason, the damaged portion is completely removed. But this in turn means that the blades are no longer fully seated in the corresponding slot of the rotor disk, which could cause them to wobble. To minimize this risk, the MTU engineers apply a thin layer of coating material to increase the thickness of the outer wall by a few tenths of a millimeter. This is done using a new, spark-free technique. “That way we can preserve the properties of the titanium material used to construct the rotor.”

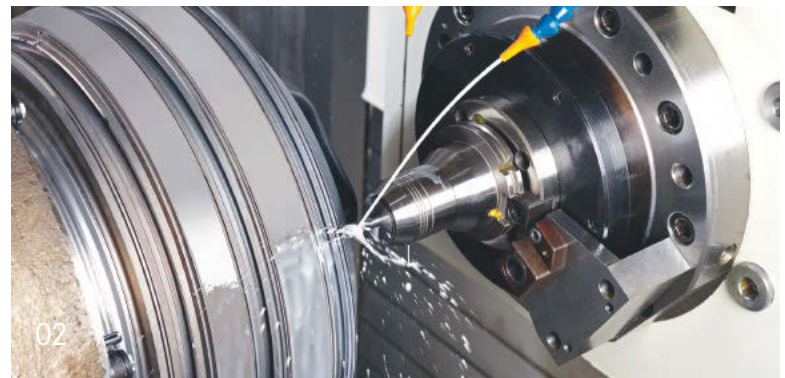
Approval after 8,000 cycles and 150-hour endurance test

Both EASA and the FAA approved the process because they recognized that the repaired rotor behaves exactly like the original rotor and no further damage occurs. For the approval, the sealing wires had to undergo 8,000 cycles on the test bench followed by a 150-hour endurance test in a complete V2500 engine. This approval certificate makes MTU Maintenance the only independent maintenance organization in the world authorized to use a repair process developed in-house to carry out repairs on a limited-life component for which it does not itself hold the design responsibility. Initial experience from practical application revealed excellent results with hardly measurable wear and tear, confirming that the repair solution works. U.S.-based airline JetBlue was the first big customer to sign up. It uses the V2500 engine with its Airbus A320 and A321 aircraft.

Most importantly, repairs reduce costs and secure the fleet’s capacity. “Every time a rotor is replaced, the engine has to be completely removed from the wing,” explains Gert Wagner, Director Engine Programs at MTU Maintenance Hannover. “This process takes a considerable amount of time.” That is time in which the aircraft cannot transport passengers or earn money. However, a positive side effect of the repair is that valuable material on the rotor remains intact longer. The new sealing wires may not be directly transferable to other engines. “But we will of course make a note of the design of the tapered wire ends.”



01



02

01 ____ *The grooves in the compressor drum walls have to be carved out manually.*

02 ____ *Milling of the sealing ring for the compressor drum.*



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A320 in

February 22, 1987: A320 first

1988

*On **July 28, 1988**, a V2500-powered A320 took off for the first time.*

13,061

*The A320 Family is the world's best-selling single-aisle aircraft family—**13,061** orders and **7,481** A320s delivered (including 82 A320neos, as of February 2017).*

7

***Every 7 hours**, an A320 Family aircraft leaves one of the A320 Family Final Assembly Lines all over the world (Europe, China and US).*

