

Changing times

Generational transition in the short- and medium-haul market

MARKET

Long-haul climber

10 years of MTU Aero Engines AG

EXPERTISE

The future of aviation

Interview with Prof. Rolf Henke

TECHNOLOGY

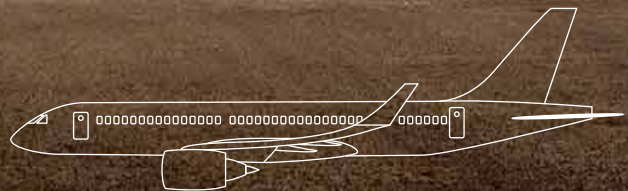
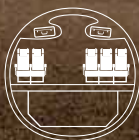
Heart and muscle

Turbine and compressor



Narrowbody Bombardier CSeries

With the new CSeries, the Canadian manufacturer Bombardier is looking for a slice of the lucrative market for narrowbody aircraft. Like many other new short- and medium-haul jets, it is equipped with the Geared Turbofan™, in which MTU Aero Engines has a significant share.



Dear reader,

Times are changing in the aviation industry and in several different ways. First of all, eight new aircraft families will expand the range of narrowbodies and regional jets available over the coming five years. Most of the new regional jets and a growing proportion of single-aisle narrowbodies have the PW1000G as their engine. The Geared Turbofan™ technology used in this engine sets new standards for reducing fuel consumption, emissions and, not least, aircraft noise. A gearbox allows the fan and turbine to run at their respective optimum speeds and highest efficiency. One of the things that make this possible is the high-speed low-pressure turbine supplied by MTU Aero Engines. Decades' worth of development work went into this component, and we will be looking back over the period in this issue.

Change is needed in the development of air transportation technologies, says Professor Rolf Henke, Executive Board Member for Aeronautics at the German Aerospace Center (DLR). For this issue, we were delighted to obtain an interview with one of the leading thinkers in the German aviation sector. Among the topics discussed were whether solar power has a future in aviation and what the industry now needs.

Change and transition can be observed in many areas of aviation, and we report on them in this issue. In only a few years, around half of commercial aircraft will belong to leasing companies. Having been walled off for a long time, the Japanese aviation market is beginning to open up. The MD-11 has drawn the era of big passenger trijets to a close. There is also news in engine development, where a new rig makes it possible to test vibration behavior in the engine before the first test run.

And the new issue of **AEROREPORT** also signals a new era for the magazine. In a revised layout, we offer you fascinating stories from the world of aviation. This issue and the ones to come invite you to explore a variety of topics relating to aviation in the air and on the ground which MTU thinks are particularly interesting.

On our new website optimized for different devices, you can also find the print version of **AEROREPORT** in its entirety and much more: www.aeroreport.de.



Happy reading.
Yours

A handwritten signature in blue ink that reads "Reiner Winkler". The signature is fluid and cursive.

Reiner Winkler
Chief Executive Officer



COVER STORY

Changing times

With an influx of new models and new providers, the market for short- and medium-haul jets is in transition.

AEROREPORT takes a look at what is now the most exciting segment in the passenger aircraft industry.

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MARKET

Long-haul climber

June 6, 2005 marked the first day of trading for MTU Aero Engines shares; since then, their value has more than quadrupled. Patience pays off in the long-term engine business.

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MARKET

End of an era

The farewell flight of the MD-11 in service marked the end of an era for the large trijet passenger aircraft. In the 1990s, it was ahead of its time as the first commercial jet with winglets.

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Interview with German Aerospace Center (DLR) Executive Board Member Professor Rolf Henke

**PARTNERS**

A smile in the sky

The aviation market in the world's third-largest economy is opening up: The most recent contract extension cooperation with Solaseed Air is one of several successful partnerships for MTU Maintenance in Japan.

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**EXPERTISE**

Now we need to aim higher

Solar technology and electric motors are still just a utopian dream for large passenger jets. But making sure aviation has a sustainable future calls for the courage to make big changes, says Executive Board Member Professor Rolf Henke from German Aerospace Center (DLR), in an interview with **AEROREPORT**.

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**TECHNOLOGY**

Heart and muscle

MTU's experience in compressor and turbine design stretches back 45 years. A recent highlight: the new Geared Turbofan™ engines.

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Falcon 8X embarks on flight testing



A successful premiere: at the beginning of February, the Falcon 8X, the new flagship jet from French aircraft manufacturer Dassault,

took off for the first time from Mérignac near Bordeaux. Over the coming months, three test aircraft will be put through their paces in an exhaustive set of test flights totalling some 500 flight hours. The trijet Falcon 8X is the latest addition to the popular business jet family, and delivers exceptional range. It can fly further than its predecessor, the 7X, but consumes less fuel. The jet is due to receive certification in 2016, with deliveries scheduled for the second half of the year. MTU Aero Engines has a 15 per cent stake in the Falcon 8X engine program, and provides the low-pressure turbine for Pratt & Whitney Canada's PW307D. The benefits of the Falcon 8X are in large part thanks to its improved engine – and that includes the low-pressure turbine.

CS300 takes off

With the CS300's first flight in February, the larger version of the medium-haul aircraft for up to 160 passengers is now also airborne. Manufacturer Bombardier currently has a total of six aircraft in testing. Flight Test Vehicle (FTV) 5, a CS100, took off for the first time in March.

The CSeries is available exclusively with Pratt & Whitney Geared Turbofan™ engines. By May, the PW1000G engine family had completed 16,000 hours of testing, 31,000 take-off and landing cycles and 3,500 flight hours. Two Airbus A320neo with PW1100G-JM engines are also in flight testing, while three further members of the engine family are either on the flying test bed or will be shortly.



A total of over 6,300 orders from 60 customers and 30 different countries have already been chalked up for the GTF family. The most recent orders came from the Malaysian start-up airline flymojo in the form of letters of intent for up to 40 CSeries, and from Air New Zealand, who booked 13 A320neo with PW1100G-JM engines.

From the Maldives to Mexico



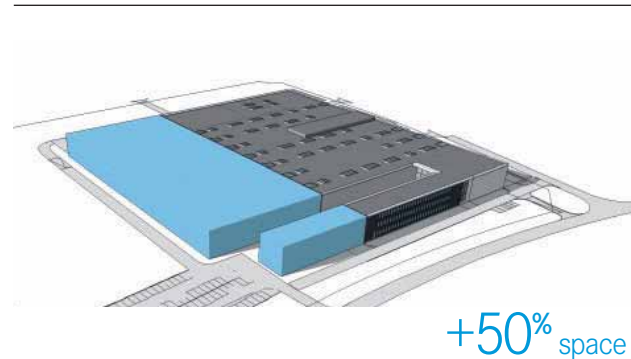
MTU Maintenance signed numerous contracts with new and existing customers in the first few months of 2015. Especially in the growth markets of South Asia and Latin America, many start-up airlines and traditional flag carriers are now entrusting MTU Maintenance's international shop network with the maintenance

of their engines and making use of the company's on-site and leasing services. One particular landmark for MTU Maintenance was the 15,000th shop visit, which took place in April and concerned a CF34-10E operated by Aéromexico.

MTU expands location in Poland

Poland's growing "Aviation Valley" is now bigger by around 10,000 square meters. That's how big the new Rzeszów location annex is that MTU Aero Engines opened in celebration on February 27. Like the new blisk production facility in Munich and the new logistics centers in Hannover and Munich, this extension is part of the MTU growth strategy. "The new annex allows us to strengthen our activities in Poland and assure the

ramp-up for geared turbofan engines," says MTU Chief Operating Officer Dr. Rainer Martens. Krzysztof Zuzak, Managing Director of MTU Aero Engines Polska, believes the 40 million euro investment confirms how much the company values the Rzeszów location. MTU Aero Engines Polska was founded five years ago with 200 employees. Now there are 500. "This is a success story we can be proud of."



The tasks that will be carried out in the new buildings will be related to the growth in production and volume for the Geared Turbofan programs and from MTU's increased share in the V2500.

Honda Prize for material development

In the record time of seven years, MTU Aero Engines materials experts and their research and industry partners developed a new, unique and lightweight material class – titanium aluminide (TiAl). Used to make high-stress engine components, this inter-metallic high-temperature material unites the properties of metal and ceramics, giving it the best of both worlds.

MTU partner Professor Dr. Helmut Clemens, Head of the Physical Metallurgy and Materials Testing



Honda Foundation president Hiroto Ushida, Professor Helmut Clemens and wife, Tsutomu Honda (from left). © Honda Foundation

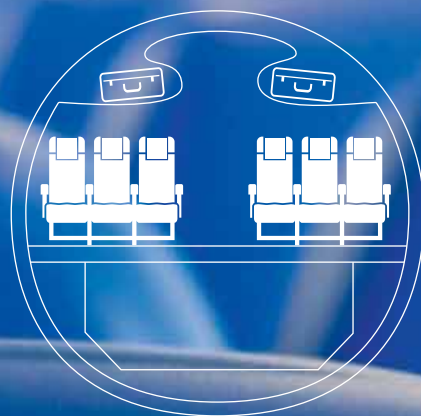
department at Montanuniversität Leoben in Austria, was given special recognition. By the end of 2014, Clemens was awarded Japan's prestigious Honda Prize for his development work. "What's really special about the TiAl alloy we've developed is that it means the forging process can now also take place using conventional forming machines," says Clemens. The first series application is the high-speed low-pressure turbine used in the PW1100G-JM engine for the A320neo.



Changing times

With an influx of new models and providers, the market for short- and medium-haul jets is undergoing a transition. These “workhorses” are the core business for airlines and aircraft manufacturers.

Text: *Silke Hansen*



Single Aisle _____ *Section of the fuselage of a narrowbody aircraft for short- and medium-haul routes, featuring a single, central aisle and five to six seats per row. According to Airbus, narrowbodies make up 78 percent of all passenger aircraft fleets worldwide.*

TPA – Tampa International Airport

A seaplane with two seats ushered in the era of commercial passenger aviation. On just such a “flying boat”, Pilot Tony Jannus carried his first passenger 17 miles (27 kilometers) as the crow flies along the east coast of Florida from Tampa to St. Petersburg. The year was 1914, the flight lasted 23 minutes, and the one-way ticket cost five dollars. Today, the sector racks up some 33 million flights and 3.5 billion passengers a year worldwide. And aviation continues to expand, at an annual rate of around five percent on average. Passengers include everyone from European cultural tourists to the new Chinese middle class, and from students flying standby to the next party to business people traveling to an important meeting. Usually they fly in a short- or medium-range jet, which are known in the industry as regional jets or narrowbody aircraft. Narrowbodies are single-aisle airplanes with five to six seats per row, while regional jets are smaller and generally have four to five seats per row. But what does “generally” even mean when we are talking about one

of the most exciting and dynamic segments in today’s aviation industry?

Narrowbodies are the workhorses in airline fleets—whether with low-cost start-ups or flag carriers. Airbus has calculated that narrowbodies make up 78 percent of all aircraft in fleets worldwide. Over half of all airplane distances traveled are flown

“For airlines, it’s always about cost-effectiveness and efficiency. All new models are developed with this in mind.”

