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Contents

News

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Friis-Petersen takes on MTU Maintenance role

Martin Friis-Petersen has become senior vice-president MRO programmes at MTU Aero Engines, heading up the sales and marketing organisation for MTU Maintenance. He replaces Leo Koppers, who retired after 16 years with MTU.

Friis-Petersen had been the managing director of MTU Maintenance Lease Services since 2014. He joined MTU in 1999 and has held various leadership roles throughout the company, including chief financial officer of MTU Maintenance Zhuhai and senior vice-president MRO operations at MTU Maintenance Hannover.

Last year MTU Maintenance Canada, a North American affiliate of German engine manufacturer MTU Aero Engines, celebrated its 20th anniversary. MTU Maintenance Canada has seen a total of more than 1,100 engine shop visits over its 20-year history. In 2011, the company introduced its accessory repair centre of excellence, which completes more than 11,000 accessory repairs a year.

The MTU Maintenance Canada facility has been part of the MTU Maintenance network of companies since 1998. Before this, the shop was owned and run by Canadian Airlines.

Based in Richmond, British Columbia, the company repairs and overhauls engines and accessories across almost a combined 12,000 square metres. The site, in the immediate vicinity of Vancouver airport, specialises in tailor-made solutions for the General Electric CF6, CFM International's CFM56 and the International Aero Engines V2500 engines, as well as comprehensive accessory and line replaceable unit services for engines ranging from the CF34 to the GE90 families.

Safran appoints SVP Airbus/ATR programmes

Safran has appointed Bruno Bergoend as senior vice-president, Airbus and ATR programmes, and vice-president, public affairs for the Occitanie region of France. He succeeds Andre Guiraud, who has retired from the position.

Bergoend is responsible for overseeing, coordinating and developing Safran's business with Airbus.

Peter Detjen, previously at Zodiac Aerospace in Hamburg, assists him.

AerSale promotes key management

AerSale has promoted its former chief operating officer, Basil Barimo, to the position of chief executive officer.

Craig Wright, formerly chief commercial officer, was promoted to president, to facilitate rapid expansion of the business.

AerSale founder, Nicolas Finazzo, will serve as executive chairman and co-founder, Robert Nichols, will serve as executive vice-chairman.

"Unburdened from the responsibility of day-to-day management, Bob and I will continue to steer AerSale's overall direction and seek new synergistic acquisitions while we expand the platform," says Finazzo.

In November, the company announced its fourth strategic acquisition of a maintenance, repair and overhaul business with the purchase of Miami-based component specialist Avborne.

Lufthansa Technik fills spokesmen positions

Lufthansa Technik filled two central management positions at the beginning of 2019.

Georg Fanta, the former head of strategic purchasing, has become spokesman for the management of the product division component services.

Fanta succeeded Harald Gloy, who moved to Lufthansa Cargo as executive board member. He has been with Lufthansa Technik since 2001 and has held numerous management positions in the company since then. Before his position in strategic purchasing, he worked in the areas of base maintenance and controlling and business development, among others.

Fanta has also been the managing director and chief financial officer at Spairliners, a joint venture of Lufthansa Technik and Air France Industries.

Dietmar Focke, former managing director of Lufthansa Technik Budapest, became spokesman for the management of the product division engines on 1 February 2019.

Focke joined Lufthansa Technik 18 years ago as a production engineer in the components division, where he subsequently worked, among other things, as a consultant for strategy and business segment development. He later took over production management in the airframe-related components division.

At Ameco Beijing, a joint venture of Lufthansa and Air China, he was initially head of component and landing gear maintenance and later head of aircraft overhaul. He then took over Lufthansa Technik Budapest, one of the six current locations in Lufthansa Technik's base maintenance network.

In the engine division, he succeeds Bernhard Krueger-Sprengel, who is now responsible for Lufthansa Group's technical fleet management.

Johnson becomes **IAG Aero** president Europe

IAG Aero Group has appointed Adrian Johnson as president of IAG Engine Center Europe.

Johnson is based in Rome, Italy, and reports directly to the chief executive officer and chairman of the group, Mauricio Luna.

Johnson is a senior level executive with strong operations, commercial and engineering experience.

Before joining IAG Engine Center Europe, he spent more than 30 years with Rolls-Royce, Vector Aerospace and StandardAero. He advanced the StandardAero engine and component business, while increasing the company's operational excellence. Johnson also worked in the customer facilities of India, Italy, New Zealand, Middle East and Germany.

SR Technics names McClave VP engine services

SR Technics has appointed Owen McClave as senior vice-president engine services. He succeeds Roberto Furlan, who has stepped down from the position.

McClave, who will report to SR Technics' chief operating officer, Jean-Marc Lenz, is a senior level executive with strong commercial and financial acumen. He has spent more than three decades working with original equipment manufacturers, independent maintenance, repair and overhaul companies and lessors, mainly on engine and component business.

MHI Aero Engines completes first PW1200G

Mitsubishi Heavy Industries Aero Engines (MHIAEL) finished assembly of the first license-built Pratt & Whitney PW1200G geared turbofan at its facility in Komaki, Japan, on 12 December 2018.

The PW1200G, developed by Pratt & Whitney to power the Mitsubishi MRJ90 and MRJ70 regional jets, also passed the Connecticut-based company's production acceptance test.

Established as a subsidiary of MHI in 2014 with investment from 10% owner Development Bank of Japan and 1% stakeholder IHI Corporation, MHIAEL Komaki is one of the two production assembly sites and supplements PW1200G production by Pratt & Whitney in Mirabel, Canada.

"Thanks to extensive and close cooperation with Pratt & Whitney, MHIAEL is developing a facility in Komaki to perform final assembly of the PW1200G engine powering the MRJ," says MHIAEL president and chief executive officer Katsuyuki Shimauchi.

He adds: "We're gearing up intensely as we prepare for production by building the capacities and expertise we need to perform this critical work. Our facility is in the process of obtaining approval from the US Federal Aviation Administration to produce these engines." Expecting to achieve certification by early 2020, the programme had clocked more than 2,400 hours of flight testing with four flying MRJ90 prototypes, as of October 2018.

Rolls-Royce introduces new engine change service

Rolls-Royce introduced a new Trent XWB engine change service in the final quarter of 2018, with Hong Kong Aircraft Engineering Company (HAECO Hong Kong) as its launch partner.

The service enables Rolls-Royce customers to access its original equipment manufacturer expertise and supplier network, with Rolls-Royce acting as a one-stop shop to organise labour, parts and/or tooling for any Trent XWB engine change event.

Offered as a foundation service within the Rolls-Royce CareStore, customers are able to request a quote for their engine change event requirements from the manufacturer's 24/7 aircraft availability centre, be that a home base or remote site location.

HAECO Hong Kong was selected as the first service provider to support Rolls-Royce in delivering the engine change service, providing established capabilities and a long-standing relationship with Rolls-Royce.

Lee McConnellogue, Rolls-Royce, senior vice-president, aircraft availability services, Civil Aerospace, said: "We are constantly looking at ways we can further improve aircraft availability and this service gives us additional capability to do just that. We wanted to launch with a partner who has a heritage of delivery and engineering expertise and HAECO Hong Kong fits that requirement perfectly."

LEAP programme to break even in 2021

Jamie Miller, General Electric's senior vice-president and chief financial officer, anticipates the LEAP programme will break even in 2021. As LEAP production has ramped up, production costs have declined.

"We continue to improve the cost position of the LEAP and, over the last two years, we've taken out more than 40% of the cost of the engine and we are ahead on the learning curve initially laid out for the programme," he says.

Miller also provided some additional transparency on the engine transition that is occurring in the narrowbody market.

"The mixing from CFM56 to LEAP resulted in a margin drag of approximately 160 basis points in 2018 and 130 basis points in the [final] quarter. The business is successfully offsetting this margin pressure through continued growth in aftermarket services, military and changing the mix of company-funded R&D spend.

"When we look at the remixing that's happening between CFM and LEAP, significant increase in LEAP shipments in the [final] quarter, up 88% over the prior year. Year-over-year, 2.4 times up, and you're seeing CFM come down meaningfully over those same periods."

He expects CFM will come down again next year. "More than 50% of CFM deliveries will be reduced next year," says Miller, "but the LEAP also ramped from the 1,118 we had this year up to 1,800-plus. So that remixing continues to occur."


CUSTOMISES

PW Shanghai engine centre receives certification for V2500 overhaul

The Shanghai Pratt & Whitney Aircraft Engine Maintenance Company (Shanghai Engine Center) received certification from the Civil Aviation Administration of China (CAAC) in November to add maintenance, repair and overhaul (MRO) capability for the V2500 engine to its aftermarket portfolio. Shanghai Engine Center is a joint venture between Pratt & Whitney and China Eastern Airlines.

"With more than 6,000 engines sold, we expect demand for the V2500 MRO to continue for the next seven to eight years. In anticipation of this demand, we have added this engine overhaul capability to our Shanghai Engine Center, which will complement our V2500 MRO capability in our engine centre in Christchurch, New Zealand," says Brendon McWilliam, senior director, aftermarket operations, Asia-Pacific, Pratt & Whitney.

Last August, the facility completed its first V2500 engine overhaul.

"The addition of V2500 engine overhaul to our portfolio demonstrates the ability of the Shanghai Engine Center to provide high-quality engine repair and overhaul services, as well as our commitment to provide world-class service excellence. We have more than 300 skilled professionals to maintain engines to the stringent industry standards," says Kenny Yap, general manager, Pratt & Whitney Shanghai Engine Center.

Operating from a 23,000-square-metre facility with an 80,000lb-thrust test cell and in-house component repair capability, the Shanghai Engine Center provides MRO services for CFM56 and V2500 engines to customers worldwide.

MTU Maintenance launches TAMS

MTU Maintenance launched Technical Asset Management Services (TAMS) for asset owners last autumn as a response to market demand and to complement its existing services. TAMS covers comprehensive technical consulting and fleet management, transitions management and housekeeping support for aircraft engines.

"As an MRO [maintenance, repair and overhaul] provider, asset manager and lessor, we are in a unique position to understand the individual requirements of operators and asset owners, mitigate risk and optimise residual value," says Martin Friis-Petersen, managing director MTU Maintenance Lease Services.

TAMS includes workscoping, shop visit management, engine exchanges and assistance with engine lease returns, as well as engine record reviews. "Asset owners benefit from the comprehensive engine know-how within the MTU Maintenance network paired with the expertise we have gained as an engine lessor," adds Friis-Petersen.

MTU Maintenance Lease Services has a team of about 50 experts, who support more than 160 transitions a year with a growing pool of engines for lease and sale. The MLS team also draws on the first class, in-house resources of MTU Maintenance, an MRO provider with nearly 40 years' technical expertise, a worldwide network and MRO specialists on hand to perform physical inspections and in-situ repairs.

TAMS is highly customised and can be integrated into further services as and when desired. Additionally, TAMS is supported by "industry-leading" software that enables the complete digitisation of documents, traceability of parts and, through a cloud-based platform, ease of access to up-to-date information for all parties involved.

CFM 2018 orders match previous year

Orders for CFM International's two product lines again achieved near-record levels in 2018, with the company booking orders for a total of 3,337 engines, including 126 CFM56 engines (commercial, military and spares) and 3,211 LEAP engines (including commitments and spares).

This compared with 3,344 engines in 2017, which included 474 CFM56 engines and 2,870 LEAP engines.

The LEAP engine continues to be the powerplant of new single-aisle choice. Since receiving the first orders in 2011, CFM has garnered a total of more than 17,275 LEAP installed and spare engine orders and commitments (excluding options).

Last year marked the production transition from CFM56 engines to the LEAP product line. CFM delivered 1,044 CFM56 installed, spare and military engines and 1,118 LEAP engines, which is more than double the 2017 LEAP rate. In 2017, CFM delivered 1,144 CFM56 engines and 459 LEAP engines.

As the ramp-up continues, CFM is on track to deliver more than 1,800 LEAP engines in 2019 and more than 2,000 in 2020.

"2018 LEAP engine orders were near a record high," says Gaël Méheust, president and chief executive officer of CFM International. "It is highly gratifying to see the continued confidence our customers have in our products. More importantly, though, the engine is doing incredibly well in commercial service, surpassing three million flight hours. Every day, the LEAP product is delivering world-class fuel efficiency and utilisation, fulfilling the commitment we made to customers more than a decade ago.

"We had some challenges on the production front but, in the end, we were able to deliver what we promised. As the ramp-up continues over the next couple of years, we will certainly work closely with Airbus and Boeing to keep disruptions to a minimum."

Speaking during the fourth-quarter results on 31 January, General Electric' senior vice-president and chief financial officer, Jamie Miller, said 379 LEAP engines were shipped during the final quarter of last year – this was 177 units more year-on-year.

"In total, we shipped 1,118 LEAP engines for the year. We're still behind on deliveries by about four weeks, but the business expects to be back on schedule by mid-2019," he says.

Miller adds: "The LEAP engine continues to perform very well, with a 58% win rate on the A320neo family and 81% win rate in the narrowbody segment when you add in the Boeing 737 Max and Comac C919."

Safran to expand engine overhaul facilities

Safran is planning to establish two additional engine overhaul facilities by 2023 to handle shop visits for the LEAP engines built by CFM International.

The French aerospace group's chief executive, Philippe Petitcolin, said during a financial results briefing on 27 February 2019 that evaluations of the investment were under way and that management would make decisions later this year.

He says that the facilities will be built at locations providing both favourable costs and access to LEAP operators.

Noting that many LEAP engines have been sold with long-term aftermarket support agreements, he says that Safran will require more overhaul capacity for a first wave of scheduled shop visits between 2022 and 2025.

Safran handles about 10% of shop visits for its products, which span commercial, military, business jet and helicopter engines and auxiliary power units.

"You cannot run these [MRO] businesses with long-term agreements if you can only do 10% of the fleet yourself," he notes.

Petitcolin notes that engine test cells represent the highest expenditure – in the region of €10 million ($11 million) to €20 million – in establishing overhaul shops.

"The rest of the shop is not that capital-intensive," he says, adding that the two planned facilities are "already in our books".

During a visit to Aero India show, Petitcolin and Shri K Chandrashekar Rao, chief minister of the Indian state of Telangana, announced that Safran Aircraft Engines would build a new plant in Hyderabad to make parts for the LEAP turbofan engine from CFM International.

Safran will invest €36 million in the new plant, which will cover 13,000 square metres (140,400 sq ft), including 8,000 square metres of workshops, in the Special Economic Zone of GMR near the Hyderabad airport. Construction is set to kick off in June, and will aim at delivering the building and producing the first parts in early 2020.

The plant will launch operations by the end of this year. By 2023, it will be able to deliver 15,000 parts a year to support the LEAP's sustained production rate.