11.5 billion

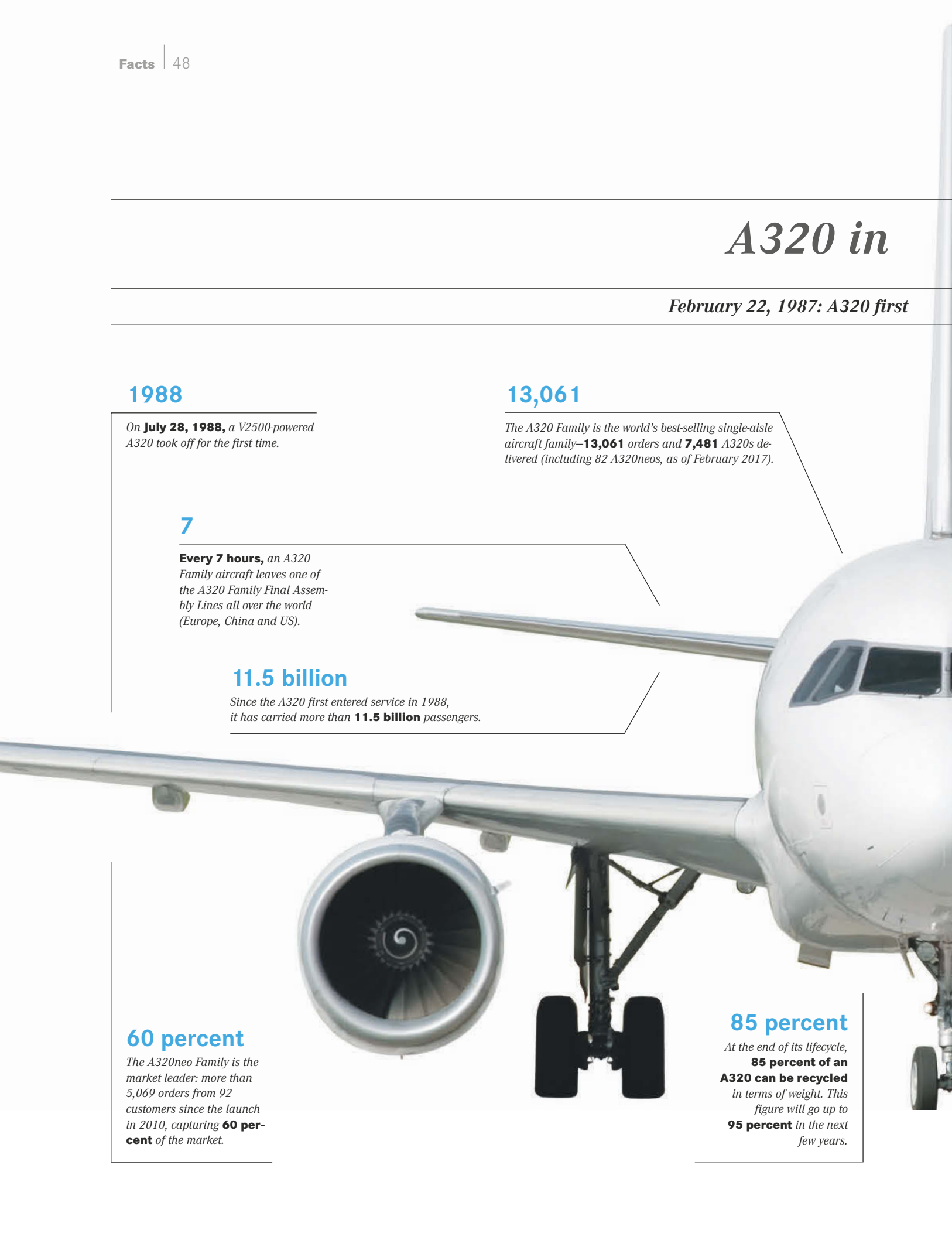
*Since the A320 first entered service in 1988, it has carried more than **11.5 billion** passengers.*

60 percent

*The A320neo Family is the market leader: more than 5,069 orders from 92 customers since the launch in 2010, capturing **60 percent** of the market.*

85 percent

*At the end of its lifecycle, **85 percent** of an A320 can be recycled in terms of weight. This figure will go up to **95 percent** in the next few years.*



numbers

flight starts 30 years success story

260 km

All A320 Family aircraft produced lined up from nose to tail would make a **260 km** long line which corresponds nearly to the length of **2,500** soccer fields.

1.

The A320 was the **first commercial airliner** around the world featuring digital fly-by-wire controls.

16 percent

MTU has a **16 percent** share in the IAE V2500 engine program that comprises, among others, the low pressure turbine.