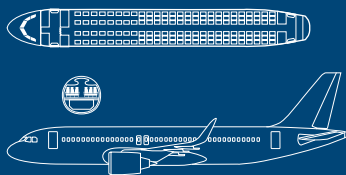
Bernhard Köppel,
MTU specialist for aircraft analyses

by single-aisle aircraft. Airlines primarily operate them within continents for point-to-point and feeder flight traffic, which require

Narrowbody vs. widebody

Narrowbody — Single-aisle aircraft with 5-6 seats per row for short- and medium-haul flights.

Airbus A320 family



EXAMPLES:



Narrowbody

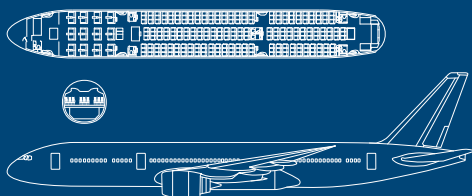
Airbus A320 family

Approx.
150 passengers on average
75 tons take-off weight

Passenger aircraft with jet engines are divided into size classes according to their range and seat capacity. A construction feature that distinguishes narrowbodies and widebodies is the number of aisles. Narrowbodies have a single aisle, a maximum fuselage diameter of 4 meters, and a range of up to 4,000 nautical miles; widebodies have two aisles and sometimes two passenger decks, a fuselage that measures 7 meters, and a range of up to 8,500 nautical miles.

Widebody — Twin-aisle aircraft with 7-10 seats per row for long-haul flights.

Boeing 787-9 Dreamliner



Twin-aisle widebody

Boeing 787-9 Dreamliner

Approx.
280 passengers on average
250 tons take-off weight



Very large widebody

Airbus A380

Up to
525 passengers
575 tons take-off weight

AIR PASSENGERS WORLDWIDE: DEVELOPMENT UP TO 2034



- 2014: 3.3 billion
- 2034: 7.3 billion

The U.S. and China are already the world's largest air passenger markets by a significant margin. The International Air Transport Association (IATA) predicts that passenger volume from, to and within China will overtake that of the United States for the first time in 2030.

Source: International Air Transport Association

aircraft to fly numerous connections spread out over a day. The planes are the most important segment for aircraft and engine manufacturers. They represent the core of Boeing's and Airbus' business in narrowbodies and of Embraer's and Bombardier's business in regional jets, respectively. However, times have begun to change, perhaps signaling the end of their predominance. "The short- and medium-haul market is very dynamic and is currently in a powerful state of flux," confirms Dr. Marc Le Dilosquer, market expert at MTU Aero Engines. Theodor Pregler, who heads the company's commercial aviation engine programs, speaks of an ongoing "generational transition." How has this come about?

NKM – Nagoya Hikojo

Nagoya Airport, Honshu Island, Japan's industrial heartland, October 18, 2014: Accompanied by drumming and a children's choir, the first Mitsubishi Regional Jet (MRJ) rolls out of the hangar. The prototype is an historic milestone in the Land of the Rising Sun. For the first time in half a century, a Japanese company has entered the commercial aircraft market. When it arrives on the market in 2017, the new regional jet MRJ90 will be taking on the top dogs from Embraer and Bombardier. The Japanese want to sell a total of 1,500 aircraft and have booked 407 orders to date. Designed for between 70 and 90 passengers, the MRJ is scheduled to commence flight testing in 2015. The customer Eastern Air Lines, based in Miami, Florida, has christened the plane "Eastern Whisperjet".

This whispering is thanks in no small part to the aircraft's engine, which features the newly developed Geared Turbofan™ (see Inside MTU). An additional gear train makes the engine significantly more efficient—it consumes less fuel, is more eco-friendly, and is quieter. These virtues were also enough to persuade Mitsubishi's competitor Embraer. The Brazilian manufacturer is revamping its bestselling E-Jet and fitting the Geared Turbofan exclusively to the wings of the E2-175, E2-190, and E2-195.

General cost pressures are driving market diversification. Airlines calculate very precisely which aircraft to use on which routes and always strive to get as close as they can to the optimum operating costs per seat mile in each case: "For airlines, it's always about cost-effectiveness and efficiency. All new models are developed with this in mind," says Bernhard Köppel, MTU specialist for aircraft analyses.

And new models are coming thick and fast. Eight new aircraft families will join the available choices over the next five years. In the aircraft and aero engine sector, where development and technology times are necessarily lengthy, that is nothing less than a deluge. "The market is large enough," reckons Le Dilosquer. He predicts that almost 27,000 new narrowbodies and regional jets will leave production halls over the next 20 years—that figure represents around half the total deliveries of commercial aircraft with jet engines. "The reasons for this are prolonged market growth and fleet renewals." Asia continues



A popular way to travel — Every year, the number of air passengers grows by 5 percent on average.



WIDEBODIES VS. NARROWBODIES AND REGIONAL JETS



Seats in standard seating design:

Widebody: 240 – 650

Narrowbody: 100 – 240

Regional jet: 70 – 100



Widebody:
5,000 – 8,500

Narrowbody:
3,000 – 4,000

Regional jet:
1,000 – 2,500

to be the region with the strongest growth in the aviation sector. The low-cost segment is developing in particularly dynamic ways there, with established airlines founding their own budget lines.

TLS – Aéroport de Toulouse-Blagnac

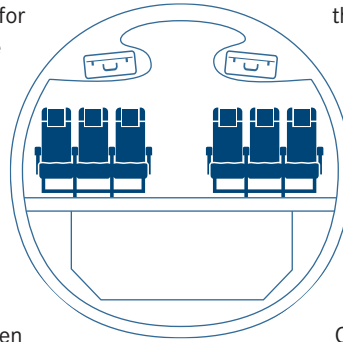
A glorious sunny day at Toulouse Airport, ideal weather for a maiden flight: the date is September 25, 2014 and Airbus is sending its new narrowbody jet out onto the runway. The A320neo is a modernized version of a bestseller—the European consortium grew up on the success of the A320 family. Now the jet has been given a new engine (neo stands for “new engine option”). Operators can choose between a variant of Pratt & Whitney’s Geared Turbofan with more powerful thrust, a similar core engine, and similar advantages in terms of consumption, noise, and environmental pollution as the “smaller” versions for the regional jets, or an engine from the new Leap family, produced by the U.S.-French joint venture CFMI. Airlines are scrambling to get their hands on the jet, whose list price is between 97.5 and 124.4 million U.S. dollars depending on the version. The biggest cost driver for airlines is kerosene, and compared to the regular A320, the A320neo can reduce annual fuel costs by around a million U.S. dollars. It is no wonder, then, that the record-breaking A320neo has sold faster than any other commercial aircraft since its official launch in December 2010. A good 3,700 firm orders from 70 customers are on the books, and that is before it has even entered service.

The aircraft’s direct competitor from Airbus’ perennial rival Boeing has still to catch up. From 2017, however, Boeing wants to gain an edge with the successor model 737MAX—exactly fifty years after the first flight of the 737-100. The 737MAX is the

fourth generation of the blockbuster. Boeing has already sold more than 2,700 737MAX. Unlike its European rival, the U.S. manufacturer opted exclusively for the LEAP-1B engine.

YMX – Aéroport International Montréal-Mirabel

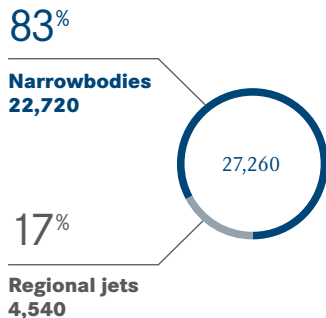
A cold Canadian winter in Mirabel, Quebec: in the night, temperatures have dropped to minus 28 degrees Celsius. On January 14, 2015, test aircraft FTV2 accomplishes flawless laps in the presence of the aviation authority—it has passed its cold weather tests, marking an important milestone on the road to certification and initial delivery of the Bombardier CSeries. With their new airplane, the Canadians are looking for a slice of the lucrative narrowbody market. Previously, Bombardier was specialized in smaller aircraft. “Boeing and Airbus’ duopoly is coming to an end,” says Le Dilosquer. “While those two still control the segment’s upper end of 150- to 200-seaters, Bombardier now occupies the lower end of up to 150 seats.” The CSeries (CS100, 110 seats / CS300, 135 seats) is currently the only aircraft designed wholly from scratch in this category and is also equipped with the Geared Turbofan.



Although new competitors further east have to gain a foothold in the business first, they are beginning to join the fray. Russian and Chinese manufacturers are developing their own products in national aircraft projects: the MS-21 from Irkut (from 2017, with Geared Turbofan) and the C919 from the Chinese manufacturer Comac (from 2018). “We’ll see whether the planes can gain acceptance and how they compete. First they’ll have to prove themselves in their domestic markets before western airlines come knocking,” says Pregler.

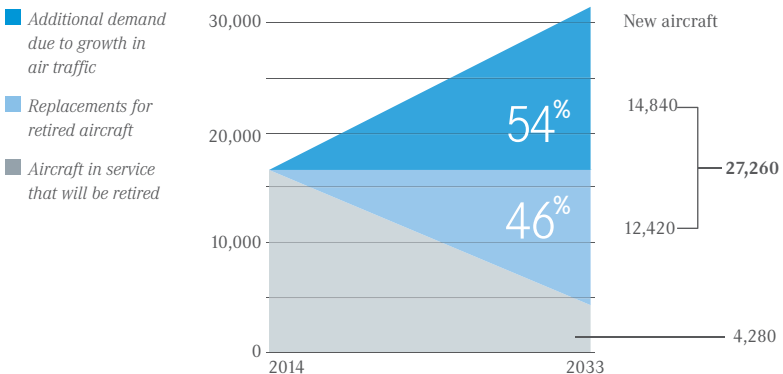
NEW AIRCRAFT OVER THE NEXT YEARS

Deliveries of narrowbody aircraft with jet engines from 2014 to 2033



Source: MTU Aero Engines

NARROWBODIES AND REGIONAL JETS: DEVELOPMENT OF FLEETS FROM 2014 TO 2033



Source: MTU Aero Engines

PRODUCTION OF NARROWBODIES AND REGIONAL JETS UP TO 2020



Airbus A320ceo



Airbus A320neo



CRJ



Boeing 737MAX



MRJ



E-Jets E2

- Narrowbodies
- Regional jets

A total of eight new narrowbody and regional jet families will go into production by the end of this decade. The Airbus/Boeing narrowbody duopoly and the Bombardier/Embraer regional jet duopoly are getting new competitors from China, Japan and Russia.

	In service	Entry into service			
		2015	2016	2017	2018
	<ul style="list-style-type: none"> ■ Airbus A320ceo 	<ul style="list-style-type: none"> ■ Airbus A320neo 			
	<ul style="list-style-type: none"> ■ Boeing 737NG 			<ul style="list-style-type: none"> ■ Boeing 737 MAX 	
	<ul style="list-style-type: none"> ■ CRJ 		<ul style="list-style-type: none"> ■ CSeries 		
	<ul style="list-style-type: none"> ■ E-Jets 				<ul style="list-style-type: none"> ■ E-Jets E2
				<ul style="list-style-type: none"> ■ MRJ 	
				<ul style="list-style-type: none"> ■ MS-21 	
		<ul style="list-style-type: none"> ■ ARJ21-700 			<ul style="list-style-type: none"> ■ C919
	<ul style="list-style-type: none"> ■ SSJ100 				
		2015	2016	2017	2018
	In service	Entry into service			

Inside MTU — MTU's medium-haul power: Geared Turbofan™ & Co.