CFM is set to deliver 1,800 engines in 2019, rising to 2,000 starting in 2020.

P&W Singapore shop completes first PW1000G overhaul

Pratt & Whitney's Singapore engine shop, Eagle Services Asia (ESA), has delivered its first PW1000G-series geared turbofan after completing overhauls.

ESA achieved US Federal Aviation Administration certification in the first quarter of this year, adding to the approvals issued by the European Aviation Safety Agency and Civil Aviation Authority of Singapore in December 2018.

The engine manufacturer says that ESA, which is jointly owned by the engineering arm of Singapore Airlines, is on track with its plan to ramp up capacity to overhaul more PW1000Gs.

P&W has retrofitted and re-designed the shop floor at ESA, as well as upgraded its test cell infrastructure and software.

In 2019, ESA plans to transition to a ground-based flow-line under which PW1000G-series engines will move between different stations – for disassembly, repairs and re-assembly – rather than stay in a single bay for a shop visit. The flow-line will have capacity to service six engines at a time.

Rolls-Royce shortens Trent 1000 TEN intervals

Rolls-Royce has begun informing Boeing 787 operators of an accelerated inspection regime for Trent 1000 TEN engines after checks revealed that a "small population" of the powerplants suffered from earlier than anticipated high-pressure turbine (HPT) blade deterioration. As part of this process, an Airworthiness Directive will be issued by EASA in addition to a Rolls-Royce Service Bulletin.

"The inspections will allow the OEM to confirm the health of the Trent 1000 TEN fleet over the next few months and "improve our understanding of the HPT blade deterioration that we have seen in a small number of engines," said Rolls-Royce president civil aerospace Chris Cholerton.

Singapore Airlines grounded in April 2019 two 787-10s after it found premature blade deterioration on some Trent TEN turbofans powering its 787s.

Rolls-Royce said it had inspected Trent 1000 TEN turbofans that had logged a higher frequency of flights at the upper end of their operating range. A "small number" of those engines have needed their HPT blades replaced earlier than scheduled.

"This blade deterioration is a known issue but it is occurring faster than we expected in some engines," Cholerton conceded.

Rolls advised airlines that the HPT blades in the Trent 1000 TEN engines would have a reduced life since their entry into service in November 2017, and engineers started development of an enhanced blade last year. The company has begun testing the enhanced version of the blades, and the OEM expects to start incorporating them into the Trent 1000 TEN fleet in early 2020.

The manufacturer insisted the new inspection regime would not affect its ongoing maintenance programs for the Trent 1000 Package B or Package C engines or on its financial outlook on the in-service cash costs of the Trent 1000s. "Based on our current understanding of the situation and fleet management plan, our guidance for in-service cash costs on the Trent 1000 in 2019 and 2020, as published with our 2018 full year results on 28 February 2019, remains unchanged."

The Trent 1000 TEN engine has been in service since November 2017, and there are currently more than 180 of this type of engine in service.

CFM maintains its dominance

CFM56-7B engine tops this year's engine poll.

The engine market follows the aircraft market and this year's engine poll result reflects difficulties in the narrowbody sector.

However, the narrowbody engine market has improved over the past 12 months. Engine availability is limited and shop visit capacity has dried up, say sources. Engine lead time has increased and operators now have to wait for several months to get an engine into the shop.

The V2500-A5 and CFM56-5B models have increased in scoring in the past 12 months in terms of investor appeal, remarketing potential and residual value, according to this year's engine poll.

One participant says those engines are a good indicator of the shortness in supply in the market.

"Airlines have been using spare engines to avoid shop visits and even if they sent engines to the shop, there was a problem with capacity. In a way, airlines have been forced to lease more engines," he says.

Coupling this with aircraft lease extensions in the marketplace, operators have had to adapt to keep their engines longer.

Once again CFM products led the engine poll in the narrowbody sector.

The LEAP-1A scored 5.9 out of seven for investor appeal, 5.7 for remarketing potential and 5.9 for residual values.

However, the LEAP-1B, which powers the Boeing 737 Max family, again led the way, scoring the highest for investor appeal. It came third in remarketing potential and second for residual values. "The issue is being able to get them. There is a queue. Rates are competitive and difficulties are in setting maintenance reserves for operations," says one participant in the poll.

The PW1100G scored slightly less than in 2018, although the consensus was that scores would be improved this year because Pratt & Whitney continues to solve the engine's technical problems.

This year's engine poll showed the continued resurgence of the mature narrowbody engines. Over the years, the mature engine saw increased activity as airlines and lessors retired older aircraft to make way for new models. The green time on mature engines is also perceived as having improved over the years.

The 737 Classic aircraft are an example: last year about 40 737-300/-400/-500s were broken up.

Investor appeal for the CFM56-3C model has dropped year-on-year but remarketing potential and residual value has remained stable, the poll shows.

According to *Airfinance Journal*'s Fleet Tracker, 30 737NGs were taken out of service in 2018.

The -7B model was the top engine performer in two of the three categories this year: remarketing potential and residual value. It scored 6.36 for remarketing potential and 6.09 for residual value versus 6.0 and 5.8, respectively in 2017.

The grounding of the 737 Max is starting to have an effect on operators. Demand for the 737-800 model, which was strong already, is expected to increase a notch as airlines seek interim uplift.

According to Fleet Tracker, there were 145 737-800s in storage or between operators at mid-April 2019. About 65 aircraft were Jet Airways aircraft that were being released. The active fleet was about 4,780 units. The 737-800 storage level is likely to disappear if the Max problems continue, says sources.

The -7B model has consistently performed above the -5B over the past few years in all three categories. This is not surprising given the engine's exclusive status on the 737NG family and because it powers one of the world's most popular narrowbody aircraft.

The -5B engine models have maintained second place in the narrowbody mature market and its popularity is still growing: 5.9 for investor appeal (versus 5.8 in 2017), 6.18 for remarketing potential (versus 5.8 in 2017) and 5.82 for residual value (versus 5.7 in 2017).

"There is a lot of demand for this engine from airlines and OEMs [original equipment manufacturers], especially now with the issues with the Neo and the Max models," comments one participant.

"The -5B still remains an engine to have and to buy for lease pools as the latest-generation single-aisles cannot be easily acquired," observes another.

Once again there is a clear distinction in the IAE V2500 engine family because the -A5 model significantly outperformed the older V2500-A1 in the poll, nearly doubling its score in all three categories.

GEnX wins 787 votes

Another success story this year is the engine that powers the 787 model. The more successful of the two, according to the *Airfinance Journal* engine poll survey, is the GEnX, which came top in all three categories: investor appeal, remarketing potential and residual value.

The other engine option, Rolls-Royce's Trent 1000, also performed well and second in two categories.

Regional aircraft

	Investor appeal (out of 7)	Remarketing potential (out of 7)	Residual value (out of 7)
CF34-8C (CRJs)	3.50	3.75	3.38
CF34-8E (E170/175)	3.88	3.88	3.63
CF34-10E (E190/195)	3.90	4.20	3.90
PW1919 (E190/195-E2)	3.63	3.25	4.25
PW127F (ATR72-500)	4.00	4.00	3.71
PW127M (ATR72-600)	4.50	4.75	4.25
PW150A (Q400)	3.88	3.88	3.75

Source: *Airfinance Journal*, April 2019

Narrowbodies aircraft

	Investor appeal (out of 7)	Remarketing potential (out of 7)	Residual value (out of 7)
BR715 (717)	1.43	1.71	2.14
CFM56-3C (737 Classic)	1.80	2.70	2.10
CFM56-5A (A320)	2.30	2.60	2.60
CFM56-5B (A320)	5.91	6.18	5.82
CFM56-7B (737NG)	6.09	6.36	6.09
CFM Leap-1A (A320neo family)	5.90	5.67	5.90
CFM Leap-1B (737 Max family)	6.10	5.80	5.90
PW1100G (A320neo family)	5.40	5.22	5.30
PW1500G (A220 family)	4.20	3.80	4.70
PW2000 (757)	3.00	3.71	3.43
PW6000 (A318)	0.71	0.86	0.86
RB211-535 (757)	2.63	3.38	2.63
IAE V2500-1 (A320 family)	1.45	1.55	1.55
IAE V2500-A5 (A320 family)	5.73	5.91	5.82

Source: *Airfinance Journal*, April 2019

However, it scored behind the Trent XWB, GEnX and the CF6 engines for remarketing potential, reflecting the problem Rolls-Royce has had over the past year with the grounding of some 787s (*see page 26*).

"GEnX-1B engines are highly sought after. A number of GECAS transactions for single-sale and portfolios have occurred," says one participant in the poll.

Another participant says the rating for the GEnX-1B engine model reflects the fact that there is little demand for the GEnX-2B model, as it is a niche market.

The GE90 engines scored lower than a year ago. "Lots of -300ERs will come into the market in the future and it is expected that there will be an oversupply of engines," says one participant, adding that the type is not attractive to investors.

In this year's *Airfinance Journal* Investor's Poll, the 787-9 was the clear winner in the twin-aisle category.

Its notable market popularity significantly outstrips the other options, with the A350-900 trailing behind. However, both scored less than previously, which reflects a certain malaise in the widebody market. Still, the ubiquity of both among airlines makes them tried-and-tested favourites of the investor community year after year.

The Trent XWB came third in two of three categories, reflecting the popularity of the A350 models.

At the other end of the table are the engines powering the Airbus A340 families. The worst performer is the Trent 553. According to *Airfinance Journal*'s Fleet Tracker, there are 10 aircraft in service all with governments, except one aircraft operated by Azerbaijan Airlines. Another 19 aircraft of the type are in storage.

The larger A340-600 Trent 556 engine is not far off. There are 28 aircraft in storage and about 60 in service. "Those engines have its value floor," says one source but there is higher demand for the CFM56-5C4/P model.

In between the Trent engines are the JT9D engines that scored the lowest for remarketing potential. Values are believed to be in the $2 million to $2.5 million range, according to one participant.

The PW4000 engine family scored higher than last year. The PW4000-100 variant is in a better place than a few years ago, says one source, with shop visits helping. The PW4000-94 engine model behaved as per the CF6-80C2. An engine fresh from performance restoration is estimated between $6 million and $7 million for the PW4000-112 variant.

Widebodies aircraft

	Investor appeal (out of 7)	Remarketing potential (out of 7)	Residual value (out of 7)
CF6-80 (747-400s, 767s)	3.70	4.20	3.90
CFM56-5C (A340)	2.30	2.70	2.90
GE90 (777s)	3.89	3.78	4.11
GEnX (787s, 747-8s)	5.10	4.50	5.40
GP7200 (A380)	2.71	2.57	2.71
JT9D (747s, 767s)	1.00	1.14	1.14
PW4000 (747-400s, 767s, 777s, A330s)	3.40	3.80	3.50
RB211-524 (767, 747-300, -400)	1.38	1.75	1.75
RB211-535 (757)	2.63	3.38	2.63
Trent 553 (A340-500)	1.00	1.00	1.14
Trent 556 (A340-600)	1.14	1.14	1.29
Trent 700 (A330s)	3.00	3.11	3.00
Trent 800 (777s)	1.88	1.88	1.75
Trent 900 (A380)	1.71	2.00	2.00
Trent 1000 (787s)	4.00	4.00	4.14
Trent 7000 (A330-900neo)	3.86	3.86	3.71
Trent XWB (A350s)	4.67	4.11	4.22

Source: *Airfinance Journal*, April 2019

Regionals

The Pratt & Whitney PW127M engine is the best-performing in-production regional aircraft in the investor appeal, remarketing and residual value categories, according to the poll.

The aircraft's popularity among operators is clearly having a knock-on effect on the market for its engines, which is particularly good news for Pratt & Whitney. The ATR72-600 reclaimed top spot in the regional aircraft market this year scoring 3.4 overall, a marginal increase over the previous year.

The turboprop is now a mature aircraft and will have had more than eight years of service in 2019. As the aircraft penetrates more markets, lessors are still in this model. Nordic Aviation Capital remains the largest leasing company for ATR aircraft, but lessor Avation is also a committed customer for the ATR72-600s.

The PW127F engine came second in the investor appeal and remarketing category, showing an appetite for the ATR72-500 model in the second-hand market.

The CF34-10E engine came second in remarketing potential, due to continued trading of Embraer 190/195 aircraft in the marketplace.

Another new entrant in this year's engine poll is the PW1919 engine, which entered into service in the first half of last year on the E2 family. The engine family received strong scores as investors believe the asset represents a good investment.

Making its mark in **engine financing**

Traditionally seen as an engine trader and spare parts provider, GA Telesis has increased its presence as an investor over the past two years.

After two funds investing in engines, Florida-based GA Telesis has now started a joint venture with existing shareholders.

"The GAIN I fund was highly successful and is now fully harvested. Having achieved double-digit returns for our investors, we decided the market timing was good to raise our GAIN II fund," recalls Abdol Moabery, president of GA Telesis.

The investment criterion and asset targets are the same and GAIN II focuses on commercial aircraft leases that are within the company's mid-life asset management speciality.

"GAIN II is roughly 40% invested, covering Airbus, Boeing and Embraer aircraft on lease to a multitude of operators," adds Moabery.

GA Telesis launched a new engine-leasing platform in December, with Japanese partners All Nippon Airways Trading Company (ANATC) and existing shareholder Tokyo Century.

Initially with its headquarters in Fort Lauderdale, Florida, Gateway Engine Leasing commenced operations with a seed portfolio of IAE V2500, CFM56-5B and CF6-80E engines already on lease to customers.

"Gateway Engine Leasing committed to a sizing of about $400 million in assets for the first-round investment. We have already closed the first four engines and have two other firm commitments to close in the coming month. Behind that, we have an additional two firm commitments that will go in next quarter. By the end of this year, it is our intention to have between 12 to 16 engines in the portfolio," says Moabery.

The decision to form Gateway Engine Leasing with Japanese partners cements the relationship with existing shareholders. ANATC acquired a 10% stake in GA Telesis last October after Bank of America subsidiary Global Principal Finance sold all its shares in the Florida-based parts specialist. At the time, Tokyo Century increased its shareholding to 49.2% of GA Telesis.

The new venture builds on a deal signed last year between GA Telesis and Tokyo Century to launch a new-technology

"Gateway Engine Leasing committed to a sizing of about $400 million in assets for the first-round investment. We have already closed the first four engines and have two other firm commitments to close."

Abdol Moabery, president, GA Telesis

engine financing initiative focused on the General Electric GEnx, Rolls Royce Trent 1000 and Trent XWB, Pratt & Whitney GTF and CFM LEAP engines.

"We maintain other portfolios of assets and partnerships in the engine leasing sector as well. The concept of adding an additional joint venture is to address the demand we have from our customers to lease more engines. Tokyo Century Corporation and ANATC were both interested in addressing this need and have partnered with us," says Moabery.