1.6

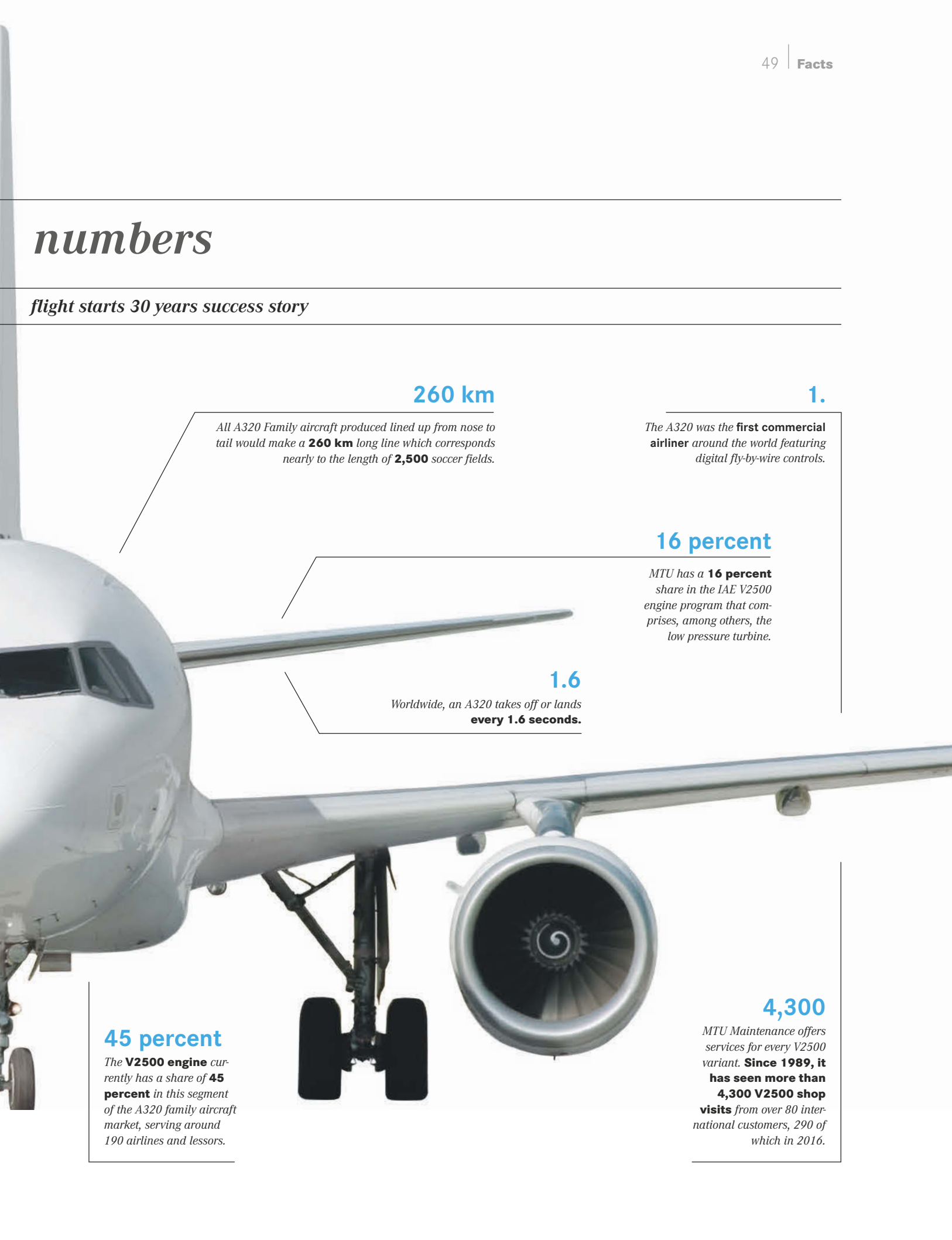
Worldwide, an A320 takes off or lands **every 1.6 seconds.**

45 percent

The **V2500 engine** currently has a share of **45 percent** in this segment of the A320 family aircraft market, serving around 190 airlines and lessors.

4,300

MTU Maintenance offers services for every V2500 variant. **Since 1989, it has seen more than 4,300 V2500 shop visits** from over 80 international customers, 290 of which in 2016.



Measurable growth

Figures from the company's 2016 financial results

Some 6.2 billion euros: MTU's market capitalization with a share price of **118 euros.** *(as of March 2017)*

14 billion euros: MTU's new record overall order backlog. This figure is up 13 percent on the previous year.





13 percent: MTU's earnings growth rate in 2016. This means MTU surpassed its 2016 target by 5.4 million euros.

7 percent: MTU's revenues increased by this much in 2016, pushing them to an all-time high of some 4.7 billion euros.

5.1 to 5.2 billion euros: MTU's forecast group revenues in 2017.

Picture puzzle

On which AEROREPORT pages can you find the full version of these partial images?

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Good luck!

AEROREPORT 0117

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www.mtu.de/maintenance



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