COMMERCIAL ENGINES

Powering recovery

Setting course out of pandemic to meet sustainability challenge

In focus

Features

Pandemic provides room for green agenda to grow

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Building back up

Almost two years since the pandemic brought the global airline industry to an abrupt halt, a sharp pick-up in air travel demand means attention is focused on returning to pre-crisis production levels

Momentum has returned as operators are back taking aircraft deliveries and ordering new equipment. That has brought a welcome upswing for aircraft and engine manufacturers, but also challenges in ramping up.

One of the main issues for engine manufacturers in the years immediately before the pandemic was to keep pace, as Airbus and Boeing worked to increase output of narrowbody jets.

Shortages, notably of cast and forged engine components, had already been a challenge before the pandemic as production rates rose.

Such troubles evaporated amid the pandemic as airlines grounded jets and deferred deliveries of new Airbus and Boeing narrowbodies.

However, after slashing staff, cutting production and shuttering facilities to counter the crisis, suppliers across the commercial aerospace sector are now working frantically to get back up to speed.

Some companies in the supply chain went belly up during the pandemic. Others shed staff and have been unable to find suitable replacements.

Such factors are hindering the ability of suppliers to increase production, particularly of complex engine components, aerospace analysts say. Suppliers are trying to keep pace with Airbus and Boeing, which are eager to bring output back to – and above – 2019 levels.

Airbus aims to produce 65 A320neo-family jets monthly by summer 2023 – and in May outlined its plan to reach 75 per month in 2025. Boeing meanwhile is working to hit a 31-per-month 737 rate as it works through delivery of Max jets built but undelivered during the type's 20-month grounding.

While supply challenges in the ramp-up have already been evident, CFM, which makes Leap turbofans for both A320neo-family aircraft and exclusively for the 737 Max, and Pratt & Whitney (P&W), which makes PW1000G-series engines for the A320neo, A220 and Embraer E-jet E2, are working to meet the challenge.

"We are aligned with the airframers on what we need to produce through 2023, and we are solidifying what we need to do for 2024," GE Aviation chief executive of commercial engines Kathy MacKenzie said in March.

"We are confident... that we will meet our commitments to the customers," she says.

MacKenzie does, however, call attention to the scope of the challenge facing GE and partner Safran – which jointly own CFM.

"We are again experiencing an unprecedented ramp in Leap production," she says. CFM intends to hike Leap production to around 2,000 engines in 2023.

GE Aviation/Safran snapshot

	2021	Change
Leap engine deliveries	845	30
CFM56 engine deliveries	107	-50
GE commercial engine deliveries (inc CFM)	1,487	-233
GE Aviation revenue	$21.3bn	-3%
Safran propulsion revenues	$7.44bn	-3%

Source: GE Aviation/Safran

CFM International

CFM delivered 845 Leap powerplants in 2021, 30 more than in 2020 but less than half the 2019 total

2,000

CFM International production target for Leap engines in 2023

CFM intended to deliver 900 Leap engines in 2021 but ended up with 845 deliveries for last year. Safran chief executive Olivier Andries cited "shortages of parts, especially coming from [CFM's] US supply chain".

Greg Hayes chief executive of P&W parent Raytheon Technologies also points to the challenge ahead. "We are in lockstep with both Airbus and Boeing on their production rates," he said in April. "We will see if we can get there."

Shortages, particularly of metal castings, left P&W unable to deliver 70 aircraft engines in the first quarter of 2022.

"We actually see supply chain constraints across the commercial portfolio. We see it in electronics... We see it in aluminium. We see it in titanium," Hayes notes.

While the ramp-up is most evident for narrowbodies, and wider production and certification issues have hit Boeing's 777-9 and 787 programmes, supply-chain issues are also a worry in the widebody segment.

Rolls-Royce, which provides its Trent powerplants for Airbus and Boeing twin-aisles, says it is working closely with its global supply chain to limit the impact of disruption and will continue to adapt its plans as the global situation evolves.

"Our long-term sourcing agreements and hedging policies, designed to limit volatility in raw material inflation, give some near-term protection and we have increased inventory levels to help mitigate the impact," it says.

"We are working with our suppliers to monitor and manage these risks and challenges."

CFM International

Increased momentum in the narrowbody sector continued over the start of 2022 as deliveries of CFM's Leap engines rose to 239 in the first three months of the year. It marks an increase of more than a quarter on the 188 delivered in the same period a year earlier.