Gateway has no geographical boundaries, but the greatest demand is from Europe and Asia. "We are putting a lot of emphasis in those regions."

Gateway will focus only on current-technology engines, "versus our other new-technology engine leasing venture launched in 2017". Moabery adds that Gateway will only hold CFM56-5B/-7B, V2500-A5, RB211-535E4, CF6-80C2, PW4000 (-94/-100 and -112), GE-90-94B/112 and Trent 700/800/900 engines.

Gateway will not focus on short-term transactions.

Some aviation insiders argue that the engine industry has shifted towards the longer-term lease but, in reality, both short-term and long-term leases are about the same. There are a number of new-technology engines that command long-term leases, but the short-term leasing market remains robust.

"Short-term engine leasing is quite complex and there are a lot of moving pieces. Gateway is not staffed to meet these demands, so GA Telesis will stay focused on covering the customer demand for short-term engine leases. However, if there is an available engine in the Gateway portfolio and a short-term lease requirement, we will most certainly address that need with a Gateway engine."

"Engine operation and engine leasing are a unique animal when it comes to operating and cost management. The operating cost of an engine can fluctuate and availability of spare engines can also. Currently, there is a bow wave of engines in the shop and spares are trading at a premium. However, there are also periods when the market might be flooded with spares and it can be a lower-cost alternative to lease in an engine versus operating an airline's own engine," says Moabery.

He adds: "About 20 years ago we created Green Time Leasing™ with a US major airline as our launch customer where we were covering a multitude of engines in their fleet with leased engines. This will ensure that we meet the investment targets of the joint-venture partners."

Engine delays 'will continue through 2019'

Airbus engine delays are still a concern for the lessor community.

Engine delays on models such as Pratt & Whitney's geared turbofan (GTF) and Rolls-Royce's Trent family will continue throughout this year, according to Peter Barrett, the chief executive officer of aircraft lessor SMBC Aviation Capital.

In an interview with *Airfinance Journal* in November 2018, Barrett said: "It's well understood there's been delays both in Toulouse and probably a lesser extent in Seattle. I think the manufacturers are acutely aware of those challenges and they are focusing on trying to get it right."

He says that, although it will take time to resolve the engine issues, the original equipment manufacturers (OEMs) have begun to improve them.

"You're going to continue to see delays throughout 2019 and obviously we've planned for that. It's very frustrating for us and particularly for our customers, when they are waiting for new aircraft and they don't turn up on time," he adds.

As SMBC Aviation Capital does not have any Boeing 787s on order, Barrett is more concerned about narrowbody engine delays. The company had 201 aircraft in its orderbook, according to *Airfinance Journal*'s Fleet Tracker, comprising 107 Airbus A320neos, 90 737 Max 8s and four 737-800s at the end of 2018.

"The delays are more pronounced for Airbus than they are for Boeing but there is an element of blame on both sides," he adds.

"I think it's a combination of the engine delays clogging up the system and all the complexities of trying to manage that, which is providing some of that delay across the fleet.

"We see it resolving itself today and we see that continuing next year. We're very much giving the message to the manufacturers that they need to focus on getting that right and the delays are a significant issue for us and for our customers."

Significant problems with Pratt & Whitney's geared turbofan first came to light in early 2016, when longer-than-expected start times led to Qatar Airways cancelling the first four of 50 A320neos on order, according to an *Airfinance Journal* report in December 2017. The issue was traced to a thermal deformation issue known as "rotor bow", which Pratt incrementally addressed with hardware and software fixes to drag PW1100G start times towards those of the IAE V2500 and CFM International's CFM56 – the A320 powerplants that the geared turbofan was designed to supersede.

Then, however, Pratt suffered production difficulties relating to the alloy-based fan blades used in all but the smallest PW1000G variants, forcing it to lower its delivery goal for 2016 from 200 to 150 GTF engines. This led to the embarrassing sight of fully assembled, but engine-less A320neo airframes marooned on the Airbus tarmac.

> *It's well understood there's been delays both in Toulouse and probably a lesser extent in Seattle. I think the manufacturers are acutely aware of those challenges and they are focusing on trying to get it right.*
>
> **Peter Barrett**, CEO, SMBC Aviation Capital

Planning for short visits **peak**

Lufthansa Technik expects a peak in shop visits for the CFM56-5B/-7B and the V2500 models in 2023/24.

According to ICF market forecast, 2019 will see the number of active engines of CFM56-5B/-7B and V2500 reaching its maximum – with more than 27,000 in total. From 2020, the retirement process of older Boeing 737NG and Airbus A320 fleets will show some effect and the fleet size will slowly decrease. However, the majority of the engines currently installed are still expecting their first shop visit. This will lead to a peak of shop visits in 2023/24, with a global demand of almost 4,000 engine overhauls a year.

The year 2018 has already been a year of tight maintenance, repair and overhaul (MRO) capacities, the situation might stay challenging until 2024. Presumably, the announced capacity expansions of MRO providers will only increase with the same pace as the demand will rise.

But Lufthansa Technik has planned for the next few years. Mobile Engine Services will provide relief for the challenging capacity situation and keep customers' engines flying through three types of services:

- on-wing repair – repair with the engine mounted on the aircraft can be integrated in your operations;
- on-site repair – in cases where a disassembly of the engine from the wing is required, our mobile repairs are offered directly at your facility; and
- repair station – more complex repairs can be performed at one of our repair stations close to your home base.

Combined with workscoping, these services can significantly help operators to avoid or postpone costly shop visits. Mobile Engine Services addresses a broad spectrum of customised repair and maintenance solutions for V2500 (A320 family), CFM56-5B (A320 family) and CFM56-7B (737NG) engines. They range from individual borescope inspections to comprehensive engine fleet programmes, and from scheduled maintenance events at the customer's site to emergency overnight repairs wherever needed.

Depending on the requirements of the individual repair solution, Mobile Engine Services can include on-wing and on-site services provided by Lufthansa Technik's airline support team or smaller events performed at the company's local repair stations in Tulsa, Montreal, Frankfurt and Shenzhen.

A Cyclean® engine wash at one of the locations of Lufthansa Technik's continuously growing regional Cyclean® station networks is also part of Mobile Engine Services' offerings for customers. It enables airlines to clean their engines quickly and very efficiently. By using Cyclean® regularly, optimum performance and an extended on-wing time of the engine can be achieved. Regular engine washes are recommended by the OEMs, especially for new engine types such as the LEAP.

Lufthansa Technik inaugurated its new engine maintenance hangar in Tulsa, Oklahoma, recently to service the two biggest commercial engine fleets, the CFM56 and V2500. The company previously used the hangar for Bizjet's business aviation and VIP completions but converted it to focus on mobile engine services.

The facility is starting with six engine bays, which are initially dedicated to the V2500, but there are plans to start offering CFM56-5B services later this year and add three more bays by the year end. The facility has space to expand up to 28 bays, if customer demand warrants it.

The philosophy behind this new engine facility supports Lufthansa Technik's strategy of performing lighter engine work, with minimum workscopes, within regions or at the customer's location. By doing this, it frees up space and allows Lufthansa Technik's Hamburg base to focus on heavy maintenance. Lufthansa Technik's Frankfurt, Montreal and Shenzhen facilities also offer the services.

How Lufthansa Technik is moving to engine maintenance on LEAP products

As soon as it became clear that Airbus and Boeing would start re-engining programmes for their popular Airbus A320 and Boeing 737 families, Lufthansa Technik developed plans to become a relevant player in the maintenance, repair and overhaul (MRO) market for these new engines. Hence, the company's preparations for the CFM LEAP started early on.

One important milestone was obtaining the official original equipment manufacturer (OEM) licences for services on the new engine type, which was achieved in June 2017. Through this general support licence agreement, Lufthansa Technik is authorised by the OEM to perform on-wing services as well as maintenance, repair and overhaul for the LEAP-1A and -1B engines of the A320neo and 737 Max families.

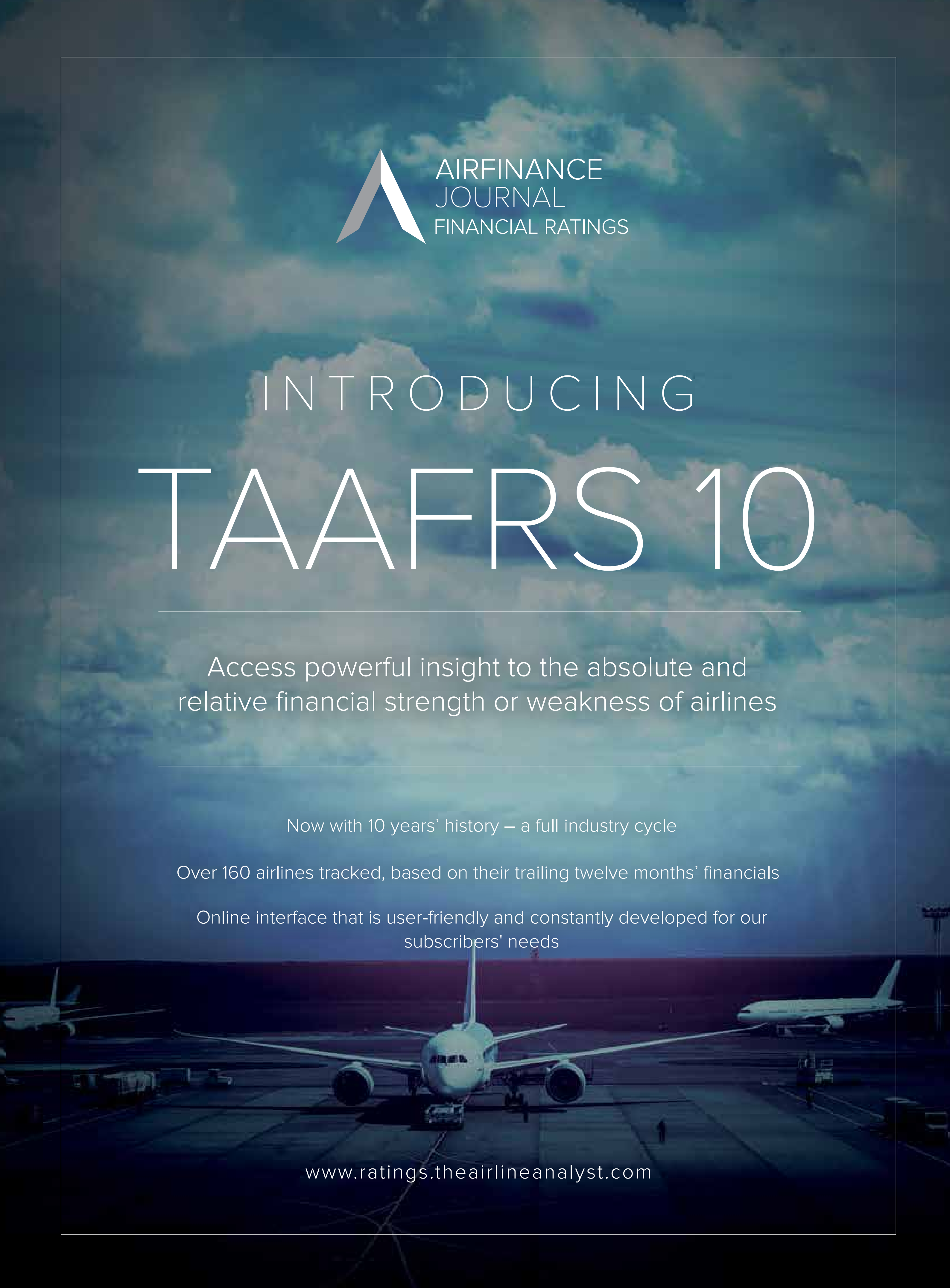
Lufthansa Technik was able to reach a second important milestone in February 2018 with the signing of the first CFM branded service agreement for the LEAP-1A, which is only available for cooperation partners of CFM International. This agreement will allow Lufthansa Technik to offer an even wider range of services for this engine type, including more sophisticated repairs than those that are possible using the general OEM licence.

Based on this achievement and the company's extensive experience with entry-into-service support for new aircraft and engine types, Lufthansa Technik is already developing numerous added-value solutions for the early adopters which have just commenced their operation of LEAP-powered aircraft. Lufthansa Technik assists the early adopters of the LEAP engine with a high level of engineering know-how and expertise, especially addressing the so-called teething troubles – technical issues that can occur during the early stages of operation.

In the transition from current-generation engines to the LEAP, Lufthansa Technik can strongly rely on the company's vast experience with a variety of engine types, such as the legacy CFM56 and the comparably new GEnx-2B powering the 747-8.

Because the LEAP and the GEnx-2B have similar engine architecture, Lufthansa Technik's engineers can effectively transfer their maintenance and repair knowledge from one engine type to the other. Furthermore, they derive many operational insights from the mother airline's operations with the GEnx-powered 747-8.

Building on this already extensive and further growing experience with various customers over the past 20 years, the build up of MRO capabilities for the CFM LEAP at Lufthansa Technik is progressing well and will result in a broad range of MRO services for this engine type. This will include on-wing support, quick-turns, minor and major shop visits, parts repair, spare engine support, engine condition monitoring, engineering, innovative workscoping and active cost of ownership management.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Opening up the **aftermarket**

The 2018 agreement was supposed to mark a turning point in the liberalisation of the engine maintenance market, to the benefit of airlines, financiers and MRO shops. Yet big questions remain about how much the deal really changes, and whether the big areas of OEM dominance are still to be tackled. **Alex Derber** reports.

In 2016 the International Air Transport Association (IATA) filed a formal complaint with the European Commission about "alleged abuses of dominant positions by manufacturers of aviation equipment". The complaint focused on anti-competitive behavior in the engine aftermarket, but two years later, IATA withdrew the elements of its complaint relating to CFM International after the manufacturer agreed a set of conduct policies.

"This milestone agreement with CFM will lead to increased competition among the providers of parts and services related to the servicing of CFM engines," said IATA director-general Alexandre de Juniac at the time.

Airlines, financiers and maintenance companies have also welcomed the deal, yet questions remain about whether it represents a fundamental change in the engine aftermarket or if it will herald wider liberalisation.

All change?

According to CFM, most elements of its deal with IATA do not represent any shift in its business practices; instead, they are designed to improve transparency by formally documenting its technical support processes.

For example, among the conduct policies that IATA said would "enhance the opportunities available to third-party providers of engine parts and MRO [maintenance, repair and overhaul] services on the CFM56 and the new LEAP-series engines" were agreements by CFM to license its overhaul manual to an MRO facility even if it uses non-CFM parts, and to permit the use of non-CFM parts or repairs by any unaffiliated licensee.

However, CFM says that these were already its policies. "It's always been the case that we provide overhaul licences to anyone who requests them," says Bill Dwyer, marketing leader for GE Aviation Services. He adds: "The only restriction is that a firm is able to be certified by a local regulatory agency."