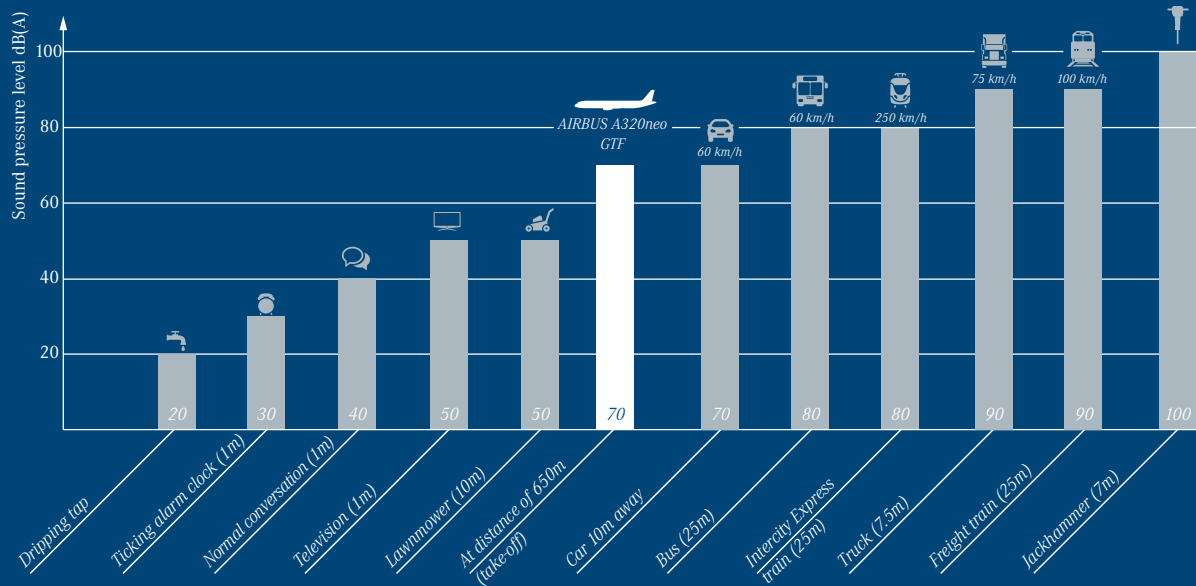


The Geared Turbofan™ engine from Pratt & Whitney and MTU Aero Engines is much in demand for short- and medium-haul routes. Five aircraft manufacturers have chosen the new fuel-efficient, low-noise technology for their new models. Thanks to the scalable core engine, the PurePower® PW1000G engine family—as it is officially titled—can cover various thrust classes from 10,000 to 35,000 pounds without the huge expense of developing a whole new solution for each new thrust strength and size.

The green engine sets new standards for environmental friendliness, reducing CO₂ emissions by 15 percent. A single A320neo, for example, emits around 3,600 tons less CO₂ a year. Multiplied by 3,700—the number of jets for which there are currently firm orders—that makes total savings of over 13 million tons a year. The Geared Turbofan also delivers significant improvements regarding nitrogen oxide. Its NO_x emissions are 50 percent lower than the statutory limits (CAEP/6) set by the International Civil Aviation Organization (ICAO). Another major strength of the Geared Turbofan is its significant reduction of flight noise: it nearly halves perceived noise levels.

It is hardly surprising, then, that the engine is so popular. The PW1000G has already secured around a third of the overall market for new narrowbodies and 80 percent for new regional aircraft. MTU has played a decisive part in this success story: its high-speed low-pressure turbine is a key component without which the Geared Turbofan would be unable to make use of its advantages, while the company also manufactures a new high-pressure compressor together with Pratt & Whitney as well as contributing brush seals. MTU is no newcomer to the short- and medium-haul aircraft business and has been involved in the development, manufacturing and maintenance of the very successful V2500 since the 1980s.

AIRCRAFT NOISE COMPARED WITH EVERYDAY NOISES



Aircraft noise compared with everyday noises: the volumes of various noise sources are expressed here as dB(A) sound pressure levels in order to obtain an approximate frequency weighting (A-weighting filter) in line with human perception.

Source: MTU Aero Engines

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

More on this topic: www.aeroreport.de

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.



+ 300% ——— Since the company went public in 2005, the MTU share price has increased by over 300 percent (as of April 30, 2015). This means it has developed considerably more favorably than Germany's MDAX index and the Euro Stoxx TMI Aerospace & Defense index. This reference group comprises the European aerospace sector's 15 most important companies.

Long-haul climber

The MTU Aero Engines share is turning ten.

Text: Larissa Klaus

MTU Aero Engines has already enjoyed decades of success developing the new technologies it takes to make flying more economical, quieter and more environmentally friendly. This is what ensures the company's long-term success, which in turn gives enduring power to the MTU share—which traded for the first time ten years ago on the Frankfurt stock exchange.

“Developed considerably better than comparable shares in the civil aviation sector”

June 6, 2005 was the first day of trading for the MTU share, which was issued at a price of 21 euros and opened at 21.89 euros. Since then, its price has increased by over 300 percent; in March 2015 it topped the 90-euro mark for the first time. “Comparable shares in the civil aviation sector have doubled in value in the last ten years—but the MTU share has developed considerably better than that,” says Michael Röger, head of Investor Relations at MTU Aero Engines. “This is because MTU's revenues and earnings have risen continuously over that period. We've generally come in at or even slightly above our targets, and we've achieved our forecasts.”

But the harsh climate of the 2008 financial crisis also caused a dip in the MTU share price. Figures sagged heavily across the aviation industry. In the first half of that year, high oil prices and a weak U.S. dollar put additional strain on earnings and, as a result, share prices. The sector also suffered due to weaker growth in air travel, which led to aircraft being taken

out of service and some orders being cancelled. “That was the first time the share price became decoupled from the company's operating performance,” says Claudia Heinle, Senior Manager Investor Relations at MTU. The economic outlook worsened over the course of the year so that by October 28, 2008, around three and a half years after its first day of trading, the MTU share price had sunk to an all-time low of 12.87 euros.

Record recovery

Recovery was not long in coming: By 2010, the share price had regained its pre-crisis level and continued to rise steadily on its way to reaching the then all-time post-IPO high of 79.25 euros in May 2013. “Although the lingering euro crisis dampened the mood on the capital market at that time, our share and the MDAX defied the volatile situation,” says Heinle. Low interest rates for other classes of investment increase the appeal of shares. The MTU share price remained fairly constant in 2014—in financial circles, this is referred to as a “sideways trend.” At the beginning of 2015, the MTU share jumped to a new record high. Starting at the end of 2014, the share got a boost from low oil prices and a strong U.S. dollar. The market also responded positively to the European Central Bank's announcement of its asset purchase program.

The future looks promising: “We've reached numerous milestones, each one enabling us to benefit from a growing market. Even the analysts agree,” says

Röger. The company is currently in a phase of high investment that is set to continue until 2017. But conditions are such that adjusted EBIT—in other words operating profit—is still expected to show some growth in this period. The coming years will above all be defined by preparations for series production of the Geared Turbofan™ programs and the advances in technology these will bring. MTU is also investing in R&D for engines that will have a big role to play in the future, such as the GE9X for the Boeing 777X, which is scheduled to hit the market in around 2020, thus securing a decisive market share in the upper thrust range.

Worthwhile investments

The benefit of these investments should start to show from 2018. “Some 30 percent of all aircraft in service today have MTU modules on board. Our engine fleet will expand greatly over the next five to ten years,” says Reiner Winkler, CEO of MTU Aero Engines AG. MTU then expects growth in the high-margin spare parts and maintenance businesses to accelerate.



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



More on this topic: www.aeroreport.de



Text:
Larissa Klaus has been writing for MTU internal and external publications for the past seven years. She also advises on corporate communications in the financial sector.



Leasing on the rise

In the time- and cost-sensitive aviation industry, airlines are increasingly using the opportunity to lease aircraft and engines.

Text: *Nicole Geffert*



Around 7.3 billion passengers will board an aircraft in 2034—more than twice as many as today. This means a huge demand for new aircraft and engines, a view shared by the forecasts of the two major aircraft manufacturers. According to Boeing, the total value of worldwide aircraft deliveries in 2015 is already around 124 billion US dollars, double the value of just a few years ago in 2010. And this trend is set to continue: by 2033, according to Airbus, about 31,000 new aircraft with a total value of 4.6 trillion US dollars will be needed.

Airlines concentrate on their core business

To keep pace with this demand, airline companies would have to invest on average around 250 billion US dollars every year in new aircraft. However, IATA estimated their recent profits at “only” 20 billion US dollars. Leasing companies with strong financial muscle are increasingly stepping in to close this gap. Since 1990, the proportion of leased aircraft has gone up by 26 percentage points to 40.7 percent. Boeing expects that in a mere five years from now, over half the aircraft worldwide will no longer belong to operators but to leasing companies. Other experts are more cautious in their estimates, but all aviation market observers agree on one thing: leasing instead of buying will be the name of the game in the future.

As in other industries, the companies benefit from the higher flexibility and lower capital costs of leased objects. Low-cost start-ups in particular can build up a fleet quickly through leasing, but even the big established players are turning more frequently to this alternative form of financing. Dr. Marc Le Dilosquer, Senior

Market Analyst at MTU Aero Engines, explains why: “Airlines tend to see their core business more as transporting people and goods than acting as investors and managing assets.” In addition, says Le Dilosquer, investing in their own aircraft holds a financial risk for airlines—one that other companies are better placed to evaluate and bear.

Aircraft as an investment opportunity

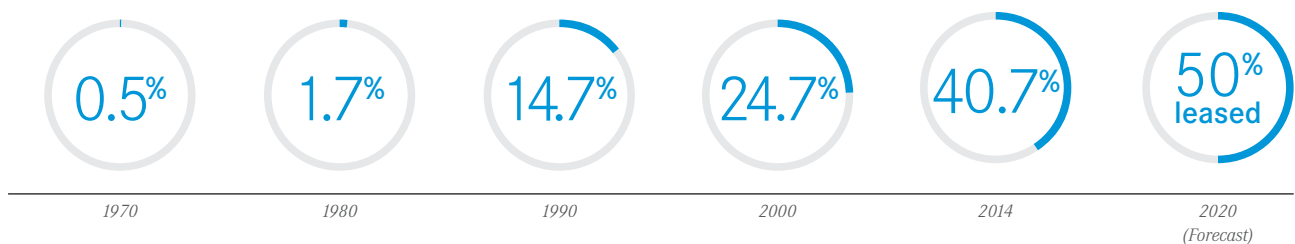
In light of the continuing liquidity glut, these companies are seeking lucrative and secure investment opportunities more than ever. Seen as attractive investments, aircraft are also drawing more and more investors and new leasing providers from the Middle and Far East. However, the largest lessor in the world is GE Capital Aviation Services (GECAS), which belongs to the US conglomerate General Electric. The industry pioneer has been operating on the market for over 40 years and currently has about 1,650 aircraft leased out to other companies—even the world’s largest airlines come nowhere near a fleet of that size. The second largest lessor is AerCap, which is based in Amsterdam and has around 1,300 aircraft.