CFM shipped 845 Leap engines in 2021, 30 more than in 2020 but a little under half the 1,736 of 2019. CFM is targeting a ramp-up in production to meet a 2,000-per-year Leap engine target in 2023.

GE Aviation

For its part, GE Aviation turned a $2.9 billion profit in 2021, more than double its 2020 earnings, reflecting cost cutting and a bump in commercial engine services revenue. Despite the improved bottom line, GE Aviation generated less revenue in 2021 than in 2020, partly as a result of fewer commercial engine deliveries last year.

"Safran is well placed to benefit from the positive trends in both aftermarket and original equipment as narrowbody traffic returns to pre-crisis levels by end-2022," says chief executive Andries, noting the "significant operational and financial progress" made last year.

Overall CFM deliveries stood at 952 engines – including 107 CFM56s – down from 972 in 2020.

Safran expects CFM will be building 25 Leap-1B engines for the 737 Max weekly by 2023 as the US airframer clears its backlog of built but undelivered narrowbodies during the type's grounding and the pandemic. Andries told the group's capital markets day that it forecasts "the inventory of Max is going to be melted down in the next two years".

He says: "In 2023, we have to expect a very strong ramp-up at Boeing. We have assumed that the rate will be around 50 [per month] by the end of 2023."

CFM Leap engines also power the Comac C919, which took a step closer to entering service when the first aircraft bound for a customer carried out its initial test flight in May.

GE Aviation

GE partially made up for fewer deliveries last year with an increase in shop visits

Rolls-Royce cites optimism over the Trent XWB-powered Airbus A350 freighter

Rolls-Royce

It shipped 1,487 commercial aircraft engines last year, which includes 952 CFM powerplants. The full-year figure is down from 1,720 commercial engine shipped in 2020.

GE partially offset fewer shipments with a 10% increase in commercial services shop visits in 2021.

Notably, the US manufacturer's new commercial engine orders bounced back to 2,248 units, including 1,457 Leaps.

Those figures are significantly higher than 2020, when GE Aviation logged new orders for 738 commercial engines, including 351 Leap units.

That upward sales trend continued in the first quarter as commercial engine orders almost doubled to 553, including 442 Leaps.

While Leap engine deliveries were also on the rise during the first quarter, overall GE Aviation commercial engine deliveries slipped to 343 from 359.

GE chief financial officer Carolina Dybeck Happe specifically cites a decline in deliveries of GEnx powerplants, which power Boeing 787s. Boeing's deliveries of those jets have been halted for most of the past 18 months because of manufacturing quality issues.

A further challenge comes from Boeing's late-April announcement that it is pushing back delivery of its first 777-9 – on which the GE9X is the exclusive powerplant – by two years, to 2025.

The airframer has temporarily halted production of the new widebody, saying its revised delivery schedule reflects the pace of certification work.

GE in October delivered its last CF6-80E1 production engine, after more than 50 years in revenue service. The powerplant was delivered to China Airlines for the airline's Airbus 330 fleet.

While the CF6-80E1 engine marked the end of production for the most powerful CF6 engine variant, GE cites growing interest in A330 passenger-to-freighter conversions and highlights support can be maintained due to parts commonality with still in production CF6-80C2 engines.

$454m

Pratt & Whitney 2021 operating profit, driven by stronger demand for aftermarket service and new engines

Pratt & Whitney snapshot

	2021	Change
P&W large-engine deliveries	623	77
P&WC engine deliveries	1,825	175
Revenue	$18.15bn	8%

Source: Raytheon Technologies

Pratt & Whitney

Pratt & Whitney swung to an operating profit in 2021, a year characterised by stronger demand for aftermarket services and new aircraft engines. P&W shipped 623 large commercial aircraft engines in 2021. That is up 14% from 546 deliveries in 2020 but still lags the 746 large commercial engines P&W shipped in pre-pandemic 2019.

Pratt & Whitney Canada also made strides, handing over 1,825 engines, up 11% from 2020. P&WC supplies turbofan engines for business jets, small turboprops and turboshafts for business aviation and helicopters, alongside turboprop engines, notably the PW127, for commercial aviation

P&W's adjusted sales of original equipment jumped 32% in 2021, while commercial aftermarket sales surged 28%.