Dwyer says that there are only a few areas where CFM has changed its policies as a result of the IATA deal (which CFM co-owner GE has also signed up to with respect to maintenance for its own-brand engines). The first concerns lower fees for airlines or independent maintenance shops that perform CFM repairs for third parties.

A criticism from airlines without an [internal] engine MRO capability was that they received rights to overhaul their own engines royalty-free when they bought the engines, but had to pay a royalty when they outsourced to a third party," says Dwyer, adding: "That was a concession CFM made; airlines without MRO shops now benefit from lower royalty fees."

A more significant change concerns parts manufacturer approval (PMA) parts and designated engineering representative (DER) repairs, though, again, the shift is not as pronounced as first appears. CFM insists that it did not restrict third-party shops from the use of PMA and DER, although it has become more flexible in its own approach as a result of the deal. Specifically, the OEM will now reinstall serviceable PMA parts that it encounters during engine overhauls, provided they are a surprise finding the customer is unaware of and the customer signs a legal release and indemnification of CFM.

"IATA asked us to install PMA and we rejected that request because we are the OEM [original equipment manufacturer] and we promote OEM parts," notes Dwyer. "There is no instance where CFM would include a PMA or DER part in a proposal to overhaul an engine, nor is there any instance where CFM would ever accept customer-furnished non-OEM material."

Competition

Beyond what CFM did and did not do before the IATA agreement, there is a broader question about differing levels of competition across the engine aftermarket. Aerothrust is an independent US-based maintenance company which has shifted its focus to heavy maintenance of the most recent variants of the CFM56 – the -7B and -5B.

"We believe that we will begin to feel the effects [of the IATA deal] immediately," says Kristoffer Palacios, sales team leader for Aerothrust, adding: "This will allow a more competitive market for MROs and the opportunity for more shops to be created."

That said, the CFM56 is already one of the most competitive engine MRO markets, especially when compared with equipment such as Rolls-Royce engines, where there are few options for maintenance outside the OEM.

"Over 40 MRO shops compete for CFM56 overhaul business," says Dwyer. "This results in lower maintenance costs and higher residual value and it gives customers control."

Dwyer's point about residual values is especially important for engine lessors and financiers, who value engines as assets not just because of their predictable income streams, but because they command the best late-to-end-of-life values of any piece of aircraft equipment. However, the ultimate value of an engine depends on its parts, and a market for used parts can only really exist if parties other than the OEM are offering maintenance services.

"Overall, a more competitive market has a positive impact for engine lessors in terms of residual value and potentially extending the competitiveness of current-technology CFM engines for years to come," says Justin Phelan, vice-president marketing of lessor Engine Lease Finance.

However, he is more circumspect than Aerothrust's Palacios about the impact of the CFM-IATA deal, saying: "It remains to be seen how the CFM-IATA agreement plays out in the market."

He adds: "Aside from fuel and interest rates, it is difficult to predict if or when the benefits of CFM-IATA will become apparent, but it is likely to be well into the next decade when new-technology aircraft proliferate, and the economics of current technology comes under great scrutiny."

Next steps

Whether or not the CFM-IATA deal significantly increases competition in the CFM56 and LEAP aftermarkets, it would be viewed as a triumph if other OEMs adopted similar policies. In mid-2018, it was reported that IATA was still pursuing a similar complaint against Honeywell over auxiliary power unit maintenance, but it does not appear to be doing so against other engine manufacturers such as Pratt & Whitney or Rolls-Royce.

"IATA is hopeful that other OEMs will review this agreement and see how it can be applied to their own aftermarket activities," says a spokesperson for the trade association.

New entrants bank on engines

Alex Derber reports on why spares are proving increasingly popular for asset managers.

Perhaps the dominant theme of the aircraft leasing market in recent times has been cut-throat competition in the sale and leaseback market and the pressure this has exerted on lease rates, and it may surprise some to learn that engine leasing is experiencing a similar – albeit less extreme – dynamic.

A surprise because aircraft and engine leasing are fundamentally different markets: aircraft are leased to add or replace capacity, whereas engines are rented as spares to cover for maintenance of frontline equipment.

That said, the two leasing markets share some similarities: both aircraft and engines are big-ticket, mobile assets that provide predictable returns, while engines have the added bonus of better residual value. The development of the two sale and leaseback markets has also followed a pattern, with a growing number of lessors chasing a scarce supply of equipment, thereby driving down returns.

"There are more competitors now – with downward pressure on lease rates," says Tom Slattery, executive vice-president of GECAS Engines, the world's largest engine lessor.

He adds: "New entrants are seeking newer assets with long leases through the purchase and leaseback market, though it remains to be seen if these competitors will be long-term participants and develop asset management expertise."

> *"There are more competitors now – with downward pressure on lease rates."*
>
> **Tom Slattery**, executive vice-president, GECAS Engines

Similar thoughts have been voiced by aircraft lessors, although it is unwise to draw too close a parallel between the two markets. Aircraft leasing has been transformed by a huge influx of Chinese money and new Chinese lessors, a trend not yet experienced in the engine market.

"It is difficult to say for sure whether the returns are appealing enough to entice significant Chinese investment, or indeed if the industry is seen as strategically important enough for any government policy changes to encourage further investment to the same extent that has been experienced on the aircraft side," says Justin Phelan, vice president marketing of independent lessor Engine Lease Finance (ELFC).

Instead, much of the new (and not so new) money in engine leasing comes from Japan. Examples include the December 2018 formation of Gateway Engine Leasing, a joint venture between Florida-based GA Telesis and Japanese companies Tokyo Century and All Nippon Airways Trading; Sumisho Aero Engine Leasing and MTU Maintenance Lease Services, both joint ventures of Sumitomo and German maintenance, repair and overhaul (MRO) and engineering company MTU; Total Engine Asset Management, a joint venture between ST Aerospace and Japanese company Marubeni; and Shannon-based ELFC, which is owned by Mitsubishi UFJ Lease & Finance.

ELFC's long-standing independent rival is Willis Lease, which in 2018 launched its fifth securitisation to finance a $467 million engine portfolio. Meanwhile, one of the newest potential players in the market is UK-based Centrus Aviation Capital, which announced plans for an aircraft and engine leasing business in late 2018.

Slattery sees potential for more new entrants to the engine leasing market, which he views as a net positive. Competition and trading partners are always positive for asset values and generally healthy for the industry," he says.

Values and lease rates

It is little surprise that the world's two most popular engine families, the CFM56 and V2500, command the most resilient values and lease rates. In fact, even as the newer engines, the CFM LEAP and

PW1000G lines, enter service in greater numbers, lease rates of the engines they are designed to replace have continued to rise.

This is because engine leasing demand is a function of maintenance demand. More engines in the overhaul shop mean more spares are needed, and the CFM56 in particular is undergoing a surge in overhauls, albeit a few years later than expected because of the exceptional reliability of the type. Furthermore, a global shortage of spares from engine original equipment manufacturers (OEMs) preoccupied with fulfilling production ramp-up targets and sorting out problems on their newest equipment has led to a global shortage of new spare parts, which has extended overhaul turnaround times.

On the widebody front, Phelan says "the most significant decline in values that we're seeing is on the CF6-80C and PW4000-112 variants". At the same time, though, he notes that leasing demand has remained buoyant for both types, in part because of relatively benign fuel prices and in part because of longer maintenance turnaround times, again because of spares shortages, for Pratt & Whitney's large turbofans. He adds that the green-time leasing market – where airlines take mature engines on short-term leases to burn off the remaining cycles – may be "drying up" for the types.

Slattery agrees with Phelan about widebody engine values, saying: "Older, out-of-production engines such as the RB211, PW4000 and early CF6 models have declined in value."

He also describes significant volatility in the market for CF34 engines, which power a range of mature regional jets. "Lease rates are always a function of supply and demand and end-of-life is more often signified by volatility in lease rates linked to pockets of demand."

Slattery is, however, much more optimistic about current-generation narrowbody engines, stating that their values have a "very strong outlook".

New technology

Although airframe and engine manufacturers are shifting their focus to new equipment, the most popular narrowbody engines are holding their value. An obvious reason for this is that they still form the bulk of the global fleet and will do for some time to come. *Airfinance Journal*'s Fleet Tracker shows about 13,000 current-generation Airbus A320-family aircraft and Boeing 737NGs in service, versus a total delivered count of about 1,100 A320neo- and 737 Max-family aircraft.

"We haven't seen any impact to date on demand for CFM56 or V2500 spare engines due to newer-technology deliveries and wouldn't have expected to do so," says Phelan.

"CFM56 and V2500 have been exceptionally reliable engines with superior on-wing performance and operators have benefited in terms of cost of ownership."

Justin Phelan, vice-president marketing of independent lessor, Engine Lease Finance

Other factors in favour of engines such as the CFM56-5B, -7B and V2500-A5 are their reliability and still-attractive operating economics. Furthermore, the peak of the maintenance cycle for those types is not expected until the mid-2020s, which means demand for spares will remain strong.

"The engines are very reliable with predictable maintenance costs that make the assets very desirable," says Slattery, adding: "Low fuel prices are also helping, and the impact of new aircraft has not dampened demand for the CFM56 and V2500."

Although Slattery highlights low fuel prices, both he and Phelan believe they have a limited effect on demand for their portfolios. Phelan points out that cheap fuel gives a bigger boost to mature and sunset engines – a small part of ELFC's stock – while Slattery notes that the GECAS engines portfolio is composed largely of newer types, "where demand is driven by entry-into-service support and customer financing".

In the very short term, current generation spare engine demand may take a small boost from the grounding of the 737 Max fleet, which has had many operators scrambling for replacement capacity. Nonetheless, the new-technology fleet is growing and so are its associated spares requirements.

Until recently, non-OEM engine lessors struggled to acquire geared turbofan or LEAP assets, but Phelan sees progress on this front as more sale and leaseback opportunities materialise.

He says: "In order to keep the in-service aircraft flying, captive OEM lessors garnered the largest share of [new-technology engine] spares produced to ensure available spare engines were deployed to minimise disruption from initial in-service issues and warranties.

"However, since late 2018 and into 2019 greater numbers of spare engines are being delivered to operators and, excluding any new operational issues, we expect this trend to continue."

Changing dynamics

A key question for engine lessors going forward in how airlines intend to manage their spare requirements. The traditional ratio of one spare to every 10 engines may be widening as airlines perceive new equipment to be more reliable. That might seem counter-intuitive given the entry-into-service problems of the PW1100G, which cause a big spike in spare engine demand, but most airlines see such issues as temporary.

"Early indications of new technology tend to suggest that more shop visits may be required in the short to medium term until further hardware evolution is achieved to drive improved performance, but overall we expect this to balance out over the lifecycle," says Phelan.

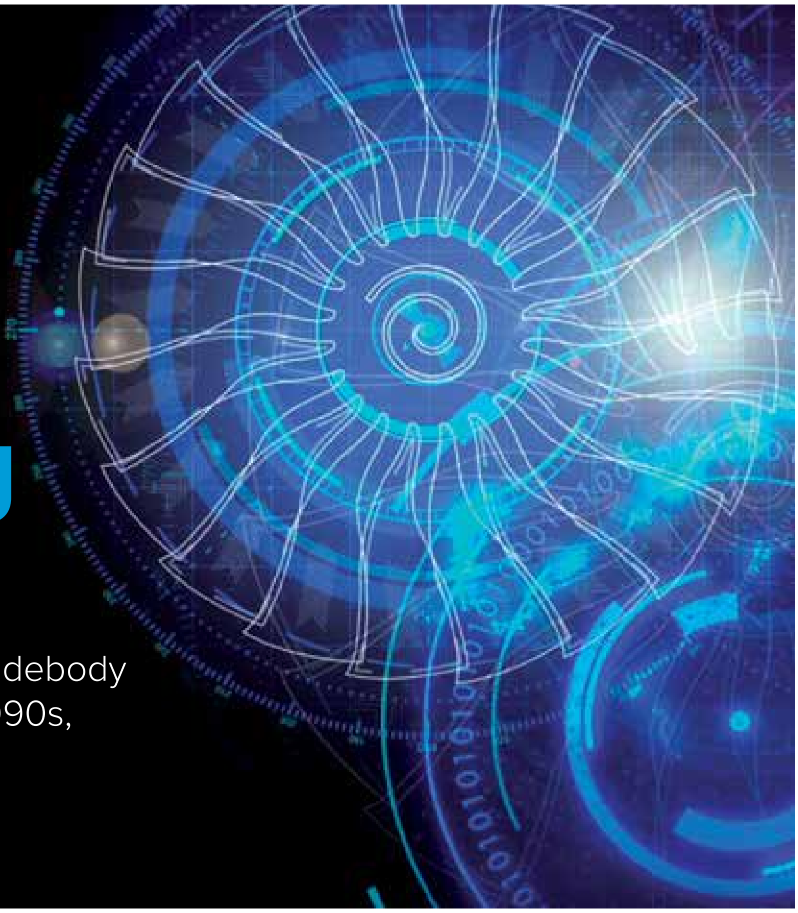
The OEMs support this view. CFM, for instance, has promised the same lifecycle maintenance costs for the LEAP as for the CFM56-5B. Since engine spare part prices rise every year by 5% to 10%, they appear to expect airlines to recoup the difference through better reliability.

Phelan agrees that the "CFM56 and V2500 have been exceptionally reliable engines with superior on-wing performance and operators have benefited in terms of cost of ownership and the requirement for spare engines". However, he does not expect a further significant widening of the spares ratio from those engines' successors.

"Given the OEM pricing structure for new engines and their reliance on aftermarket revenue streams, we don't see this advancement dramatically affecting the requirement for shop visits and spare engine support in the future."

Slattery, meanwhile, says that lessors will need to adapt to any changes in maintenance demand, and notes GECAS's advantage in this respect.

"The key for lessors is to have the flexibility to right-size their portfolios for the available demand," he says. "An aircraft portfolio enables alternative uses for spare engines, adding portfolio flexibility."



Power of **number crunching**

New engines generate about 10,000 times more data than widebody powerplants designed in the 1990s, writes **Alex Derber**.

With each new generation of engines, their manufacturers trumpet advances in fuel efficiency, reliability and power. Such attributes will always remain important differentiators, but competition is set to be influenced increasingly by the data that engines produce – and how it is transmitted, analysed and acted on.

There are several reasons for this. First, engine original equipment manufacturers (OEMs) are just as reliant now on services revenues as they are on new equipment sales. Second, the newest engines generate vastly more data than their predecessors. Third, machine learning and artificial intelligence means that data can be analysed more effectively, which feeds into an OEM's service offering – for instance, by improving the accuracy and scope of predictive maintenance. Fourth, enhancements in aircraft connectivity mean it is becoming cheaper to transmit data in real time during a flight, opening the possibility for more responsive maintenance and support work.