These leasing companies supply aircraft to airlines for a contractually agreed period of time. In the case of narrowbodies such as the A320 and B737, the term is usually three to seven years. The leasing costs are made up of a monthly rate, which is generally one percent of the price of buying the aircraft new, as well as maintenance and contingency reserves, which are refunded at the end of the contract term.

LEASED AIRCRAFT AS A PROPORTION OF THE WORLDWIDE FLEET



Already, more than one in every **3** aircraft is leased today.



In 1970, not even 1 percent of aircraft were leased. Ten years later, this figure was 1.7 percent. By 1990, the number had multiplied by almost ten, and the market has grown strongly since then. Firstly, many airlines are scarcely able to finance the requisite aircraft purchases to cover increasing passenger numbers based on current profit margins. Secondly, investors are increasingly discovering aircraft as an attractive investment opportunity.

Source: Ascend and Boeing

Inside MTU — New leasing power

In 2013, MTU Aero Engines and the Japanese trading company Sumitomo founded two joint ventures for engine leasing: MTU Maintenance Lease Services (MLS), with an MTU stake of 80 percent, and Sumisho Aero Engine Lease, with an MTU stake of 10 percent. Both companies are headquartered in Amsterdam.

MLS offers integrated solutions for different customer needs, such as short-term leasing and standby arrangements. On top of this, it provides a range of additional services for all MTU Maintenance engine programs, including engine replacement, logistical services and maintenance and repair. For older engines, leasing can be a cost-effective alternative to repairs. This is where MTU^{plus} Mature Engine Solutions come in.

Asset management and materials management round off the services offered. The portfolio ranges from evaluating engines and analyzing their residual value, to purchasing or sub-leasing the entire engine, to comprehensive parts management. This includes taking the engine apart, repairing parts that can still be used, and warehousing and reusing spare parts.

Sumisho Aero Engine Lease specializes in long-term leasing, which involves customers using engines for a longer period defined in advance. Their portfolio also includes sale-and-leaseback solutions.

Engine leasing growing

Aircraft leasing companies benefit from continuous payment flows and the ownership of assets that retain their value for a long time. These two factors also characterize the engine business. It is no wonder, then, that a growing number of engines is leased, as well engine lessors include original equipment manufacturers (OEMs) and independent providers. MTU Aero Engines, too, is active in this promising market. In 2013, it founded two joint ventures together with Sumitomo, one of the largest trading companies in Japan, so as to be able to better meet airlines' growing demand for financing solutions: MTU Maintenance Lease Services (MLS) and Sumisho Aero Engine Lease (see Inside MTU).

Thanks to leasing, airlines no longer have to invest in their own replacement engines, preserving their capital base. However, they want more. "We've received a clear message from our customers: They want a comprehensive service that allows them to efficiently manage their engines," says Martin Friis-Petersen, Managing Director, MTU Maintenance Lease Services. "Consequently, we have added asset and materials management to our portfolio in order to take the value that lies in an engine and optimize it for our customers' benefit."

This facilitates optimum engine management and cost-effective support that encompasses everything from delivery and maintenance through to the recycling of the engine's parts at the end of its service life. "Aside from the OEMs, there are only a few competitors worldwide that can offer the entire service chain like we do," says Friis-Petersen.



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

MTU MAINTENANCE LEASE SERVICES

The company's engine portfolio includes:
V2500-A5/-D5, PW2000, CF6-50/-80C2,
GE90-115B, CFM56-3/-5B/-7 and CF34.

SUMISHO AERO ENGINE LEASE

The company's engine portfolio includes:
CFM56-5B/-7, V2500-A5, Leap-1A/-1B,
PW1100G-JM, CF6-80C2, GE90-115B,
GENx and CF34-10E.



End of an era — A tradition going back decades connects the illustrious Dutch airline KLM and the aircraft manufacturer McDonnell Douglas, which is now part of the Boeing Group: KLM is the only airline in the world to have bought every McDonnell Douglas model since 1934—most recently the MD-11 trijet, which was retired at the end of 2014.

End of an era

*KLM gives the last McDonnell Douglas MD-11 in passenger service a fitting send-off—and **AEROREPORT** was there to witness it.*

Text: *Andreas Spaeth*





Boarding _____ For the price of 111 euros each, aviation enthusiasts from all over the world enjoyed the last flight of the MD-11 in passenger service on a glorious fall day.

Some occasions call for a bit of symbolism: the first of three farewell flights for the very last McDonnell Douglas MD-11 in passenger service took off on 11.11.2014 at 11:00 a.m., with tickets priced at exactly 111 euros. There was a massive response: all 592 seats that KLM put on sale in September were sold out in just four minutes, almost causing the KLM internet server to collapse. Aviation enthusiasts from all over the world converged on Amsterdam to fly for the last time on board one of these classic commercial airplanes. The day marked the end of several eras in aircraft construction, including the unique relationship between the illustrious Royal Dutch Airlines and the manufacturer McDonnell Douglas, which was incorporated into the Boeing Group many years ago.

KLM is the only airline in the world to have operated every single model brought to market by the Californian aircraft manufacturer since 1934. It all started with the DC-2, an airworthy example of which still exists in the Netherlands. Next came the DC-3, which KLM also chose to exhibit on the apron on this valedictory November day as one of its classic aircraft alongside a further MD-11. After that, KLM operated the DC-4 and even the largely forgotten DC-5, only twelve of which were built. And of course there were the classic four-engine long-haul aircraft, the DC-6 and the DC-7, and the first intercontinental jet, the DC-8. The twinjet DC-9 was the backbone of KLM's European fleet for many years, while the DC-10 and later the MD-11 served long-haul routes.

No less significant an event on this sunny day in late fall was the bowing out of trijets from commercial passenger service—the final regular MD-11 flight had already flown from Montreal to

Amsterdam on October 26, 2014. There had been times, though, when commercial aircraft with three engines were extremely widespread. In the 1960s, twinjet aircraft were not certified to cover longer distances or cross oceans, and three engines were generally more cost-effective than four. The prime example of these trijets was the Boeing 727, more units of which were manufactured than any other commercial aircraft in the world for many years – a grand total of 1,832. By comparison, the British Hawker Siddeley Trident 3 was more of a footnote in trijet history with only 117 airplanes built. By the end of the decade, people were beginning to consider fitting long-haul widebody jets with three engines, as airlines needed a smaller alternative to the Jumbo Jet, the nickname for the groundbreaking Boeing 747, which set the standard back then. And so the McDonnell Douglas DC-10 was born, and entered regular service in 1971. Hot on its heels came the Lockheed L1011 TriStar, although this competitor never achieved the success of the DC-10. A total of 446 units of the remarkable DC-10 were made between 1968 and 1988, of which 374 were built for passenger service. Competitor Lockheed was destined to always lag behind, with just 250 aircraft leaving the factories between 1968 and 1984. And then in 1990, the MD-11 was launched as a successor to the DC-10.

The MD-11 is more elegant than its predecessor, and not only thanks to its longer fuselage—almost six meters longer than the DC-10's—but because it is the first commercial aircraft ever to feature winglets. In addition, the vertical stabilizer above the middle engine is shorter and smaller, and another major improvement was new engines, especially the GE CF6-80-C2D1F, in which MTU Aero Engines has a stake (see Inside MTU). On top of this, the MD-11 was the first trijet to have a modern

two-person cockpit. “The MD-11 is a very robust and elegant aircraft,” says flight captain Charley Valette, until recently chief MD-11 pilot at KLM.

However, in 1995 competition came along in the form of the Boeing 777-200ER and soon demonstrated that aircraft with two engines and ETOPS certification were capable of safely flying longer distances over water. That was the beginning of a trend that ultimately spelled the end for the trijet in commercial passenger service—as well as greatly diminishing the importance of quad-jet aircraft. As a consequence, MD-11’s commercial performance fell far below expectations. What is more, once the first operator Finnair had put the new trijet into service in November 1990, it soon emerged that the aircraft was unable to fulfill the range and fuel consumption claims that had been made for it. The manufacturer introduced a whole package of improvements, but it was too late. Major clients such as Singapore Airlines cancelled their orders and bought the subsequently launched quad-jet A340-500 for ultra-long-haul flights instead. The number of engines also played a large role psychologically at the start of the 1990s, when many passengers and even some pilots were still uncertain about crossing the Atlantic in a two-jet aircraft. “We could have flown to America with the Boeing 767 no problem, but because the competition was doing it with quad-jet aircraft, LTU was forced to choose the MD-11,” says German flight captain Joe Moser, who was head of operations for LTU at the time.

In the end, the MD-11 was delivered to airlines all over the world—200 aircraft in total—over a period of only nine years. The manufacturer, who was taken over by Boeing in 1997, would have had to sell 300 to break even. 144 of the MD-11s that were built started their careers in passenger service, while the rest were cargo aircraft. And it was in the transportation of goods that the MD-11 found its niche. Soon the majority of passenger versions were converted into freighters, the first after serving only five years as a passenger aircraft. Of the 150 MD-11s that were active in the summer of 2014, all of them were used as cargo aircraft—except for the remaining four of what were originally ten KLM passenger airplanes. In February 2010, the first MD-11 customer Finnair became the second to last airline to retire its fleet. Then KLM flew its first MD-11 out into the American desert to cannibalize it for spare parts in July 2012. And finally, on November 11, 2014, the hour came for the very last commercial trijet passenger flight.

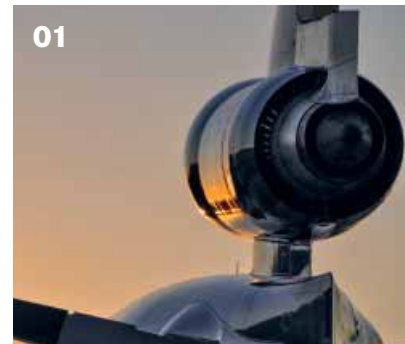
*“I’ll miss the MD-11; she’s my favorite
and that won’t ever change.”*

**Flight captain Charley Valette,
16 years and more than 5,000 flight hours in the MD-11 cockpit**

The atmosphere ahead of final flight KL9899 from Amsterdam to Amsterdam is relaxed—KLM’s CEO Pieter Elbers can be seen mixing with the passengers under bright sunny skies. “It’s actually a good day for us, as the successor aircraft A350 and Boeing 787-9 are up to 25 percent more cost-effective to operate than the MD-11,” says Elbers. “Although we knew that many of our customers have a soft spot for the MD-11, we were still surprised at the response to the farewell flights, which have really struck a chord,” he admits. While boarding, passengers are already writing their farewell messages on the outside of the plane beside the doors. Each guest receives a gift bag with the legend “I fly MD-11,” whose contents include a freshly printed safety card prized by collectors. The galleys are festooned with garlands for the occasion, while the cabin is a hive of excited activity and the flight attendants have a job to get the guests to put their seat belts on.

A LEGEND BOWS OUT

- 01** — Typical: the third engine beneath the rudder.
- 02** — Impressive fleet at Lufthansa.
- 03** — MD-11 to remain active in cargo service.
- 04** — KLM had one of the largest MD-11 fleets.