As a result, P&W generated $18.2 billion in sales last year, an 8% improvement from 2020, with 2021 operating profit hitting $454 million. By comparison, P&W lost $564 million in 2020.

That brighter trend continued, even with supply-chain issues hampering engine deliveries, into the first quarter as P&W posted an operating profit of $308 million on revenues up 12%. The improved results partly reflect sales of commercial aftermarket services, which jumped nearly 40%.

P&W shipped 119 large commercial engines in the first quarter, down from 177 in the previous quarter and compared with 137 in the first quarter of 2021.

P&W is also set to receive a boost as United Airlines was poised at the end of May to reintroduce its PW4000-powered Boeing 777s into service. The aircraft have been grounded since February 2021 following an in-flight engine failure, but the path for their return to service came when the US Federal Aviation Administration in December issued three proposed airworthiness directives.

In March, Japan's aviation regulator lifted its operating ban on PW4000-powered Boeing 777s, flown by local carriers All Nippon Airways and Japan Airlines.

P&W ticked off a noteworthy milestone in late April with delivery of the 1,000th Airbus A320neo powered by its GTF. The customer was European low-cost player Wizz Air, which now has 54 GTF-powered examples. The company says it has 10,000 orders and commitments for the GTF with 80 customers.

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P&W passed the 1,000 mark for GTF-powered A320neos with a delivery to Wizz Air

Rolls-Royce

Rolls-Royce (R-R) recorded a 42% increase in large-engine flying hours for the first four months of this year, compared with the same period in 2021 – underscoring the improved outlook for long-haul travel.

The UK engine manufacturer had reported that large-engine flying hours rose by 11% last year – and by 57% in the second half of 2021 – as signs of gradual recovery emerged in the air transport sector.

R-R delivered 195 large civil engines in 2021, down by more than 25%, and less than half of the pre-crisis figure of 510. R-R engine deliveries had been lifted in 2019, by a ramp-up of Airbus A330neo production for which it supplies Trent 7000 engines.

R-R is optimistic over recovery prospects and development of the A350 freighter for which it will provide Trent XWB engines.

The manufacturer has now largely completed a wide-ranging restructuring programme – focused primarily on civil aerospace – which it says is generating higher productivity and lowering costs.

R-R's civil aerospace division sharply cut its underlying operating loss to £172 million ($231 million) last year – contrasting with £2.5 billion in 2020, a figure in part reflecting one-off pandemic-related charges. That was despite a 29% fall in original equipment revenues in 2021.

R-R is also hopeful that it can increase the market share of its Trent 1000 on the Boeing 787 now that it believes the engine's durability issues are behind it.

Speaking to investors in May, Chris Cholerton, R-R president of civil aerospace, admitted that the manufacturer's reputation had "taken a knock" from the durability problems with compressor and turbine blades on the Trent 1000, which saw 787s withdrawn from service while R-R developed a fix.

"That disruption is now behind us, and we have made good progress in validating and implementing permanent fixes to those issues," he says. Seven of nine fixes developed for the Trent 1000 engine have now been implemented, according to a slide displayed as part of Cholerton's presentation.

Durability and reliability levels are now in line with other Trent powerplants, he says. That presents the company with "opportunities to make wins" and increase a share of the 787 market that Cholerton admits is "lower" than that of its rival.

Cirium fleets data shows the Trent 1000 has a 30.7% share on the 787, lagging the 62.7% of the GE Aviation GEnx. A further 6.6%, or 98 aircraft, are on order where no engine selection has been disclosed.

Meanwhile, Rolls-Royce is eyeing a return to smaller aircraft, with Embraer's potential new regional aircraft programme in its sights.

Cholerton says the company continues to invest in technologies to "drive a step change in the efficiency" of gas turbine engines across a range of sizes. "At the smaller size we are investing in technology which we are bidding on the Embraer turboprop," he says.

Embraer expects to take a decision on launching the programme by year-end or in early 2023.

Rolls-Royce snapshot

	2021	Change
Large engine deliveries	195	-69
Civil engines revenues	$5.56bn	-10%

Source: Rolls-Royce

After being forced to put their development plans on ice during the crisis, airlines have picked up the pace of aircraft orders and engine selections as they plot growth for the post-pandemic market

Fleet decisions

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Boeing 737 operator Jet2 will stick with CFM engines after making the leap to A321neos

Air France-KLM set to cap A320neo Leap deals for CFM International

Air France-KLM is in exclusive talks with CFM International over a potential Leap-1A engine deal to power its future fleet of Airbus A320neo and A321neo aircraft.