Data acquisition

Before examining the utility of engine data, it is worth understanding how engine parameters are monitored and how engine sensor technology is developing. This is important because new engines such as the Rolls-Royce Trent 1000 generate about 10,000 times more data than widebody powerplants designed in the 1990s, yet this has not been accompanied by a huge increase in the number of engine sensors.

"There have always been surprisingly few sensors around the engine, as each sensor added adds to cost, weight and wiring or maintenance complexity," notes Nick Ward, head of product management, servitisation and user experience for Rolls-Royce.

Of the 25 or so sensors that a typical engine contains, the following systems are some of the most important:

- engine gas path. A combination of temperature and pressure sensors that measure critical parameters such as exhaust gas temperature;
- power indicators. These measure rotor speeds to assist with functions such as thrust control and trim balancing;
- fuel sensors. Used to calculate fuel consumption and to maintain fuel temperature within an optimum range to prevent fuel icing or overheating;
- oil system. A suite of sensors to monitor the temperature, pressure and debris in oil and lubrication systems; and
- vibration. If vibration exceeds design limits, this information is sent to the aircraft as maintenance messages and flight-deck warnings.

Sensors in these systems measure and transmit signals, but the real magic happens in the data-collecting device, such as the engine management unit (EMU) or prognostics and health monitoring unit. Within these systems data points are combined and analysed by software algorithms, with some stored for later (or sometimes immediate) transmission off the aircraft and some discarded.

"A lot of the data doesn't actually add much value," explains Ward. "Seeing a valve position is static for several hours of a flight isn't very useful – what you want to do is look at it when it changes position."

Further number crunching happens on the ground at OEMs, airlines and maintenance companies, but this does not diminish the sophistication of an aircraft's onboard capabilities. For example, Rolls-Royce uses "edge analytics" to sift through terabytes of data and automatically decide what is worth transmitting.

Advances are also occurring at source, as OEMs seek to improve the accuracy, responsiveness and durability of engine sensors. One avenue being pursued is plug-and-play sensors – self-powered devices that could be installed later in an engine's life to record different parameters and transmit them to the EMU.

Other developments include combination sensors, which will prove increasingly important for new-technology engines. This is because newer engines tend to run hotter, placing greater strain on the durability of internal equipment. Since the size of sensors is determined principally by their protective packaging, it makes sense to combine functions.

Data action

Certain trends in engine data have been used for some time to indicate when maintenance is required or, ideally, when to perform small corrective actions that reduce the need for more expensive and time-consuming repairs or replacements at a later date. Perhaps the most common example is exhaust gas temperature margin. Low EGT margin can indicate deterioration of expensive parts such as turbine blades and nozzles, while trend analysis allows users to formulate a wear profile for an engine.

Other areas of analysis are relatively new, such as the development of "digital twin" engines. OEMs and maintenance companies use these to better understand the design and service lives of their physical counterparts, and improvements in data acquisition and parsing will only enhance the information such digital twins provide.

On the ground there is also potential to combine engine sensor readings with other inputs. Under its cooperation agreement with Microsoft, Rolls-Royce uses cloud-based applications to access humidity data for every airport served by the Trent XWB engine on the Airbus A350 and then combine it with turbine gas temperature reports. This provides a more accurate picture of when servicing is needed because high humidity can influence the TGT reading and make it appear that an engine needs servicing earlier than necessary.

"Analytics evolve much more rapidly than the onboard data capture," says Ward, adding: "We can see new generations of techniques within six to 12 months as new methods appear in the data science community."

Machine learning is likely to drive some of the fastest improvements in data analytics. This is because engine systems do not work in isolation, so, although there might be relatively few (25 or so) sensor inputs, the number of ways they can interact is enormous. A machine-learning model can learn normal patterns of interaction and then alert to any divergence.

"Imagine a 30-dimensional shape describing the engine gearbox," explains Ward. "As the aircraft operates, that shape moves and is animated throughout the flight, which is normal. But occasionally it moves in a new way, and the system picks that up for us."

"The new Pearl 15 business jet engine allows remote engineers to 'listen' to the engine and certify it fit to return to base."

Nick Ward, head of product management, servitisation and user experience, Rolls-Royce

Another example is non-linear lifing for valuable engine components. The traditional approach for calculating the life of life-limited parts is based on one or just a few engine parameters, which, while reliable, are imprecise. New techniques developed originally for military engines are being applied now in the civil sphere; these calculate remaining life based not just on a few parameters and bare flight-hour assessment, but also on how an engine is used, which encompasses factors such as flight profiles and operating environment.

Ward says that such techniques are "several generations beyond the traditional and simple engine performance model trend analysis".

Live data

Passenger demand for in-flight connectivity has driven big improvements in the speed and cost of aircraft internet capabilities. These improvements can also be leveraged by health monitoring systems, making it economically viable for aircraft to transmit larger quantities of real-time systems data.

Many aircraft already transmit snapshots of data at take off, climb and cruise via the aircraft communication addressing and reporting system (ACARS), but this VHF system is limited to messages of only a few kilobytes, whereas much larger data volumes are transmitted once an aircraft is hooked up at the gate.

However, although wi-fi now allows almost continuous in-flight reporting of systems data, the value of doing so then, versus a short time later when the aircraft lands, is in doubt.

"Our techniques should be picking up any meaningful engine conditions several days ahead of the issue needing attention, so the question would be: 'What more would I do during the flight it I streamed the data?' The answer is generally that there are only very rare occasions we'd do anything differently," says Ward.

Two-way street

It may transpire that future software applications enhance the use case for in-flight, live systems data, but for now there is plenty of value in real-time transmission from the ground, in part because of the development of the Internet of Things and aircraft and engine systems that can communicate – and be communicated to – remotely.

One example is Rolls-Royce's new Pearl 15 business jet engine, which incorporates a feature that may soon be seen on commercial powerplants – the ability to live stream data during a ground run. Furthermore, engineers can talk back to the Pearl 15's EMU to give it instructions for the ground run.

"This allows remote engineers to 'listen' to the engine and certify it fit to return to base where in the past it might have been grounded as an engineer flew out to it, conducted a test and flew back," says Ward.

Thus, one can see how powerful engine data can be in multiple scenarios: in real time for testing and avoiding aircraft on ground situations; in the medium term for enhancing predictive maintenance and lowering lifecycle costs; and in the long term through the development of digital-twin engines, analysis of which can speed up design improvements for both current and future engine technology.

Transitioning CFM56 production to LEAP

Jamie Jewell, director, strategic communications, CFM International, explains the approach on moving production to the LEAP programme.

On 13 July 2008, GE Aviation and Safran Aircraft Engines, partners in the 50-50 CFM International joint venture, made aviation history by launching the advanced LEAP-X engine programme. More than a decade later, the engine is delivering everything that was promised that day and more.

Going where no manufacturer has gone before

The LEAP engine has enjoyed the fastest order ramp-up in aviation history. The company received its first order in June 2011 and, through March 2019, had orders and commitments for more than 17,350 engines across all three models (LEAP-1A for the A320neo; LEAP-1B for the Boeing 737 Max; LEAP-1C for the Comac C919).

Along with that came an unprecedented ramp-up that will have the company producing more than 2,000 engines a year by 2020.

This production ramp-up is unlike anything CFM – or the industry – has ever seen. CFM delivered more LEAP engines in the first 12 months of the programme than the company did in the first five years of the CFM56 product line. And there is no sign that the demand is going to slow.

Faced with numbers such as these, CFM knew it had to do things differently.

The company adopted a dual – and, in some cases – multisource strategy for all critical parts. This will serve the company well when it achieves a sustained rate, but it initially presented some challenges because CFM had to work closely with suppliers to stabilise first-time yields and cycle times.

CFM kept the more advanced technology components (the fan blade, CMCs, turbine technology, etc) in-house and multisourced those, as well (ie, three Safran factories to manufacture fan blades and cases; three GE facilities for CMCs, etc).

CFM's investment in the LEAP production ramp-up began about a decade ago. During that time GE and Safran invested several billion dollars to upgrade existing facilities, as well as building new factories, adding more than 3.5 million square feet of manufacturing space.

Safran has added four new factories to produce the carbon fibre composite fan blades and fan case – Rochester, New Hampshire; Commercy, France; Queretaro, Mexico; and a factory to produce the low-pressure turbine blades in Sedziszow Malopolski, Poland.

GE has established five new factories: Ellisville, Mississippi (advanced coatings); Auburn, Alabama (additive manufacturing); Asheville, North Carolina (CMC production); Lafayette, Indiana (LEAP core and -1B final engine assembly); LEAP-1B final engine assembly (CMC raw materials).

In addition to new facilities, CFM has about a $1 billion annual investment in new equipment to ensure ramp-up capabilities.

One of the biggest challenges CFM has faced in the production ramp-up has been delivering on significant demand for the new LEAP engine model while serving peak demand for the CFM56; LEAP production began as CFM's popular CFM56 engine was still ramping-up and in peak demand (2016).

CFM56 production rates:

- 2016: 1,671 engines – peak rate of about 32 engines a week.
- 2017: 1,412 engines.
- 2018: 1,044 engines.
- 2019: 384 engines – and delivered the 10,000th CFM56-5 to Airbus and the 15,000th CFM56-7B to Boeing.
- 2020: 195 engines planned; the final commercial CFM56 engine will be produced.

Despite the end of commercial CFM56 engine production, the company plans to produce CFM56 spare parts until 2045. There are more than 24,000 CFM56 engines still flying and the fleet has

achieved more than one billion engine flight hours, another industry first.

Overall, CFM delivered 1,000 LEAP engines in just 27 months. That is three times faster than either the CFM56-5B or CFM56-7B, the latter being the fastest ramp-up in aviation history prior to the introduction of the LEAP engine.

LEAP production rates:

- 2016: 77 engines.
- 2017: 459 engines.
- 2018: 1,118 engines.
- 2019: 1,800-plus engines planned.
- 2020: 2,000-plus engines planned.

For much of 2018, the company was about four to six weeks late in delivering engines to airframer request. However, the company has worked diligently to get deliveries back on track to keep customer disruptions to a minimum.

The multiple-source strategy is now in place and CFM is actively developing additional sources while partnering with suppliers to solve first-time yield and cycle-time constraints. In addition, the ramp-down of the CFM56 production line is adding additional assembly and test capacity.

The company is keeping pace with demand rate, and production is steadily improving. LEAP production rates increased 30%, quarter-over-quarter in 2018, and it has gone from being about six weeks late to airframer request early in the year to meeting aircraft delivery requirements now.

LEAP engine in service

In commercial service, the LEAP engine is providing airlines around the world with industry-leading fuel efficiency, environmental improvements in both noise and emissions and the highest daily asset utilisation in this thrust class.

More than 2,000 engines have been delivered to date to more than 100 operators worldwide. This fleet has logged more than four million engine flight hours – four times faster than the CFM56.

The LEAP engine:

- powers 75% of all new single-aisle aircraft deliveries.
- provides up to 20% improvement in fuel consumption compared with current CFM56 fleets, along with a 75% reduction in noise and 50% lower NOx emissions versus current industry requirements.
- allows for longer flight legs – 2.5 hours versus 1.8 for the CFM56.
- both the LEAP-1A and -1B have sustained a 96% daily utilisation – the best in the industry, surpassing even the CFM56 fleet – which equates to 25% more hours flown a day, helping customers maximise revenue.
- the LEAP fleet is flying 350 out of 365 days annually.
- LEAP engine reliability supports 25-minute gate turn times – which means more flights a day and more revenue.

The LEAP engine has also had triple the number of new entry-into-service customers versus CFM56 in the same timeframe. This is something else the company planned for, well in advance.

CFM has long been noted for its world-class customer and product support and the company has worked hard to maintain the reputation with its LEAP customers.

CFM has 30 specifically trained LEAP experts who can be deployed where they are needed to customer sites around the world. These experts made a multi-year commitment to the programme and know the LEAP engine inside and out.

This team is backed by 250-plus field service engineers stationed worldwide. In addition, three call centres provide 24/7 support. These centres field about 2,200 inquires a month and have maintained a less than four-hour turnaround on critical cases.

There are 10 overhaul shops globally and eight of the facilities have quick-turn capability. These shops have been averaging a less than 30-day turnaround time, wing-to-wing, which has helped to minimise operational disruptions for some field issues.

From a maintenance and overhaul perspective, CFM has 10 overhaul shops that have quick-turn capability, eight component repair shops and 15 on-wing support sites which can dispatch a team of experts to locations around the world to support customers in situations such as an aircraft on ground.

"We have designed an engine that has met every one of our commitments and we are incredibly proud of this accomplishment. But even more important than that, our customers love this engine; that is the true measure of our success," says Gaël Méheust, CFM president and chief executive officer.

CFM International is a 50-50 joint venture between GE and Safran Aircraft Engines. The company was founded in 1974 and has gone on to produce the two best-selling aircraft engine product lines in history – the ubiquitous CFM56 and the LEAP engine families. In July 2008, the two parent companies signed a landmark agreement extending the existing partnership to 2040.

Rolls-Royce **battles to resolve issues**

The problems with the Trent 1000 engine have proved costly for the manufacturer.

Engine manufacturer Rolls-Royce is hopeful that the number of Boeing 787s grounded by Trent 1000 problems could drop to single figures by the end of 2019.

About 31 Boeing 787s were grounded, Rolls-Royce's chief executive officer Warren East confirmed to investors on 28 February 2019, as the company announced its 2018 results.

Rolls-Royce is undertaking an extensive retrofit programme on the Trent 1000 Package C and B engines for the 787-8 and -9 models and the Trent 1000 TEN powering the larger 787-10 variant.

The issues have caused airlines a huge level of disruption.

"A portion of those Trent 1000 customers have been seriously affected, and clearly we've been putting an awful lot of effort into managing that from an operational point of view and helping those customers by minimising the number of aircraft they have on the ground," says East. "The Trent 1000 situation was very unusual in having multiple issues in one engine."

This is set to cost the company at least £1.5 billion ($1.99 billion) between 2017 and 2022, with £431 million spent in 2018 and £450 million budgeted for 2019.

East says the company benefited from a "fantastic Christmas present" after the US Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA) approvals in December of the redesigned intermediate pressure (IP) compressor blade for Package-C engine.

Some 386 Package-C engines were in the worldwide 787 fleet at the end of February 2019. East says the first engines fitted with the redesigned blade were now flying, signalling what he called "healthiness" in the Trent 1000 fleet.

Rolls-Royce says it has dealt with the Package C first because most of the 600 Trent 1000 engines that are in service are Package C.

Hard life limits for the Trent 1000 TEN's intermediate compressor rotor drum were transitioned over to an inspection regime, by EASA in December and by the FAA earlier in February, says East.