Inside MTU — *MTU and the MD-11*

“It’s a pity that the MD-11 won’t be carrying passengers anymore,” says Norbert Möck. “It was always so nice and spacious inside.” The director for General Electric and CFM engine programs at MTU Maintenance in Hannover has his own experiences as an MD-11 passenger—and with the aircraft’s GE CF6-80C2D1F engine. “We had the engines of several MD-11 operators here for maintenance, most recently from Saudi Arabian Airways, but before that from FedEx and Cargoitalia too,” says Möck. “The engine’s performance level was pushed to the maximum with the trijet.” MTU itself has a 9.1 percent stake in the CF6-80 engine, amongst others supplying parts for the high-pressure turbine. “With some 3,400 units delivered, the CF6-80 is the third largest program for us, although a total of only 119 MD-11s were fitted with GE engines,” explains Wolfgang Hiereth, director of new business for GE programs at MTU in Munich. Between 50 and 60 units of this model are still being manufactured every year—one of which even powers the U.S. President’s “Air Force One” Boeing 747-200B.

Shortly after the scheduled time of 15:30, the MD-11 bearing the name Florence Nightingale and the registration PH-KCD, which was delivered back in September 1994, begins its taxi to the runway. All three turbofans give full thrust at takeoff, and the distinctive MD-11 sound so loved by its fans can be heard particularly well in the rear of the cabin. It is only a brief blast, however, as the ascent ends at an altitude of around 2,000 feet (not even 700 meters). What follows is a special sightseeing tour of the Netherlands from the air in clear fall weather, taking in the North Sea coast, Rotterdam, Eindhoven and Lake IJssel; polders, ships and windmills. Many of the enthusiasts on board, however, scarcely look out the windows. They are too busy filming in the cabin—which still looks amazingly modern—posing for photos and drinking wine from bottles sporting special MD-11 stickers. Chief pilot Charley Valette himself sits in the cockpit and plays the role of tour guide over the loudspeakers during the low-altitude flight over the Netherlands. There’s a clamor for waterproof felt-tip pens in the cabin, with everyone looking to write a farewell message on storage compartments and walls. The CEO too takes a pen and scribbles the following message on the luggage compartment over row 12: “Thanks MD-11 for 21 years of loyal service to this royal airline.” All too soon, the airplane lands again in Schiphol after only 54 minutes in the air. In honor of the MD-11, a procession ensues over the airport’s main taxiways, with the twenty-year-old trijet led by KLM’s legendary DC-3 aircraft, which was built exactly 50 years earlier. Captain Charley Valette, who sat in the MD-11 cockpit for more than 5,000 flight hours over a period of 16 years, is succinct in his assessment: “I’ll miss the MD-11; she’s my favorite and that won’t ever change.”



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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 to discuss current events in the sector.





A smile in the sky _____ *Cheerful brand image of MTU Maintenance customer Solaseed Air. The Japanese market was nearly inaccessible to foreign providers for a long time.*

A smile in the sky

Step by step, MTU Aero Engines is unlocking the Japanese market, which was sealed off for a long time. Deeper cooperation with the up-and-coming Solaseed Air is the latest success.

Text: Nicole Geffert

By the 1980s at the latest, Japan—the nation of 6,800 islands at Asia’s furthest eastern edge—had joined the ranks of the leading global economic powers. Its 125 million-plus inhabitants generate the third-highest GDP in the world, outpunching traditional industrial heavyweights such as Germany and the United Kingdom.

This economic power is also reflected in air travel. With 72.8 million passengers, Haneda Airport in Tokyo—the hub for the major Japanese airlines—is the world’s fourth busiest airport. According to data from the World Bank, airlines registered in Japan carried just shy of 106 million passengers in 2013. And although the market is largely saturated, the Japan Aircraft Development Corporation (JADC) predicts an average growth in passenger volume of 1.6 percent a year for the next 20 years. Accordingly, the aircraft market is dynamic at the moment. A year ago, the largest airline, All Nippon Airways (ANA), ordered 40 long-haul jets from Boeing and 30 medium-haul jets from Airbus all at once for a total of 16.6 billion US dollars.

More passengers and more aircraft also mean more maintenance. However, this business was reserved for domestic providers over many years—on top of the two largest airlines, which have their own shops, there is also the veteran IHI Corporation. Leo Koppers, Senior Vice President, Marketing and Sales at MTU Maintenance, knows all about the barriers: “Japan is a closed market that is scarcely accessible to providers from abroad.”

Nevertheless, in 2010 the Japanese Civil Aviation Bureau (JCAB) approved MTU Maintenance Zhuhai to maintain engines. For the first time, a Japanese authority had certified as top quality a relatively young company located in their big neighbor and competitor China. The Zhuhai plant had successfully specialized in CFM56 and V2500 engines. Later the same year, the Japanese industry leader ANA brought its first CFM56-3 to the shop and has been regularly using their maintenance expertise ever since.

One year later, a second Japanese customer came on board in the shape of Solaseed Air. Since 2011, the company with

a jaunty smiley on the green tails of its aircraft has been entrusting the Zhuhai location with the repair of its fleet's CFM56-3 engines. Solaseed Air, incorporated as Skynet Asia Airways Co. Ltd., has been serving destinations in the south of Japan since 2002. "Seed smiles in the sky" is its motto. Since then, its network has expanded to 62 flights a day on eight routes. The airline connects big cities on its home island of Kyushu with Tokyo, Kobe—which is located just a short distance from Japan's second largest economic hub Osaka—and the subtropical vacation paradise of Okinawa.

In January 2015, the two companies deepened their partnership with an exclusive contract for the maintenance of all 24 CFM56-7B and -7BE engines for the airline's Boeing 737-800 fleet. "MTU Maintenance has proved a reliable and trustworthy partner who delivers an outstanding service quality," Solaseed Air CEO Hiroshi Takahashi explained. "We are delighted that the company will now also be looking after our latest engine models."

ANA's decision to expand its cooperation with MTU also attests to how much the Japanese prize high quality and excellent service. Even though the airline has its own shops, it has also been delivering engines to MTU's German maintenance location in Hannover-Langenhagen since the end of 2013. "JCAB certification for the maintenance of complete engines from Japanese customers is just around the corner," says Jan Steenbock, Vice President, Marketing and Sales for Asia at MTU Maintenance.

At the same time, MTU is expanding its presence in Japan into other areas of business by means of two joint ventures with Japanese trading company Sumitomo (see Inside MTU on page 20). Step by step, MTU is gaining a foothold in the Japanese market: It was a landmark in the country's aviation history when in October 2014 the Mitsubishi Regional Jet (MRJ) had its rollout in Nagoya. The new eco-friendly aircraft for up to 100 passengers is powered exclusively by the highly innovative PW1200G engines, which were developed with MTU participation.

Typical Japan ——— *Cherry blossoms, pagoda, and in the background Mount Fuji, Japan's highest and holiest mountain. A stylized picture of the mountain adorns the cabin ceiling of the Mitsubishi Regional Jet.*



**ENGINE MAINTENANCE AT
MTU MAINTENANCE ZHUHAI**

- 01** _____ *Inspection of a V2500.*
02 _____ *A high-pressure compressor is prepared for high-speed grinding.*
03 _____ *A CFM56-3 prior to a test run.*
04 _____ *Engine casings await assembly.*
05 _____ *A CFM56-3 on the test stand.*



Inside MTU _____ *Partnerships in Japan*

MTU Maintenance's breakthrough into the Japanese market came about in 2009 through a maintenance contract with All Nippon Airways (ANA). Maintenance of ANA's engines has been carried out since then by MTU Maintenance Zhuhai in China, a 50:50 joint venture between MTU Aero Engines and the holding company of China's largest airline, China Southern. Since 2011, Solaseed Air has also entrusted its engines to the expanding plant on China's south coast.

In September 2013, MTU and the Japanese trading company Sumitomo Corporation founded two joint ventures: MTU Maintenance Lease Services and Sumisho Aero Engine Lease (see Inside MTU, page 20).

Japan's first commercial aircraft in decades, the Mitsubishi Regional Jet (MRJ), had its rollout in October 2014 in Nagoya. MTU Aero Engines and the Japanese Aero Engine Corporation (JAEC) are among the partners involved in the aircraft's PW1200G Geared Turbofan™ engine. JAEC is a joint venture that pools together the engine activities of Kawasaki, Mitsubishi and Ishikawajima Harima. The alliance was occasioned by the foundation of International Aero Engines (IAE) in 1983 with the objective of developing the V2500 for the A320 family together with four other partners. One of JAEC's longstanding IAE partners is MTU Aero Engines.



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



“Now we need to aim higher”

Professor Rolf Henke, Executive Board Member for Aeronautics Research at the German Aerospace Center (DLR), believes that large passenger aircraft powered by solar technology and electric motors are still a utopian dream. But he looks forward to more revolutionary ideas.

Text: Eleonore Fähling

Professor Henke, the round-the-world flight by solar airplane Solar Impulse 2 has grabbed the public's attention. Does the future of aviation lie in solar power?

Rolf Henke: It is certainly a fascinating project, for which, incidentally, DLR's Institute of Aeroelasticity carried out ground vibration tests. But I can't imagine that we will see commercial flights by solar-powered aircraft seating more than ten passengers any time in the foreseeable future. However, there is an area in which solar energy can be exploited, and that's fuel production. This idea is already being worked on.

And what about electric motors—another widely debated subject?

Henke: In the road transportation sector, the initial enthusiasm for electric cars has cooled down somewhat, because the range of these vehicles is still too limited. In the aviation sector, electric motors could be an exciting option for two- to four-seat airplanes. Airbus has already developed the world's first motor-assisted glider with a hybrid, serially distributed power system, in a joint project with Diamond Aircraft and Siemens, as well as the two-seater E-Fan electric aircraft. But it will take not just one but several new generations of battery technology to reach the point where electric motors can be used to power large passenger jets. To illustrate this point: The thrust





Professor Rolf Henke — *A leading light in the German aviation industry*

Prof. Rolf Henke has been responsible for aeronautics research as a member of the Executive Board of the German Aerospace Center (DLR) since November 2010. After studying aerospace engineering, he embarked on an impressive career path in science and industry. From the mid-1980s onward, he conducted research for Messerschmitt-Bölkow-Blohm (now Airbus Operations GmbH), specializing in laminar technology. From 1992 to 1998 he directed all Airbus programs in this field, before taking on responsibility for managing the ADIF Adaptive Wing project. In 2000 he took responsibility for Airbus high-lift technology, and from 2002 onward additionally directed work on the EU's AWIATOR (Aircraft Wing with Advanced Technology Operation) technology platform for wing development.

In 2006 he returned to his home region of Rhineland-Westphalia to take up a professorship at RWTH Aachen University where he became head of the Institute of Aeronautics and Astronautics (ILR). At RWTH, Henke established design, analysis and simulation facilities and built up a system for field measurements of aircraft noise. An enthusiastic teacher, he set up new courses in aircraft design and aircraft systems engineering, and has continued to lecture even now that he is a member of the DLR Executive Board. Since 2013 he has also served as chairman of the Deutsche Gesellschaft für Luft- und Raumfahrt – Lilienthal-Oberth e.V. (DGLR), the scientific and technical umbrella organization and action and information forum for aerospace activities in Germany.

“Drastic improvements in noise reduction will be needed so as not to compromise public acceptance.”