If an agreement is secured, it would cap a year in which the GE Aviation-Safran joint venture secured Leap-1A orders from a number of A320neo-family aircraft customers, including lessor BOC Aviation, UK leisure carrier Jet2 and Saudia.

Air France-KLM's announcement followed the European airline group's 100-aircraft order for A320neo-family aircraft disclosed in December. The aircraft will be used to renew KLM and Transavia Netherlands fleets, as well as to replace and grow the Transavia France fleet. The deal, which also includes acquisition rights for a further 60 jets, will see deliveries commence in the second half of 2023.

Air France-KLM group chief executive Ben Smith says: "We look forward to working with CFM International in the coming weeks through these exclusive negotiations. We are confident that our two groups will be able to continue a long-term relationship and to build a sustainable future together."

CFM engines already power a significant number of aircraft in the Air France-KLM fleet today, including Boeing 737NG-family jets operated by KLM and Transavia, as well as the A320ceo-family aircraft in Air France's fleet.

The engine manufacturer in March secured an order from UK operator Jet2 covering Leap-1A engines to power its incoming fleet of up to 75 A321neo jets.

The deal, the value of which has not been disclosed, includes spare engines and a long-term support agreement.

Jet2 is currently a Boeing 737 operator, but announced an order switching to A320neo-family aircraft in August last year. The carrier has been a CFM customer since 2002, notably of the CFM56 engines that power its 737 fleet.

"We are pleased to extend our long-standing relationship with CFM, who have been a key partner of our continuous growth since our creation," says Jet2 executive chairman Philip Meeson.

Aircraft lessor BOC Aviation has also placed an order for CFM Leap-1A engines to power A320neo-family aircraft.

The order for eight shipsets from CFM, announced during February's Singapore air show, covers aircraft due for delivery in 2023.

BOC Aviation chief executive Robert Martin says: "CFM engines have powered our fleet since 1998, and we are pleased to build on this long-standing relationship.

"This contract signifies our continued confidence in the CFM Leap engine and reflects our customers' satisfaction in CFM Leap-powered A320neo aircraft as an efficient and reliable airframe and engine combination," he adds.

The lessor notes the order takes to 486 the number of aircraft powered by CFM engines in its portfolio.

Meanwhile, Middle Eastern carrier Saudia in December formally reached an agreement to take Leap-1A engines for the A320neo-family fleet it placed an order for in 2019.

The airline ordered 30 A320neos and 35 A321neos after opting to scrap a previous agreement for the Boeing 737 Max.

CFM builds the Leap-1B for the Max and Saudia has chosen to retain the engine manufacturer for the Airbus agreement.

Saudia is ordering 149 Leap-1A engines and the deal includes a multiyear, rate-per-flight-hour services pact. This also covers 20 leased A320neos in addition to the newly ordered powerplants.

Saudia is already a strong CFM customer, with 61 conventional A320s fitted with the CFM56 engine, while budget division Flyadeal has 11 CFM56-powered A320s as well as five Leap-powered A320neos.

CFM says it will support Saudia Aerospace Engineering Industries to develop its own Leap-1A engine overhaul operation as part of the deal.

160

Number of Airbus A321neo family jets Air France-KLM could take under fleet switch, including 100 on firm order

Qantas, Spirit and Air Canada lead Pratt & Whitney A320neo-family jet wins

Another eye-catching recent narrowbody switch is Qantas's move to order Airbus A320neos, together with A220-300s – deals that would could see Pratt & Whitney (P&W) land orders covering up to 134 aircraft.

The Australian operator has now finalised its narrowbody agreement, which adds to fresh P&W geared turbofan engine commitments on A320neos from US ultra-low-cost carrier Spirit Airlines and aircraft lessors Aviation Capital Group and BOC Aviation.

Qantas in late December detailed its plan to place an order for 20 A321XLRs and 20 A220s – and its intention to use P&W engines on both types. The firm's PW1500G geared turbofan (GTF) is the sole powerplant option on the A220.

The Oneworld carrier in May firmed its order for the aircraft, deliveries of which are set to begin in late 2023. These aircraft will be supplemented by options and purchase rights for 94 additional aircraft over a delivery window of 10 or more years.