The company is now in the process of redesigning the IP compressor rotor blades for that engine too as a precautionary step with certification expected in the third quarter of 2019.

Work is also ongoing to redesign the IP compressor blades for Package-B engines, approvals for which are expected at the back end of the year.

The Package B (Trent 1010) is the new engine going into service and that is why, logically, that is the next one to deal with. The compressor blade design is effectively the design that is done and Rolls-Royce is now going through the process for certification.

The equivalent blade for the Package B engines is coming along behind that, because there is a relatively small number of Package B engines in service.

The incidents in the Package B of the fault is much lower than in the Package C. So in disruption terms to the company's customers, this has minimal effect and that is why it is being done it in that order.

Fewer AOGs

East admits that the number of Trent 1000-powered aircraft on the ground is going to be a feature for at least the remainder of 2019, but the Rolls-Royce chief does expect it to be in single digits.

The number of aircraft on the ground in the second half of 2018 oscillated between 40 and 45 engines. It was about 35 engines in the first quarter of 2019.

Speaking at the *Airfinance Journal* Dublin 2019 conference in the first quarter, Richard Goodhead, senior vice-president marketing, civil aerospace, said there will be fewer aircraft on the ground (AOG) during the first half of this year.

Goodhead says: "I'd say that the problems we've had on the Trent 1000 are not atypical of new engines going into service and, indeed, there are other examples across the rest of the industry."

Last June, the UK engine manufacturer identified a durability issue on the intermediate pressure compressor on the Package B version. The variant has flown in service on 787s since 2012.

In November, the European Aviation Safety Agency said that cracking had been discovered in the Trent 1000s with the Package C performance enhancement measures. Rolls-Royce then issued a bulletin to instruct inspections of the compressor's rotor sections.

"What has given us the big challenge on the Trent 1000 is that several of those problems have occurred at the same time. That said, of the four issues that were causing that disruption around 2018, three of them are definitely sorted and new parts are being flown into the fleet and we're about three-quarters of the way in terms of getting those new blades on the IP turbine and the HP turbine," says Goodhead.

He adds that for the other main problem, on the engine intermediate pressure compressor, Rolls-Royce obtained certification at the end of September.

"This will lead to an improvement in AOGs throughout the first half of 2019 and we can get back to a more normal level," he adds.

Rolls-Royce's market share in the Trent 1000 market has declined in terms of the new orders and it sits at about 35%.

"We had obviously hoped, ahead of this issue, that that share would be growing from mid-30s towards 50%. I would interpret what's happened as a delay in that trajectory," says East.

The Trent 1000 is actually a very reliable engine. It has a 99.9% dispatch reliability.

East says: "Our customers who are flying the Trent 1000-powered 787s, whilst not initially – clearly they were very disrupted – are able to partition in their minds the operation of the aircraft when the engine is behaving normally and take that away from when the engine isn't there at all."

UltraFan 'targets' widebodies

Now that Rolls-Royce has rejected the opportunity to join the NMA market, its UltraFan programme may turn its sights on the widebody sector.

Rolls-Royce has blamed a tight development schedule for its decision to pull out of the engine competition for Boeing's proposed New Midsize Airplane (NMA).

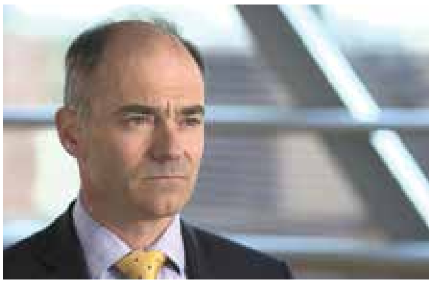
Perhaps mindful of ongoing problems with its Trent 1000 engines, the UK-based original equipment manufacturer (OEM) says it is "unable to commit to the proposed timetable to ensure we have a sufficiently mature product which supports Boeing's ambition for the aircraft and satisfies our own internal requirements for technical maturity at entry into service".

Its withdrawal leaves CFM International and Pratt & Whitney as the two OEMs in the hunt for NMA engine selection.

While commenting on the 2018 fourth-quarter results, chief executive officer Warren East said it was all a matter of overlapping Rolls-Royce's UltraFan development programme with the NMA requirements and seeing if the UK manufacturer could achieve a sufficient overlap there to make a sensible answer from a commercial and a risk point of view.

"We have concluded that there is not sufficient overlap to create an engine out of the UltraFan architecture within the Boeing timescales at a sufficient level of maturity to tick those boxes in terms of risk and commercial common sense," he says, adding that Rolls-Royce had notified Boeing shortly before the end of 2018.

East says Rolls-Royce wishes to avoid supplying an engine that is not sufficiently mature. "If you don't achieve a sufficient level of maturity, you lay yourselves open to all sorts of in-service issues, potential customer disruption and that's not a good place to go from a risk and a commercial point of view," he adds.



"We have concluded that there is not sufficient overlap to create an engine out of the UltraFan architecture within the Boeing timescales."

Warren East, chief executive officer, Rolls-Royce

Rolls-Royce will now pursue development of that engine programme, "in preparation for future applications" – and the route will probably be the widebody market.

"It sounds to me at least as if the UltraFan development has been primarily aimed at the larger widebody market," says one analyst source. "East stated a range from 25,000 to 115,000lbs but, it seems clear that most of the engine thrust requirements would be in the 70,000 to 90,000lbs thrust."

East highlights that the UltraFan technology is a scalable architecture. "It is scoped to scale from about 25,000lbs of thrust through to about 100,000lbs of thrust. This means we can go after widebody; we can go after single aisles. We expect the first opportunities will be in widebody market."

The source adds: "Rolls-Royce probably has well-developed ideas around UltraFan for the lower end of its stated thrust range, but the adaptation of the larger scale technology doesn't appear to suit Boeing's intended NMA development profile.

"It is also known that Boeing is trying to close the business case for the NMA around the lowest production costs possible. More than CFM International or Pratt & Whitney, Rolls-Royce appears to be pushing significant changes to its current architecture. These are perhaps not entirely compatible with Boeing's aim to build a low-cost, entry-level, twin-aisle aircraft like the NMA," says the source.

"If the UltraFan is really designed for larger applications, then a "simple" scaling down may not produce the same efficiencies as a GTF [geared turbofan]-based design or even an upscaled LEAP engine," he adds.

Rolls-Royce says the UltraFan, which will offer a 25% fuel-efficiency improvement over the first-generation of Rolls-Royce Trent engines, is the foundation of its future large civil aero engine programmes.

The UK manufacturer has tested the UltraFan core, power gearbox and composite fan-blade system. "We had begun its development before the Boeing opportunity emerged and it must undergo a rigorous testing regime before we offer it to customers, which we do not believe can be achieved within the NMA timeframe," says Chris Cholerton, Rolls-Royce's president, civil aerospace. "We must ensure that it has as smooth an entry into service as possible."

ABS transaction for 55 engines closes

US-based engine lessor Willis Lease Finance issued its fifth asset-backed securities transaction in 2018.

Engine lessor Willis Lease Finance closed an asset-backed securitisation (ABS) debt offering that covered 55 engines through the Willis Engine Structured Trust IV (WEST IV), a subsidiary of Willis Lease. The $373.4 million 144A transaction was the largest engine financing of the year.

The fixed-rate notes were issued in two series, with $326.8 million of Series-A notes and $46.7 million of Series-B notes.

The Series-A notes have a fixed coupon of 4.75%, an expected maturity of about eight years, an expected weighted average life of 6.3 years and a final maturity of 25 years.

The Series-B notes have a fixed coupon of 5.438%, an expected maturity of about eight years, an expected weighted average life of 6.3 years and a final maturity of 25 years.

The Series-A notes priced at 99.99504% of par and the Series-B notes priced at 99.99853% of par.

Bank of America, MUFG and Wells Fargo acted as active bookrunners in the transaction.

The transaction marked Willis' fifth securitisation. The lessor retained the equity in WEST IV as in its previous securitisations.

The 2005 and 2007 transactions were paid in full before their respective maturity dates, while the 2012 and 2017 transactions had an outstanding balance of $248.5 million and $321.9 million, respectively, as of 15 June 2018.

Proceeds from the notes were used to acquire 56 assets, including 55 engines and one Boeing 737-800 aircraft airframe leased to Scandinavian Airlines. The 737-800 had an initial age of 17.6 years and a remaining lease term of 2.3 years at the time of the closing.

A total of 54 assets were on lease to 28 lessees. At closing, two engines were not subject to a lease agreement.

As of July 2018, the portfolio had a remaining lease term of about 19.6 months, with about 2.9% of the portfolio initially not subject to a lease.

The portfolio consisted of a variety of engines that equip narrowbody aircraft (74.9%), widebody aircraft (17.6%) and regional jet aircraft (7.5%).

Kroll Bond Rating Agency (KBRA) rated the transaction with an A rating of the A tranche and a BBB rating of the B notes.

The rating agency said four engines are in the latter stage of their lifecycle in relation to their host aircraft, while a large portion of the portfolio has stronger near-term re-leasing prospects. KBRA views such composition as a credit positive.

The portfolio has an initial value of about $466.8 million, based on the average of the maintenance-adjusted base values provided by three appraisers for the engines and two appraisers for the airframe of the one aircraft, as of the second quarter of 2018. The portfolio has an aggregate maintenance-adjusted current market value of about $454.4 million. Willis posted a record annual pre-tax profit of $56 million last year, up 56% from $36 million in 2017.

The engine lessor's 2018 pre-tax results were driven by 27% revenue growth, to a record $348 million, from its core leasing business and higher spare parts and equipment sales.

As of 31 December 2018, Willis directly owned 308 lease assets worth $2 billion, and managed 422 engines, aircraft and related equipment on behalf of third parties. The company, which has its headquarters in Novato, California, maintained $463 million of undrawn revolver capacity at the end of 2018.

WEST IV ABS transaction engine collateral

Engine type	Number of engines	Engine value (% of portfolio)
V2500-A5	14	27.50%
CFM56-5B	11	20.90%
CFM56-7B	15	22.80%
Genx-1B	3	13.60%
LEAP-1A	1	3.70%
CF34-10	2	3.70%
CF34-8	4	3.60%
CFM56-5C	2	1.50%
Trent 700	1	1.40%
PW4060	1	1.00%
CF34-3B	1	0.10%

Source: KBRA, August 2018

Will there be **independent engine lessors** in 2049?

Given the prevailing OEM dominance in all things engines related and as Engine Lease Finance Corporation (ELFC) approaches the celebration later this year of its first 30 years as an independent engine lessor, Tom Barrett, ELFC's recently appointed president and chief executive officer, suggests the independent spare engine lessor will be around in 2049.

When I joined ELFC with the industry in its infancy, I was of the view that the leasing industry, along with its independent lessors (and my career in it), would only exist for a handful of years. Almost 30 years later, I am of the view that strong independent leasing entities are a crucial component of the market and it remains vital that companies such as ELFC continue to serve airlines for the next 30 years.

Before outlining why I hold this view, I think it is worth reflecting on how original equipment manufacturer (OEM) dominance of maintenance, repair and overhaul (MRO) has evolved over the past 30 years.

In 1989, when ELFC was founded, there was little mention of OEM dominance of the aftermarket. OEM dominance was confined to the process of manufacture and sale of new engines and engine parts. The OEM was happy to take the margin (or loss in the case of installed engines) on spare engines and engines parts. At the time there were sufficient airlines and MRO shops which would only purchase and install new OEM parts. However, like most of the inefficient industries of the world that need to adapt, the historically loss-making airlines (heavily regulated and often government subsidised) eventually had to focus on their core purpose of efficiently serving the travelling public, their customers. The consequence was their exit from MRO shop ownership and their reduced use of the "new-only" restriction for engine parts. This, in turn, led to the proliferation of used serviceable parts (USM) suppliers which created efficiencies through their pricing and logistical expertise.

In response, OEMs sought to generate alternative revenues through the acquisition of MRO shops, locking in the use of their new parts through these shops and their full maintenance programmes that would come later, along with their entry into the spare engine leasing business. With the aftermarket percentage of total revenues running at well over 60% for one of the OEMs, and with new parts price increases on an engine in production for several years over the past five years running at more 4.4% per annum, it is clear the OEMs have succeeded in preserving revenues in the MRO and parts supply sectors. This then brings me on to the engine leasing sector.

In 1989, all the OEMs were beginning to dabble in engine leasing: Rolls-Royce was founding RRPF; CFMI (together with its partner GPA) had founded Shannon Engine Support in 1988; and GE was later in the 1990s going to get much more active through GE Engine Leasing. However, at the same time, ELFC, Willis Lease Finance (1986) and a few other (long gone) independent lessors were to be founded with a view to entering this new industry sector. While many of the early independent entrants are no more, ELFC and others have succeeded by always remembering that they must maintain their focus on the customer – in our case, the airlines which, in turn, serve the travelling public.

Do airlines need independent engine lessors?

Undoubtedly, the past 30 years have seen a proliferation of independent aircraft leasing companies, up to 100 active at present, which are very well funded, structured and managed. This has resulted in airlines being sure of obtaining very competitive pricing and being able to demand customer-oriented terms.

With the aircraft asset, which is increasingly being commoditised by its 100 active participants, there is no OEM exerting dominance (acknowledging of course GECAS's strong position) and arguably fewer barriers to entry. However, the very complex nature of the engine as an asset, with so much value attributable to operational life, it has made it impossible for so many independents to proliferate successfully.

With the success of GE Engine Leasing, RRPF and PWEL in owning, managing and leasing very significant portfolios, there is undoubtedly a possibility that the dominance in the MRO sector could be replicated in the engine leasing sector. ELFC is of the view that its role as a strong independent controls the potential for the OEMs to dominate at the delivery of the spare engine, during the operational period and ultimately at the point of overhaul or retirement when USM fulfils a crucial role.

"In 1989, when ELFC was founded, there was little mention of OEM dominance of the aftermarket."

Tom Barrett, president and chief executive officer, Engine Lease Finance Corporation

ELFC itself, or through its INAV parts company subsidiary, provides vital competition in all these stages of the engine life cycle for the benefit of airline customers.

Strong independents, which are very competitively funded, such as ELFC, see to it that the initial sale and leaseback lease rentals are very competitively priced. Similar to the aircraft leasing sector right now, the competition is particularly fierce, with several new entrants providing pricing that will leave them short in the event of any cyclical downturn. ELFC, as a customer-focused entity, will continue to react to these competitive market forces as appropriate.

Beyond periods of the initial introduction into service, it remains vital that short-term lease rentals and spot rentals are competitively priced, and it is only through the independents' short-term activity and those long-term lessors with inventory that the airlines can be satisfied that rentals will continue to remain competitive.