Professor Rolf Henke,
*Executive Board Member for Aeronautics Research
at the German Aerospace Center (DLR)*

generated by the GE90, deployed in the Boeing 777 and currently the world's largest engine, corresponds to a power output of around 70 megawatts, which has to be maintained for a flying time of up to 24 hours. This is equivalent to the total output of the largest privately operated solar park in the United States, which Apple plans to build in Arizona. Aircraft noise is another issue that needs to be considered when designing electric aircraft, because the main source of engine noise is the fan, a component that is also required in electric propulsion systems.

Here at DLR, we are researching ways of making greater use of electricity to deliver power to onboard devices. The More Electric Aircraft recuperates energy from the engine and transforms it into electricity that can then be used to power control devices for various subsystems which until now have been operated using hydraulic or pneumatic controls. Typical functions include moving the wing flaps or pumping hot air from the engine and directing it over the wings to prevent ice formation. Electrically operated systems consume less energy and their low weight helps to save fuel. I see this as a worthwhile development.

At DLR, you tie together the diverse areas of aerospace research in Germany. What are your current priorities with respect to aircraft design in general?

Henke: We conduct research into all aspects of the air transportation system, which can be divided into three main areas. The first concerns the environment, where we are studying the issues of noise reduction during takeoff and



landing and fuel-efficient route planning. These modified procedures have an impact on our next area of research, which concerns aircraft design in general, from the overall design process to the integration of specific components. This in turn gives rise to new technological requirements, which are implemented in the third step—the development of new components, technologies and materials. DLR can develop all-round solutions to meet all needs of the aerospace sector by applying a holistic approach that forges links between and within these individual areas.

What areas offer the greatest prospects for advances in aerospace technology?

Henke: Progress comes from knowledge. For example, the better our understanding of the mechanisms that cause vortex trails, the more easily we will be able to calculate the required minimum distance between aircraft when leaving or approaching the runway during takeoff and landing, which in turn will enable us to define more efficient and environmentally friendly flight control procedures. And the more we learn about the contrail-induced formation of cirrus clouds, the greater our knowledge concerning the impact of aviation on the global climate and the technical improvements needed to reduce these effects. Finally, it is obvious that a better understanding of the behavior of materials used in engine components will enable us to reduce engine weight and hence aircraft fuel consumption.

What is your realistic estimate of the reductions that can be achieved in CO₂ emissions, fuel consumption, and noise levels in the near future?

Henke: The European aeronautics industry was the first to define fixed goals in its “Vision for 2020” published 15 years ago. 2020 is approaching fast, and we are well on the way to achieving a considerable number of these goals. Meanwhile, the original targets have been updated in the Flightpath 2050 initiative, in which DLR had a hand. Our aim is to reduce aircraft fuel consumption and CO₂ emissions by 75 percent by 2050, compared with the 2000 baseline. Nitrogen oxide (NO_x) emissions are to be reduced by 90 percent and noise by 65 percent. In my opinion these are realistic targets, provided the necessary efforts are made.

You mention fuel, emissions, and noise: Which of these requires the most work?

Henke: Given the continuing growth in global air traffic, the issue that stands out is aircraft noise. Drastic improvements will be needed here so as not to compromise public acceptance. But there is also a need for action in a wide range of other areas. One of these is ground handling processes—which extend from transportation services to the airport to the flow management of passengers and cargo and maintenance services. Another important issue is the product lifecycle of aircraft. One of the Flightpath 2050 objectives concerns the recycling of aircraft. We are still a long way off from achieving this goal, especially in the case of modern aircraft in which more than half of their structural components are made of fiber-reinforced composites.



“Major advances also demand courage and above all determination, on a political level as well as on the part of companies.”

Professor Rolf Henke,
Executive Board Member for Aeronautics Research
at the German Aerospace Center (DLR)

What drives progress in aviation?

Henke: As I see it, the days of simple solutions and quick progress are over. We have stripped the tree of all low-hanging fruit. Now we have to aim higher, for instance by developing innovative materials that will enable us to increase wing strength or by learning more about stress and strain in engine components, which might enable us to reduce the number of engine stages. We also have to think about the resilience of the air transport system as a whole, to ensure that it doesn't entirely collapse if a part of it fails. This was what happened in 2010, when the volcanic eruption in Iceland shut down all air traffic in Europe.

However, major advances also demand courage and above all determination, on a political level as well as on the part of companies.

What role does Germany's research community play in this context?

Henke: It could play a central role. DLR is one of Europe's largest research organizations, and its interdisciplinary approach to research provides the basis for assuming such a leading role. What is needed now is close collaboration between industry, government and research, and the political will to take on this central role, in order to provide the technological system capability needed for the air transport system as a whole.

Do we have enough up-and-coming scientists and engineers to do this?

Henke: The decline in the birth rate in Germany is currently having more of an effect on the availability of skilled workers than on the number of engineers. University places in the relevant disciplines are still being filled, but that could change too. Industrial companies will have to play their part, for instance by facilitating lifelong learning. It's already rare today for someone to exercise the same profession for 40 years after completing their training or studies.

As I see it, experience is the most problematic issue. During my time at Airbus, I got to see the final development phase of the A320, then the work on the A330 and A340 as well as the A380 and the beginning of the A350 program. This most recent Airbus offspring is now also already in scheduled service. If Airbus starts developing a completely new aircraft in five or ten years' time, it is possible that the people working on the project will never have done this sort of thing before, even though they left school or university 20 years before.

Will it always be necessary to invest so much time in developing new technologies to the point where they start earning money?

Henke: Yes, the development phase in the aviation industry will always be relatively long compared with other sectors. By the time a new engine or aircraft is placed in service, it will have gone through around ten years of design studies and development, and another five years to produce a prototype, including one or two years of flight testing. This requires billions of euros in up-front investments that will take years to amortize, owing to the relatively low number of units produced. But these investments are still very worthwhile, as can be seen from the manufacturers' order books, which are full for many years ahead. Nonetheless, researchers are looking into ways of reducing development lead times and hence the level of investments. An example is the "Virtual Product" project currently in progress at DLR.

What effect does progress in space technology have on commercial aviation?

Henke: It has a huge effect. Just look at the Apollo program, where engineers and technicians introduced systematic project management for the first time. Or the satellites that provide support for air traffic control. One day in the very distant future, our descendants might fly in hypersonic aircraft, combining aviation and space travel. At DLR, researchers in aeronautics and space technology often work hand in hand.

You brought up the subject of hypersonic aircraft. What changes in air travel can we expect to see generally in the second half of this century?

Henke: For one thing it will hopefully be quieter, more comfortable and more sustainable. There will probably also be an increase in the use of unmanned systems, for transporting cargo for instance. However, most of the changes in the foreseeable future will be evolutionary, not revolutionary. In the near future, I don't see anything like a supersonic aircraft that can take you from Europe to the States and back on the same day—unless it is demanded (and paid for) by one of the new billionaires, that's to say mega-businesses such as Google or Alibaba.

And what will change for me as a passenger in the next 40 years?

Henke: When I think back to my first flight in 1970, nothing much has changed from the passenger's point of view. Airplanes are quieter, the cabins more comfortable, but the major technological developments in recent years with regard to fuel consumption, emissions, and maintenance processes don't really affect the passengers onboard. One area where improvements could be made is ground handling processes—such as all those time-consuming security checks. There is also plenty of room for improvement in the networking of different modes of transportation, for instance from road to rail and from there to the airplane. This calls for clever solutions—and the courage and determination to implement them.



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Eleonore Fähling is MTU's Editor in Chief for AEROREPORT and has been in charge of the MTU employee magazine for over 15 years. Prior to that she was a PR journalist covering technical topics and a member of the editorial team at a non-fiction publishing house.



German Aerospace Center (DLR)

- The German Aerospace Center (DLR) is the national aeronautics and space research center of the Federal Republic of Germany. Approximately 8,000 employees work at its headquarters in Cologne and 15 other locations in Germany. DLR has its own flight facilities in Braunschweig and Oberpfaffenhofen near Munich.
- Four offices in Brussels, Paris, Tokyo and Washington D.C. are responsible for organizing cooperative ventures with international partners.
- DLR's 32 institutes work on numerous projects concerning the future of aviation and spaceflight, and develop environmentally friendly technologies for applications in energy supply, mobility, communications and security.
- DLR operates the largest civilian fleet of research airplanes and helicopters in Europe—ranging from the A320ATRA to the Cessna 208B and including one aircraft powered exclusively by fuel cells.
- DLR has been given responsibility by the federal government for the coordination and implementation of the German space program, and also takes part in joint international missions.
- DLR has a long history. Its earliest predecessor, the "Modellversuchsanstalt für Aerodynamik der Motorluftschiff-Studien-gesellschaft" (institute for aerodynamic model testing of the society of studies for motorized dirigibles), was created in Göttingen in 1907.
- The German Aerospace Center in its present form was created in 1969, initially as the Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (German institute of aerospace research and testing, DFVLR), which brought together Germany's hitherto widely dispersed aeronautics and space research activities under one roof.
- In 1997, this organization was merged with the Deutsche Agentur für Raumfahrtangelegenheiten (German agency for space affairs, DARA), creating the German Aerospace Center (DLR) as it is today.



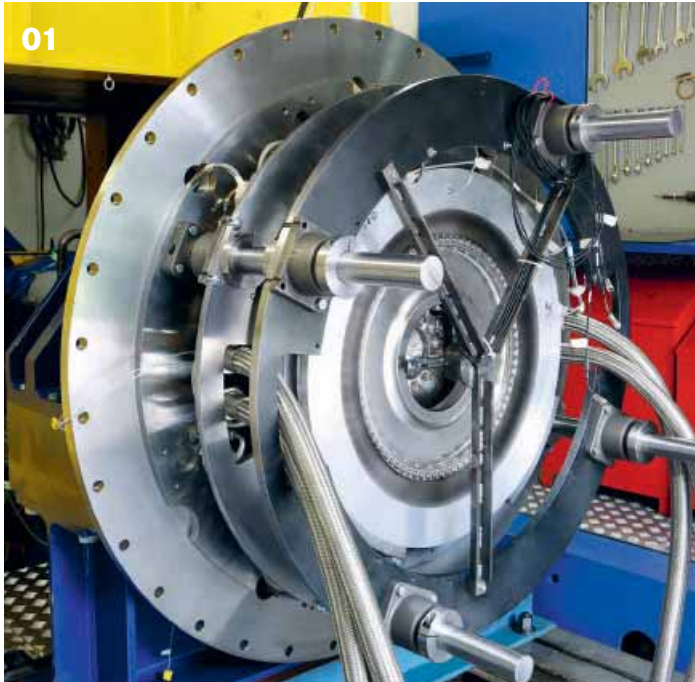
Rotor testing

Using an excitation rig, the component testing department at MTU Aero Engines in Munich analyzes the vibration behavior of compressor and turbine blades well before the complete engine's first test run.

Text: Achim Figgen

The basic design of a jet engine is more straightforward than you might think. Air is sucked in at the front and then compressed and mixed with kerosene. The mixture is ignited, and the combustion gases propel the aircraft forward. Of course, the whole

thing is much more complex in reality for a variety of reasons, not least because most of the compressed air does not even pass through the combustion chamber, but flows past the outside of the core engine and generates the thrust.