However, it is in the area of used serviceable material that the independent lessors, having harvested the operational life of the engine, will truly serve the customer by keeping used serviceable materials in supply and ensuring that they remain a viable alternative to the new materials, favoured by the OEMs with their full list pricing.

It is not just about pricing

The services offered by the independents are not confined to ensuring good pricing for the airlines – over the past 30 years they have provided a vital service to their customers by their concentration, focus, development and refinement of the engine lease product itself. This is done by their constant need, through competitive pressures from the OEMs and other independents, to refine their lease language, offer flexibility, balance the risks appropriately and ensure a constant evolution of the engine leasing product.

In the infancy of engine leasing, it was often the case that the airline retained no flexibility with regard to the redelivery conditions, which were inevitably zero time since overhau. But through the years ELFC and others have consistently refined their product offerings to the point where customers are now able to access varied redelivery conditions, FX leases, floating rentals, variable lease terms (to mention just a few) thought to be impossible back in 1989. To paraphrase my colleague Joe O'Brien when he referred to the "residual" in providing feedback on the engine poll for this publication last year, "it's about the customer stupid".

It is only the strongest of independents which can offer these variations of the core product and it remains crucial for the airlines that these independents serve them in this way.

Customer is not the only pillar

As many lessors have found out over the years, there are many non-customer-related reasons to fail. While many of these revolve around factors outside their control, such as shareholder or staff turnover issues, at ELFC the constant business focus on the other two pillars – shareholder and staff – have allowed us continue strongly in the business.

Since 2014 and the acquisition of ELFC by Mitsubishi UFJ Lease & Finance, ELFC has been supported by a very strong parent company with a long-term strategy to grow its international leasing businesses. Its success in doing this has been evident by the growth of its aircraft leasing company, Jackson Square Aviation, ELFC and the decision to invest vertically into the engine parts business in INAV which ELFC completed in 2017.

ELF's refurbished Shannon headquarters ready for the next 30 years

For any business success, constant emphasis on staff is critical but in the engine leasing business where the asset class is so complex with considerable downside risk if poor management prevails, it is crucial that the engine lessor staff understand the asset, have considerable experience of managing the asset and are willing to work hard in a global industry to deliver the required expertise to the customer. In order to do this, it is safe to say that the engine leasing community has to leave its ego outside the door. Culturally, the focus in ELFC is on working with the customer, maintaining the relationship and ensuring that the customer will be happy to do repeat business.

OEMs are our customers too

While the customer emphasis outlined above might suggest to some that the strong independents are diametrically opposed to or in conflict with the OEMs, it is crucial for any independent lessor to acknowledge and recognise the fact that the success of the OEM product is critical to its own long-term prospects of success in this industry. It is for this reason that the independents will always want to work with the OEMs – eg, ELFC acquired more than $100 million directly from one OEM in 2018 and also has several engines on OEM leases – in order to serve its customer requirements in what has been a very buoyant market for the past few years.

While different OEMs will reciprocate their relationship with the independent lessor in different ways, it is fair to say that most OEMs acknowledge that independent lessors provide a service that their customers require and consequently they are willing to work with the independent engine lessors to find ways to access the market beyond their own capabilities.

Uncertainties exist

It is obvious that the engine leasing sector, like the aviation business in general, will remain cyclical and go through periods of irrational exuberance and unwarranted pessimism. If a company is to weather the uncertainties and storms ahead, it is crucial that it sticks to what it does best, understands its customer and reacts with a very high degree of flexibility as challenges are presented.

The current challenges that I see for this industry are late or postponed entry into service, technical performance of the new engines entering service, uncertainty in particular markets brought about for a variety of regional reasons, the state of the global economy and irrational behaviour by leasing executives who seems to have forgotten the lessons of the past.

For more than 30 years this industry has experienced cyclical, be they regional or global, downturns. It is fair to say, despite some regional issues at the moment, that the industry is going through a sustained period of profits and favourable market conditions for the airlines and the industry servicers of which the lessors are just one part.

However, the common thread for the past 30 years is that each period of stability and growth has been followed by a period of oversupply. With the manufacturer production rates on new aircraft, despite the global growth forecast for travel, it is difficult to see how a period of oversupply will not arise at some point. This period of oversupply may be brought about by a slow market downturn where it can be managed appropriately, or it could be brought about by a significant market event that will provide less room for management of the downside risk. With the operating lease pricing, particularly on sale and leasebacks of aircraft and engines, prevalent at the moment, in my opinion, many lessors (particularly new entrants) are not building up sufficient reserves and cushion for them to survive any period of sustained downturn.

This situation when (not if) it comes will result in a significant shake-out of the aircraft leasing community and will damage some of the new engine leasing entrants. ELFC can, with a high degree of confidence, predict that although its profitability will be impacted, it will, like it has before, be well positioned to react to the customer's needs for flexibility and work through all of the challenges that the changing market will dictate. This can only be achieved by staff applying themselves creatively and innovatively to work with customers to solve their individual problems.

As an independent, it is incumbent on ELFC to deliver in this way to its customers for the next 30 years.

Teething problems are price to pay

SGI Aviation's Francesco Baccarani expects the narrowbody new engine models to take time to achieve reliability.

Pratt & Whitney and CFM International have, in the past three years, released new and innovative engines that power various narrowbody aircraft. Those engines are the new engine options for the Airbus A320neo, the Boeing 737 Max and the Embraer E170/E190-E2 families. They will also power new regional jets, such as the Mitsubishi MRJ, the Irkut MC21 and the Comac C919.

Even if these new engines started their operations a few years ago, SGI Aviation has already performed some shop visits management and has supported airlines during maintenance contracts negotiations, engine model selection, risk analysis and more. SGI Aviation has been mainly involved with the GTF1100G, the LEAP-1A and the LEAP-1B models.

Pratt & Whitney and CFM International designed the new engines with the purpose of dramatically reducing the fuel burn, the emissions and noise. All engines have been able to meet the performances promised by the original equipment manufacturers (OEM) so far, and the PW1100G, the LEAP-1A and LEAP-1B were capable to burn 15% less fuel than their predecessors (IAE V2500 and CFM56) and decrease the CO_2 and NOx emissions by up to 50%. This is an incredible improvement if we consider the amount of fuel an airline burns every year and its impact on the company's accounts.

Pratt & Whitney and CFM had a completely different approach to reaching the promised performances. P&W hit the pre-fixed target through a new engine design, which introduces a gearbox between the low-pressure compressor (LPC) and the fan. The gearbox reduces the rpm of the low-pressure shaft and allows the installation of a fan which is definitely larger than the fan of a CFM56-5B or a V2500-A5.

With this solution, both fan and low-pressure turbine (LPT) spin at their optimum speed and only three stages of LPT are required to spin the big fan, thereby allowing a lighter LPT module with simpler architecture. The engine core has a standard design and did not introduce major innovations in comparison with the current mature engines.

CFM preferred to keep a classic and proven engine design and reach the promised performances through new technologies and new materials, which allow the engine to operate at higher temperatures, and increase the efficiency. The LEAP-1A and LEAP-1B fans are also much larger than the CFM56-5B and -7B, respectively, but not as wide as the PW1100G fan.

As expected, every new technology and new design creates problems, some unforeseen when in operation. In fact, both engine types suffered, and are still suffering, problems and unexpected removals. This scenario is typical when new engines, developed with innovative solutions, enter into service. The reliability of these engines is therefore significantly lower than mature engines such as the V2500-A5, the CFM56-5B and '7B.

SGI Aviation performed an analysis of the historical data available for the CFM56-5B. The -5B variant started its operations in 1996 and its reliability data were much lower than today and comparable to the current reliability of the new engines. The result of the analysis highlights that the -5B started to get an acceptable rate of unscheduled engine removals and a good shop visits rate about seven to eight years after entry into service. SGI Aviation did not perform a detailed analysis of the V2500-A5 variant, but it behaved similarly to the -5B and took several years to get to an acceptable reliability.

SGI Aviation expects the new engine models will follow a similar scenario. The unscheduled engine removals and shop visit rates have already improved since entry into service and the trend shows they are getting better. Similarly to the CFM56-5B and the V2500-A5, SGI Aviation believes the new engine options will reach a proper level of reliability not before seven to eight years after entry into service.

Both the CFM56-5B and the V2500-A5 were an improved version of the CFM56-5A and of the V2500-A1 variants and as such did not introduce new technologies but they were an enhanced version of basic models. The GTF and the LEAP engines are new models, which are completely different than their predecessors, therefore the time to maturity might also be higher than seven to eight years.

All aviation industry stakeholders hope that these new engines' reliability will improve as quickly as possible in the next few years. All these operational issues are the price to pay when new designs, new materials and new technologies are introduced in new powerplants and, in general, in any new product. As a return, the new engines did an incredible step forward in terms of reduced fuel consumption, emissions and noise, aspects that operators enjoy.

New engine models and their aircraft

Engine	Aircraft
PW1100G	Airbus A320neo
PW1200G	Mitsubishi MRJ
PW1400G	Irkut MC21
PW1500G	A220 (previous CSeries)
PW1700G	Embraer E175-E2
PW1900G	E190-E2 and E195-E2
CFM LEAP-1A	A320neo
CFM LEAP-1B	737 Max
CFM LEAP-1C	Comac C919

OEM	Engine	Fair Market Value ($m)	Base Value ($m)	Monthly Rental	QEC Value Range ($m)	LLP Cost) (new) ($m)	Overhaul (ex LLP) ($m)	MTBO	FH:FC
CFM	CFM56-3B1	$0.480m	$0.480m	$25,000	$0.025 - $0.100	$3.300m	$1.280m	9,000	1.4
CFM	CFM56-3B2	$0.580m	$0.580m	$25,000	$0.025 - $0.100	$3.300m	$1.340m	8,000	1.4
CFM	CFM56-3C1 - 23.5k	$0.850m	$0.850m	$25,000	$0.025 - $0.100	$3.300m	$1.400m	7,000	1.4
CFM	CFM56-7B22	$3.650m	$3.540m	$50,000	$0.600 - $1.800	$3.780m	$3.020m	24,000	1.8
CFM	CFM56-7B24	$4.310m	$4.180m	$58,000	$0.600 - $1.800	$3.780m	$2.950m	22,500	1.8
CFM	CFM56-7B26	$4.930m	$4.790m	$65,000	$0.600 - $1.800	$3.780m	$2.910m	20,600	1.8
CFM	CFM56-7B24E	$5.980m	$5.740m	$57,000	$0.600 - $1.800	$3.780m	$3.300m	26,000	1.8
CFM	CFM56-7B26E	$6.910m	$6.650m	$66,000	$0.600 - $1.800	$3.780m	$3.220m	24,000	1.8
CFM	CFM56-7B27E	$8.160m	$7.880m	$78,000	$0.600 - $1.800	$3.780m	$3.190m	23,000	1.8
CFM	CFM56-5B5/P	$3.710m	$3.600m	$50,000	$0.700 - $2.300	$3.890m	$3.020m	22,400	1.7
CFM	CFM56-5B4/P	$5.020m	$4.870m	$70,000	$0.700 - $2.300	$3.890m	$3.000m	21,400	1.7
CFM	CFM56-5B4/3 PIP	$7.210m	$6.800m	$80,000	$0.700 - $2.300	$3.890m	$3.130m	24,500	1.7
CFM	CFM56-5B3/P	$5.580m	$5.420m	$65,000	$0.700 - $2.300	$3.890m	$2.820m	17,700	1.7
CFM	CFM56-5B3/3 PIP	$7.910m	$7.460m	$77,000	$0.700 - $2.300	$3.890m	$3.160m	21,500	1.7
CFM	CFM56-5C4/P	$1.550m	$1.550m	$52,500	$0.100 - $0.800	$3.950m	$2.670m	13,500	6.0
EA	GP7200	$10.000m	$10.000m	$120,000	$1.100 - $1.900	$8.600m	$6.600m	20,000	8.0
GE	CF34-3B1	$1.350m	$1.170m	$27,500	$0.185 - $0.500	$1.980m	$1.080m	11,500	1.3
GE	CF34-8C5	$2.956m	$2.870m	$40,000	$0.500 - $0.600	$2.910m	$1.590m	11,000	1.3
GE	CF34-8E5	$3.400m	$3.300m	$41,000	$0.800 - $0.900	$2.910m	$1.590m	11,000	1.3
GE	CF34-10E6	$5.120m	$5.120m	$67,000	$1.370 - $1.900	$2.600m	$2.240m	13,000	1.3
GE	CF6-80C2B6F	$2.850m	$2.590m	$150,000	$0.300 - $0.600	$8.200m	$4.300m	16,000	6.0
GE	GEnx-1B74/75/P2	$17.022m	$17.022m	$245,000	$1.800 - $4.200	$9.530m	$6.500m	19,500	6.0
GE	CF6-80E1A3	$9.610m	$9.420m	$135,000	$1.300 - $2.500	$11.660m	$4.860m	15,000	5.0
GE	CF6-80C2D1F	$1.600m	$1.600m	$120,000	$0.300 - $0.600	$8.200m	$4.300m	16,000	6.0
GE	GE90-115BL	$23.200m	$23.000m	$235,000	$1.200 - $2.500	$13.580m	$10.570m	19,000	7.5
GE	CF6-80C2B1F	$2.090m	$2.090m	$120,000	$0.300 - $0.600	$8.200m	$4.300m	16,000	6.0
IAE	V2527-A5	$5.230m	$5.080m	$78,000	$0.700 - $2.500	$4.070m	$3.460m	16,400	2.0
IAE	V2527-A5 Select	$6.090m	$5.910m	$73,500	$0.700 - $2.500	$4.070m	$3.670m	19,300	2.0
IAE	V2533-A5	$6.120m	$5.940m	$74,000	$0.700 - $2.500	$4.070m	$3.550m	11,200	2.0
IAE	V2533-A5 Select	$7.270m	$7.060m	$82,500	$0.700 - $2.500	$4.070m	$3.500m	13,600	2.0
PW	JT8D-219	$0.210m	$0.210m	$20,000	$0.070 - $0.080	$2.200m	$2.000m	9,000	1.5
PW	PW4060	$2.500m	$2.400m	$55,000	$0.300 - $0.600	$7.520m	$5.500m	17,500	6.0
PW	PW4168A	$4.000m	$3.900m	$90,000	$0.700 - $1.800	$9.550m	$7.190m	17,000	6.0
PW	PW4090	$6.100m	$6.100m	$137,500	$1.000 - $2.500	$15.730m	$11.310m	19,000	7.0
RR	AE3007A	$0.680m	$0.680m	$22,500	$0.085 - $0.280	$2.000m	$1.200m	8,450	1.3
RR	Tay 650-15	$0.800m	$0.830m	$25,000	$0.100 - $0.300	$1.800m	$2.100m	11,000	1.1
RR	BR715A	$2.650m	$2.650m	$40,000	$0.300 - $0.900	$2.300m	$2.400m	12,300	1.6
RR	RB211-535E4	$2.852m	$2.852m	$45,000	$0.450 - $0.900	$5.800m	$4.900m	22,000	3.1
RR	Trent 1000-J2	$17.120m	$17.120m	$170,000	N/A	$7.500m	$7.600m	25,000	6.9
RR	Trent 772B-60EP	$8.500m	$8.500m	$105,000	$2.000 - $2.050	$9.200m	$9.200m	26,200	4.4
RR	Trent 895	$8.110m	$8.280m	$145,000	N/A	$11.500m	$9.500m	20,500	5.4
RR	Trent 556-61	$3.350m	$3.550m	$95,000	$0.200	$8.800m	$6.700m	22,000	8.4
RR	RB211-524H-T	$1.876m	$1.876m	$27,500	$0.200 - $0.700	$6.100m	$6.600m	24,250	6.5
RR	Trent 970	$14.500m	$14.900m	$145,000	$0.600	$10.100m	$7.600m	23,000	8.8