EXCITATION RIG IN ACTION

- 01** — Excitation rig on MTU's spin test rig.
02 — An individual rotor (here an example) runs on the excitation rig in order to analyze the vibration behavior at the blades.

High speeds in the engine interior put considerable strain on the rotating components in the compressor and turbine. To keep vibration stresses low, particularly at the junction of disk and blade, is a major design challenge for development engineers. They must ensure as far as possible that the blades' natural frequencies never lie within the operating range—in other words, at the speeds that normally occur. When that is structurally impossible, other solutions are required, such as the installation of dampers between blade root and disk to dissipate vibration energy via friction in the case of resonance.

However, their effectiveness cannot be verified using the traditional testing methods at component level, such as on a spin test rig, which is capable only of calculating the centrifugal stress acting on the rotor and therefore on the blades; it cannot simulate vibrations. In the

shaker test, on the other hand, individual blades are clamped to a shaker unit and vibrated, but this method lacks the simultaneous action of centrifugal forces. For this reason, the only way of verifying the effectiveness of the dampers in the past was by test running the complete engine. This led to extremely time- and cost-intensive design variations and lengthy wear tests.

The engineers at MTU Aero Engines in Munich found a solution to this dilemma around five years ago: an excitation rig. In this test rig, explains Dr. Ulrich Retze from the component testing department, an individual rotor is set in rotary motion; simultaneously, by pumping in air, forces are applied to the blades whose strength and frequency can be set such that the vibrations at the blades correspond to those that occur in a real engine. Now various dampers can be tested at an early stage of development

and without extensive alterations, and comparisons can be made with a non-damped system.

The excitation rig essentially consists of the existing spin test rig, to which the air injection system and other additional functionalities were added. Existing methods can be used to record and evaluate the vibrations. A key role is played here by the non-contact blade vibration measurement system (BSSM) developed in house by MTU, which is also used for testing with complete engines. Put simply, the system measures the times at which a blade tip passes a certain spot. Arithmetical conclusions about vibration behavior can then be drawn from the differences in time intervals.


In view of the clear advantages of the new method, it is unsurprising that prospective users were already lining up


before development of the excitation rig was even fully completed. First up was an order from MTU Maintenance, who had developed a new repair method for the high-pressure compressor used in the V2500 engine and urgently required information about the wear and damping behavior of various damping wire configurations.


Subsequently, the test rig was also able to prove its worth in the development of new engines—namely, while testing the low-pressure turbine of Pratt & Whitney’s PW1000G Geared Turbofan™ family. The versions PW1500G (for Bombardier’s CSeries) and PW1100G-JM (for Airbus’s A320neo family) are already in flight testing, while the first flight of the Mitsubishi Regional Jet MRJ90 (with PW1200G engines) is imminent.

The excitation rig has also already been used for research projects. As part of the European Clean Sky program (see below), research is being carried out to further develop Geared

Turbofan technology, and here MTU was able to use the rig to test a new low-pressure turbine technology it had developed even before the first run of the demonstrator engine.

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

 More on this topic: www.aeroreport.de

 Text: **Achim Figgen** is a graduate engineer specializing in aerospace technology and is assistant editor in chief at aviation magazine Aero International. He has written several books on aviation subjects.

Clean Sky and Clean Sky 2

Clean Sky is the most comprehensive research program ever undertaken in Europe for the development of new technologies to improve the environmental sustainability of aviation. Six Integrated Technology Demonstrators (ITDs) form part of the project, which was launched in 2008 and will run until 2017. In the SAGE (Sustainable and Green Engines) ITD, five engine demonstrators are being constructed and tested for different power classes and market segments. MTU Aero Engines is responsible for the demonstrator designed to validate improved Geared Turbofan™ technology.

Clean Sky 2 is already underway. The successor program was launched in 2014 and is due to be completed in 2024. MTU Aero Engines is involved as one of 16 lead companies in the aviation sector.

- MTU’s activities are focused primarily on further optimizing the low-pressure turbine and the high-pressure compressor.
- Core topics include developing lighter and more temperature-resistant materials and improving the aerodynamics.
- Components such as compressors and turbines are no longer to be considered separately, but as integral parts of the engine.

600

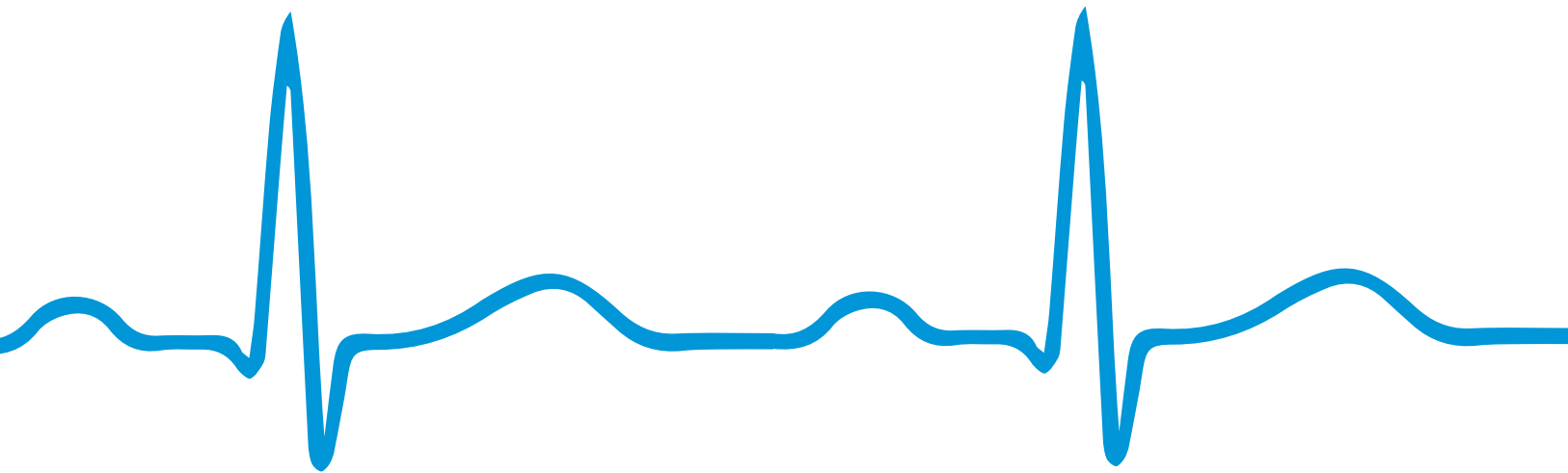
companies and institutes are working together in Clean Sky, Europe’s largest aviation research program to date, to develop technological improvements for aviation.

2014

saw the launch of Clean Sky 2, the successor program that is due to run until 2024 and in which MTU Aero Engines is involved as one of 16 lead companies.

5

engine demonstrators are being constructed and tested for different power classes and market segments as part of Clean Sky’s SAGE (Sustainable and Green Engines) project. MTU Aero Engines is responsible for one of them. Its first test run is planned for the second half of 2015.

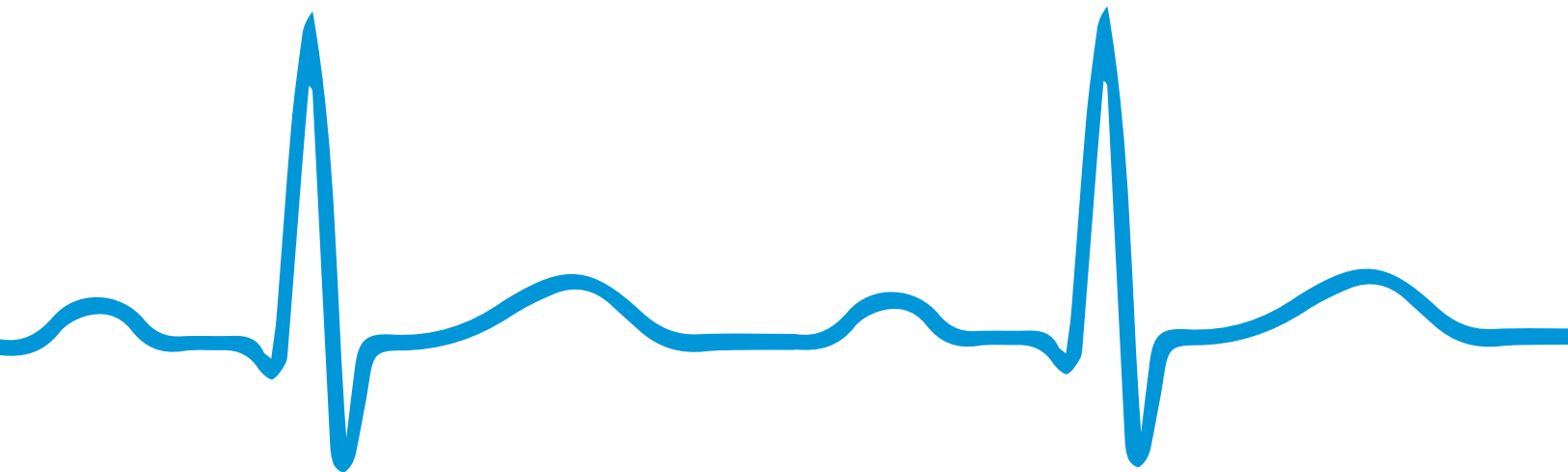


Many consider the compressor to be the heart of any engine – and rightly so, because ultimately this component determines the power of every jet propulsion system. But efficient turbines are equally indispensable. In both cases, MTU Aero Engines has accumulated a wealth of experience in the past forty five years.

Heart and muscle

*45 years of turbine and compressor development
at MTU Aero Engines.*

Text: Patrick Hoeverler

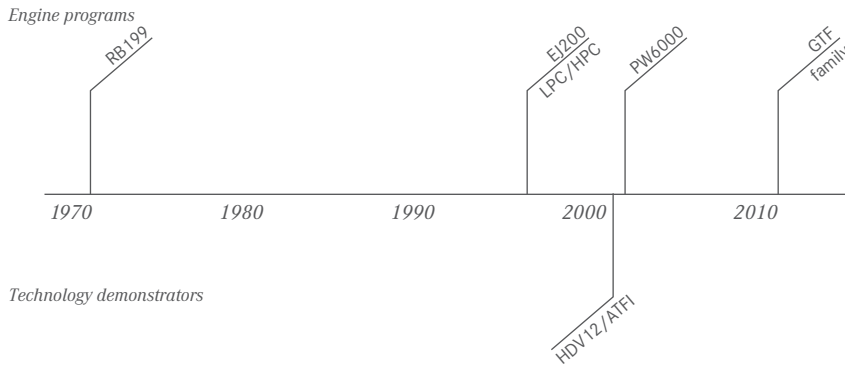


It all began with the development of the RB199 engine for the Panavia Tornado. “This was when we started to build up our skills in compressor engineering,” says Dr. Stefan Weber, who heads MTU’s department for technology and industrial design. As a partner in the Turbo-Union consortium, the German company was responsible for the intermediate- and high-pressure compressor stages, a new departure for a company which until then had only manufactured engines under license. “The RB199 compressor had to satisfy a demanding spectrum of mission requirements. This project enabled us to build up solid experience in all relevant fields, including aerodynamics, mechanical engineering, modeling and design. The many tests carried out

by MTU Aero Engines on the new compressor gave rise to theoretical and practical knowledge that is still being applied today.”