Source: IBA, April 2019

Aircraft Model	Engine Options
1900C	PT6A-65B
1900D	PT6A-67D
340A	CT7-5A2
340B	CT7-9B
717-200	BR700-715A1-30
	BR700-715C1-30
	BR715A1-30
737-10	LEAP-1B27
737-200A	JT8D-15
	JT8D-15A
	JT8D-17
	JT8D-17A
	JT8D-9A
737-300	CFM56-3B1
	CFM56-3B2
	CFM56-3C1
737-300QC	CFM56-3B1
	CFM56-3B2
	CFM56-3C1
737-300SF	CFM56-3B1
	CFM56-3B2
	CFM56-3C1
737-400	CFM56-3B1
	CFM56-3B2
	CFM56-3C1
737-400SF	CFM56-3B1
	CFM56-3B2
	CFM56-3C1
737-500	CFM56-3B1
	CFM56-3C1
	CFM56-3C1-18K
737-600	CFM56-7B20
737-7	LEAP-1B23
	LEAP-1B25
737-700	CFM56-7B20
	CFM56-7B20/3
	CFM56-7B20E
	CFM56-7B22
	CFM56-7B22/3
	CFM56-7B22E
	CFM56-7B24
	CFM56-7B24/3
	CFM56-7B24E
	CFM56-7B26
	CFM56-7B26E
737-8	LEAP-1B25
	LEAP-1B27
	LEAP-1B28
737-800	CFM56-7B24
	CFM56-7B24/3
	CFM56-7B24E
	CFM56-7B26
	CFM56-7B26/3
	CFM56-7B26E
	CFM56-7B27
	CFM56-7B27/3
	CFM56-7B27/3B1
	CFM56-7B27/3B1F
	CFM56-7B27/B1
	CFM56-7B27E
	CFM56-7B27E/B1
	CFM56-7B27E/B1F
737-9	LEAP-1B27
	LEAP-1B28
737-900	CFM56-7B24
	CFM56-7B26
737-900ER	CFM56-7B26/3
	CFM56-7B26E
	CFM56-7B27
	CFM56-7B27/3
	CFM56-7B27/B1
	CFM56-7B27E
747-200F	CF6-50E2
	JT9D-7R4G2
	RB211-524D4
747-300	CF6-50E2
	JT9D-7R4G2
747-400	CF6-80C2B1F
	CF6-80C2B5F
	PW4056
	RB211-524G
	RB211-524G-T
	RB211-524H2
	RB211-524H2-T
747-400BCF	CF6-80C2B1F
	PW4056
	RB211-524H2-T
747-400ER	CF6-80C2B5F
747-400ERF	CF6-80C2B1F
	CF6-80C2B5F
	PW4062
747-400F	CF6-80C2B1F
	PW4056
	PW4062
	RB211-524G-T
	RB211-524H2
	RB211-524H2-T
747-400ISF	CF6-80C2B1F
	PW4056
747-400M	CF6-80C2B1F
747-8	GEnx-2B67/P
	GEnx-2B67B
747-8F	GEnx-2B67/P
	GEnx-2B67B
757-200	PW2037
	PW2040
	RB211-535C
	RB211-535E4
	RB211-535E4-B
757-200 ETOPS	PW2037
757-200PCF	PW2037
	PW2040
	RB211-535E4
757-200PF	PW2037
	PW2040
	RB211-535E4
757-200SF	PW2037
	PW2037M
	PW2040
	RB211-535C
	RB211-535E4
	RB211-535E4-B
757-300	PW2040
	RB211-535E4-B
	RB211-535E4-C
767-200ER	CF6-80A2
	CF6-80C2B2
	CF6-80C2B2F
	CF6-80C2B4F
	CF6-80C2B6F
	JT9D-7R4D
	JT9D-7R4E
	JT9D-7R4E4
	PW4052
	PW4056
767-300	CF6-80A2
	CF6-80C2B2
	CF6-80C2B2F
	CF6-80C2B4F
	PW4056
	PW4060
767-300ER	CF6-80C2B2
	CF6-80C2B6
	CF6-80C2B6F
	CF6-80C2B7F
	PW4052
	PW4056
	PW4060
	PW4062
	RB211-524H
767-300ERF	CF6-80C2B2
	CF6-80C2B6
	CF6-80C2B6F
	CF6-80C2B7F
	PW4060
	PW4062
767-400ER	CF6-80C2B7F
	CF6-80C2B8F
777-200	GE90-90B
	PW4077
	PW4084
	TRENT 875
	TRENT 884
777-200ER	GE90-90B
	GE90-94B
	PW4074
	PW4090
	TRENT 884
	TRENT 892
	TRENT 892B
	TRENT 895
777-200LR	GE90-110B1L
777-200LRF	GE90-110B1L
777-300	PW4090
	TRENT 892
	TRENT 892B
777-300ER	GE90-115BL
777-8	GE9X
777-9	GE9X
787-10	GEnx-1B74/75
	GEnx-1B76
	TRENT 1000-J
787-8	GEnx-1B64
	GEnx-1B67
	GEnx-1B70
	GEnx-1B70/75
	TRENT 1000-A
	TRENT 1000-C
	TRENT 1000-D
787-9	GEnx-1B70
	GEnx-1B70/75
	GEnx-1B74/75
	GEnx-1B76
	TRENT 1000-J
	TRENT 1000-K
787teenager	GEnx-1B64
	GEnx-1B70
	TRENT 1000-A
	TRENT 1000-D
A300-600R	CF6-80C2A5
	CF6-80C2A5F
	PW4158
A300-600RF	CF6-80C2A5
	CF6-80C2A5F
	PW4158
A310-200	CF6-80A3
A310-300	CF6-80C2A2
	CF6-80C2A8
	PW4152
	PW4156A
A318-100	CFM56-5B8/3
	CFM56-5B8/P
	CFM56-5B9/3
	PW6124A
A319-100	CFM56-5A4
	CFM56-5A5
	CFM56-5A5/F
	CFM56-5B4/P
	CFM56-5B5/3
	CFM56-5B5/P
	CFM56-5B6/2P
	CFM56-5B6/3
	CFM56-5B6/P
	CFM56-5B7/3
	CFM56-5B7/P
	V2522-A5
	V2524-A5
	V2524-A5 SelectOne
	V2527M-A5
	V2527M-A5 SelectOne
A319CJ	CFM56-5B7/P
A319neo	LEAP-1A24
	PW1124G
	unknown
A320-200	CFM56-5A1
	CFM56-5A3
	CFM56-5B4
	CFM56-5B4/2P
	CFM56-5B4/3
	CFM56-5B4/P
	CFM56-5B6/3
	CFM56-5B6/P
	unknown
	V2500-A1
	V2527-A5
	V2527-A5 SelectOne
	V2527-A5 SelectTwo
	V2527E-A5
	V2527E-A5 SelectOne
	V2530-A5
A320-200 pre 1993	CFM56-5A1
	CFM56-5A3
	V2500-A1
A320neo	LEAP-1A26
	LEAP-1A32
	PW1127G
A321-100	CFM56-5B1
	CFM56-5B1/3
	CFM56-5B1/P
	CFM56-5B2
	CFM56-5B2/P
	V2530-A5
A321-200	CFM56-5B1/3
	CFM56-5B1/P
	CFM56-5B2/3
	CFM56-5B2/P
	CFM56-5B3/2P
	CFM56-5B3/3
	CFM56-5B3/3B1
	CFM56-5B3/P
	V2527-A5 SelectOne
	V2530-A5
	V2530-A5 SelectOne
	V2533-A5
	V2533-A5 SelectOne
	V2533-A5 SelectTwo
A321neo	LEAP-1A32
	LEAP-1A33
	PW1130G
	PW1133G
A330-200	CF6-80E1A3
	CF6-80E1A4
	CF6-80E1A4/B
	PW4168A
	PW4170
	TRENT 772B-60
	TRENT 772B-60EP
	TRENT 772C-60
	TRENT 772C-60EP
A330-200F	PW4168A
	TRENT 772B-60
A330-300 HW	CF6-80E1A3
	CF6-80E1A4
	CF6-80E1A4/B
	PW4168A
	PW4168A-1D
	PW4170
	TRENT 768-60
	TRENT 772-60
	TRENT 772B-60
	TRENT 772B-60EP
	TRENT 772C-60
A330-300 LW	CF6-80E1A2
	PW4164
	PW4168
	TRENT 768-60
	TRENT 772-60
A330-800	TRENT 7000-70
A330-900	TRENT 7000-70
	TRENT 7000-72
A340-200	CFM56-5C2
	CFM56-5C3/F
	CFM56-5C4
A340-300	CFM56-5C2
	CFM56-5C3/F
	CFM56-5C3/G
	CFM56-5C4
	CFM56-5C4/P
A340-500	TRENT 553-61
	TRENT 553A2-61
	TRENT 556-61
A340-600	TRENT 556-61
	TRENT 556A2-61
A350-1000	TRENT XWB-97
A350-800	TRENT XWB-75
A350-900	TRENT XWB-84
A380-800	GP7270
	GP7270E
	TRENT 970
	TRENT 972
ATP	PW126
ATP Freighter	PW126
	PW126A
ATR 42-300	PW120
ATR 42-320	PW121
ATR 42-500	PW127E
	PW127M
ATR 42-600	PW127M
	PW127N
ATR 72-200	PW124B
	PW127
ATR 72-500	PW127F
	PW127M
ATR 72-600	PW127M
	PW127N
AVRO RJ100	LF507-1F
	LF507-1H
AVRO RJ70	LF507-1H
AVRO RJ85	LF507-1F
	LF507-1H
BAE 146-100	ALF502R-3
	ALF502R-5
BAE 146-200	ALF502R-5
BAE 146-300	ALF502R-5
	LF507-1H
C-212-200	TPE331-10
CRJ-1000	CF34-8C5
	CF34-8C5A1
CRJ-1000ER	CF34-8C5A1
CRJ-100ER	CF34-3A1
CRJ-100LR	CF34-3A1
CRJ-200ER	CF34-3B1
CRJ-200LR	CF34-3B1
CRJ-700	CF34-8C1
	CF34-8C5B1
CRJ-700ER	CF34-8C1
	CF34-8C5B1
CRJ-705LR	CF34-8C5
CRJ-900	CF34-8C5
	CF34-8C5A1
CRJ-900ER	CF34-8C5
CRJ-900LR	CF34-8C5
CS100	PW1519G
	PW1521G
	PW1524G
CS300	PW1521G
	PW1524G
DC-10-30	CF6-50C2
	CF6-50C2B
DC-10-30F	CF6-50C2
	CF6-50C2R
DHC-6-100	PT6A-20
	PT6A-27
DHC-6-200	PT6A-20
	PT6A-27
	PT6A-27A
DHC-6-300	PT6A-27
	PT6A-28
	PT6A-34
DHC-6-400	PT6A-34
	PT6A-35
DHC-7-100	PT6A-50
DHC-8-100	PW120A
	PW121
	PW121A
DHC-8-200	PW123C
	PW123D
DHC-8-300	PW123
	PW123B
	PW123E
DHC-8-400	PW150A
DO-228-100	TPE331-5
DO-228-200	TPE331-10
	TPE331-5
DO-328 Jet	PW306B
DO-328-100	PW119B
	PW119C
E-170	CF34-8E5
	CF34-8E5A1
E-170AR	CF34-8E5
E-170LR	CF34-8E5
	CF34-8E5A1
E-175	CF34-8E5
	CF34-8E5A1
E-175AR	CF34-8E5
E-175LR	CF34-8E5
	CF34-8E5A1
E-190	CF34-10E5
	CF34-10E5A1
	CF34-10E6
E-190AR	CF34-10E5
	CF34-10E5A1
	CF34-10E6
	CF34-10E6A1
	CF34-10E7
	CF34-10E7B
E-190LR	CF34-10E5
	CF34-10E5A1
	CF34-10E6
	CF34-10E6A1
	CF34-10E7
E-195	CF34-10E5A1
	CF34-10E7
E-195AR	CF34-10E5
	CF34-10E6
	CF34-10E7
E-195LR	CF34-10E5
	CF34-10E5A1
	CF34-10E7
EMB-110	PT6A-27
	PT6A-34
EMB-120	PW118
	PW118A
	PW118B
ERJ-135ER	AE 3007A1/3
	AE 3007A2
	AE 3007A3
ERJ-135LR	AE 3007A1/3
	AE 3007A1E
	AE 3007A3
ERJ-140LR	AE 3007A1/3
ERJ-145ER	AE 3007A
	AE 3007A1
	AE 3007A1/1
	AE 3007A1P
	AE 3007A3
ERJ-145LR	AE 3007A
	AE 3007A1
	AE 3007A1/1
	AE 3007A1/2
	AE 3007A1E
	AE 3007A1P
ERJ-145XR	AE 3007A1E
F100	TAY MK 620-15
	TAY MK 650-15
F27-500	DART7MK532
	DART7MK535
	DART7MK536
	DART7MK552
F50	PW125B
	PW127B
F70	TAY MK 620-15
J31	TPE331-10
J32	TPE331-12
J41	TPE331-14
MD-11F	CF6-80C2D1F
	PW4460
	PW4462
MD-82	JT8D-217
	JT8D-217A
	JT8D-217C
	JT8D-219
MD-83	JT8D-217C
	JT8D-219
MD-87	JT8D-217C
	JT8D-219
MD-88	JT8D-217C
	JT8D-219
MD-90-30	V2525-D5
	V2528-D5
METRO23	TPE331-12
METROII	TPE331-10
	TPE331-11
	TPE331-3
METROIIIA	TPE331-11
METROIIIB	TPE331-12
S2000	AE 2100A
SH330	PT6A-45R
	PT6A-65B
SH360-200	PT6A-65AR
	PT6A-67R

Source: Avitas, April 2019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