After the fighter bomber engine, the next military projects were the Eurojet EJ200 for the Eurofighter Typhoon and the Europrop TP400-D6 for the Airbus A400M. The EJ200 benefited from the use of improved 3D modeling techniques to optimize its aerodynamics and an integrally bladed rotor (or blisk) system that helped to improve the engine’s power ratio. Backed by this experience, the engineers then turned to commercial engine design. MTU gained particularly valuable insights while working on the HDV12 technology program, which laid the foundations for MTU’s

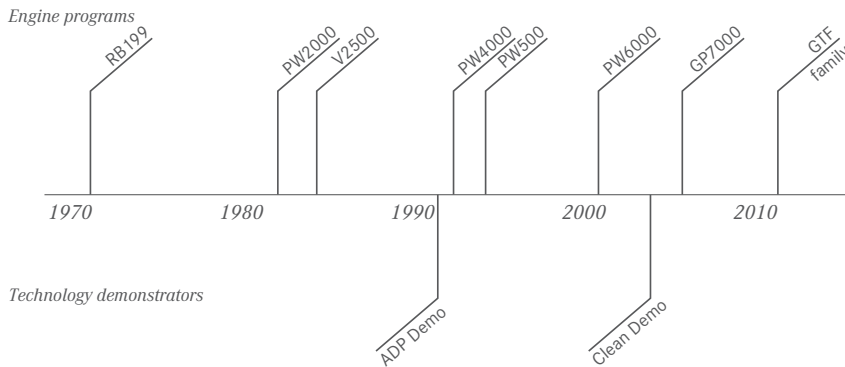
45 YEARS EXPERIENCE IN COMPRESSOR DEVELOPMENT



MTU's experience in compressor and turbine development and design engineering dates back over 45 years to 1970. After focusing initially on military programs, the company has been more involved in commercial engine programs since the early 1980s.

To date, MTU's compressor technology has been utilized in nearly 20 engine programs. The high-pressure compressor for the PW6000 marked the transition from military to commercial engine applications. The compressor for the Geared Turbofan™ engine family is a derivative of this earlier work, developed in collaboration with Pratt & Whitney.

45 YEARS EXPERIENCE IN DEVELOPMENT OF CONVENTIONAL AND HIGH-SPEED TURBINES



From the early 2000s onward, MTU has played a major role in the development of high-speed low-pressure turbine technology which was deployed for the first time in the new family of Geared Turbofan™ engines.

entry into Pratt & Whitney's PW6000 program, and during test runs of the ATFI (Advanced Technology Fan Integrator) geared turbofan demonstrator, in partnership with Pratt & Whitney Canada. These insights enabled MTU to make further improvements to its computer-assisted design methods, and ultimately assured the company of a stake in the successful PurePower® engine family of Pratt & Whitney. "We've been developing compressors since 1970, and during that time we have consistently improved engine efficiency. The EJ200 is roughly one percent more efficient than the RB199, and we have achieved another two percent in today's GTF programs in collaboration with Pratt & Whitney," says Weber. This might not sound much, but it's a huge leap in the engine design world.

MTU was also responsible for the RB199's air-cooled intermediate-pressure turbine, marking the beginning of MTU's turbine development activities. Compared with compressors, MTU's step

from military to commercial engines was relatively short for turbines. The first was the low-pressure turbine for the PW2000, which was quickly followed by turbines for other engines, such as the best-selling V2500 that powers the Airbus A320 family and the GP7200 for the Airbus A380. Here too, the continuous improvement of design techniques resulted in greater engine efficiency coupled with lower weight and reduced noise levels. Among the new technologies that the MTU design teams had been developing since the early 2000s was the so-called high-speed low-pressure turbine. Gear units were integrated in the ADP (Advanced Ducted Propfan) and ATFI technology demonstrators to optimize transmission component speed. "Our turbine design enabled the low-pressure shaft to rotate faster than the fan, making it possible to reduce the number of turbine stages and thereby reduce engine weight and noise emissions. To achieve this result it was necessary to modify the design of the rotor blades and the disk on which they are mounted, thus





PRODUCTION OF COMPRESSOR AND TURBINE COMPONENTS AT MTU

- 01** — Polishing of high-pressure compressor parts.
- 02** — Assembly of the GP7000 low-pressure turbine.
- 03** — Inspection of a V2500 low-pressure turbine.
- 04** — The experimental HDV12 high-pressure compressor, which led to MTU's participation in the development of the high-pressure compressor for the GTF family.
- 05** — Conducting measurements on the low-pressure turbine case for the PW1100G-JM Geared Turbofan™ engine.



improving their ability to withstand the higher centrifugal forces,” explains Weber. Titan aluminide, an extremely lightweight titanium-aluminum intermetallic compound developed in collaboration with Pratt & Whitney and other research partners played a decisive role in reducing the module’s weight. Its first application is in the high-speed low-pressure turbine for the PW1100G-JM engine that powers the A320neo.

Tests of the turbine as part of the Clean technology demonstrator attested to the viability of this approach. Further proof of concept was provided by flight tests of the Geared Turbofan™ demonstrator engine. “The high-speed turbine is the result of our continuous development efforts without which this engine might never have been built, and represents a major factor in the market success of the GTF family, which will also determine our success in the future. Looking back, we have been able to improve engine efficiency by an average of one-tenth each

year, which places us among the international leaders in engine design.” MTU’s participation in German aerospace research programs has also been a contributing factor (see page 48). And this is far from the end of the story: MTU’s specialists are continuing to work on improvements that will enable operating costs, fuel consumption and emissions to be reduced even further.



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Text:
Patrick Hoeverler has been a member of the editorial team at aerospace magazine FLUG REVUE for some 15 years. His responsibilities there include the engines, regional aviation and history sections.

Giant on the test bench

The A380 engine undergoes endurance tests

The development of an engine does not end with its commissioning. New materials become industrially available, new coatings get developed, and minor design changes are implemented. This



is why MTU is currently running endurance tests on the A380's GP7000 engine.

The test data are extreme:

630 hours

The engine will run for a total of 630 hours. This is roughly the time it would take to fly the long-haul route between Frankfurt and New York 70 times.

1.4 tons air per second

Every second, the test engine draws in up to 1.4 tons of air. This corresponds to just under 1,170 cubic meters, which is about equivalent to the volume of a two-meter-deep swimming pool with sides around 20 and 30 meters long.

950°C

During testing, the exhaust gas temperature at the turbine outlet housing rises as high as 950°C, which is roughly the melting point of silver.

MTU Aero Engines in figures

Facts and figures from the 2014 financial report

4.2 billion euros MTU's worth on the stock exchange with a share price of around 80 euros.

11 billion euros MTU's overall order backlog as of the end of 2014, which represents a sustained workload of approximately three years.

6.2 percent MTU's earnings growth rate in 2014.

250 to 300 million euros

Since MTU does the majority of its business in U.S dollars, a ten-cent rise against the euro is enough to generate this much additional revenue.

5.9 percent The growth rate for global air travel in 2014 according to IATA.

Time travel

Facts about the Paris Air Show – the largest international air show in 2015



Source: Christophe Verrier

1909 ____ The first ever International Exhibition of Aerial Locomotion (Exposition Internationale de la Locomotion Aérienne) is held at the Grand Palais in Paris from September 15 to October 17. Some 100,000 visitors come to admire the latest innovations in aviation presented by 380 exhibitors.

1953 ____ The Paris Air Show (Salon International de l'Aéronautique) moves to Le Bourget airport, where the event is held to this day. Located to the north-east of Paris, Le Bourget is where Charles Lindbergh landed after his Atlantic crossing in 1927. Work is completed on the famous central exhibition building, the "Rotonde", featuring a huge semi-circular door that opens out onto the tarmac. Constantin "Kostia" Rozanoff, chief test pilot for Dassault, is the first pilot to officially break the sound barrier at the air show, flying a Mystère IV.

1973 ____ Visitors to the Paris Air Show can admire the world's first commercial supersonic passenger jets, the Franco-British Concorde and the Russian Tupolev TU-144.

2005 ____ The Airbus A380 makes its début in Paris.

2013 ____ The 50th Paris Air Show. 315,000 visitors come to see new innovations and established aerospace products presented by 2,215 exhibitors from 44 countries.

Airport charts

The world's ten busiest airports based on passenger numbers 2014

96.2 million

Atlanta Hartsfield
+1.9%*

86.1 million

Beijing Capital
+2.9%*

73.4 million

London Heathrow
+1.4%*

72.8 million

Tokyo International
+5.7%*

70.7 million

Los Angeles Int.
+6%*

70.5 million

Dubai International
+6.1%*

70.0 million

Chicago O'Hare
+4.8%*

63.8 million

Paris CDG
+2.8%*

63.6 million

Dallas/Fort Worth
+5.1%*

63.1 million

Hong Kong Int.
+5.9%*

20 years of aviation research

The German federal government has been supporting research and technology projects in the field of civil aviation since 1995.

The German Federal Ministry for Economic Affairs and Energy (BMWi) has so far funded a series of five programs to promote joint research and development in the field of civil aviation by industry-led groups working in collaboration with universities and independent research institutes.

LuFo I and II (1995 to 1998 and 1999 to 2002) The first two programs focused on new technologies for future widebody and narrowbody aircraft.

LuFo III (2003 to 2007) The scope of the third program was widened to include innovative solutions for airlines and airports. One of the projects in which MTU Aero Engines

played a significant role was the ATFI (Advanced Turbofan Integrator) demonstrator engine.

LuFo IV (2007 to 2015) In the fourth funding period, MTU Aero Engines worked on projects to develop new compressor and turbine technologies, manufacturing processes, and advanced materials.

LuFo V (2014 to 2020) The fifth period of the funding program is devoted to an air transportation system of the future. This broad description also covers IT systems, industrial automation and trainee education. MTU Aero Engines will be working mainly on projects to develop technologies for the next generation of Geared Turbofan™ engines.

QUIZ

Put your aviation knowledge to the test

Take part in our quiz and win a prize:

How many models has aircraft manufacturer McDonnell Douglas developed and manufactured since 1934?

Hint: You'll find the answer in a picture somewhere in this issue.

We will draw ten entries at random from among the correct responses, and the winners will receive an MTU Aero Engines power bank.

Send your answer to aeroreport@mtu.de. Please don't forget to include your return address!

All decisions are final. The deadline for entries is July 31, 2015.



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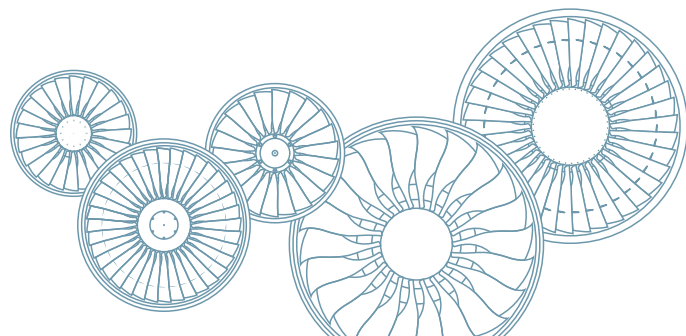
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