P&W chief commercial officer Rick Deurloo says: "We thank Qantas for selecting us to power not just one, but two of their next-generation fleets."

Qantas is to use the aircraft to replace Boeing 737-800s and 717s.

Spirit meanwhile is sticking with P&W geared turbofans to power at least another 100 incoming A320neo-family jets.

The Miramar, Florida-based airline in October chose

PW1100Gs for 100 jets on firm order with Airbus and for another 50 aircraft for which it holds options to purchase. Those aircraft are scheduled for delivery starting in 2023.

Spirit has also agreed to have the engines maintained under the engine maker's long-term maintenance programme, called EngineWise Comprehensive, says P&W.

Spirit has been a long-term P&W engine customer. The airline's all-Airbus-narrowbody fleet includes about 120 A320ceos powered by V2500s, made by International Aero Engines, of which P&W is the majority owner. Spirit also operates almost 50 PW1100G-powered A320neos, according to Cirium data.

Spirit has a combined 162 A320neo-family jets on order with Airbus – all of which will have PW1100Gs.

Air Canada in April picked GTF engines to power 30 A321XLR aircraft, with another 14 jets covered by purchase rights.

The Canadian carrier had earlier disclosed plans to acquire 26 Airbus A321XLRs, emerging as the undisclosed customer behind an order for six of the jets in the airframer's backlog. The airline is taking another 20 of the long-range model through leasing companies, including 15 from Air Lease and five from AerCap.

Deliveries begin in the first quarter of 2024 and continue to the first quarter of 2027. The Star Alliance carrier's purchase rights cover deliveries between 2027 and 2030.

Air Canada already operates the P&W1500-powered A220. "The GTF's efficiency and reliability will help us lower costs and also allow us to expand our network," says Air Canada senior vice-president, operations and express carriers Richard Steer.

Aviation Capital in May placed a follow-on order for P&W engines to power A320neo-family aircraft.

134

Qantas's total firm orders, options and purchase rights for P&W-powered narrowbodies over 10 years from 2023

The lessor ordered GTF engines for a further 20 firm A320neos, as well as taking options on another 20 single-aisle jets.

The lessor had in October committed to the engine for an additional 10 firm A320neo-family aircraft, as well as options to power an additional seven of the jets with GTF engines.

The commitments take to 60 the number of firm A320neo-family aircraft it has ordered with PW1100Gs – together with a further 27 options. It had earlier at the Singapore air show firmed an order for 20 PW1500G-powered A220s.

Another lessor, BOC Aviation, picked GTF engines to power an order of 10 firm and 15 optioned A320neo-family aircraft. This covered aircraft entering service this year.

The lessor previously ordered 25 GTF-powered A320neo-family aircraft, which have been delivered to operators worldwide.

Delta Air Lines meanwhile became the latest operator of P&W-powered A321neo jets when it operated its first revenue flight with the narrowbody in late May. The US carrier selected GTF engines to power its A321neo fleet in December 2017, with a total of 155 purchase commitments through 2027.

Spirit Airlines

Spirit has chosen PW1100Gs for an order of up to 100 Airbus A320neo-family airliners

Akasa Air

Akasa Air in May unveiled the first Leap-powered 737 Max in its colours, after ordering 72 Boeing jets last year

CFM bolstered by new Max customers

As the sole powerplant provider on the Boeing 737 Max, CFM International is lined up for a raft of new business following a pick-up in orders and deliveries for the type that has taken place since its return to commercial service 18 months ago.

That includes a notable win from US budget carrier Allegiant Air in January. The Las Vegas–based operator, an all-Airbus operator today, ordered 50 Boeing 737 Max jets and took options to acquire a further 50, with deliveries starting in 2023.

Allegiant is already a CFM engine customer, operating 110 CFM56-powered A320-family aircraft.

Allegiant chairman and chief executive Maurice Gallagher says: "CFM has been a great partner for us. They helped us transform our fleet, providing us with high-quality, reliable engines that allowed us to improve operational efficiency over the years.

"When we made the decision to purchase new 737s, we knew CFM would be the ideal partner to work with us as our fleet continues to evolve."

Indian start-up carrier Akasa Air placed firm orders for 72 737 Max aircraft, including some for the higher-density Max 8-200 version, at November's Dubai air show. It signed a $4.5 billion deal with CFM covering Leap-1B engines to power the incoming narrowbodies. Akasa aims to launch flights this summer and in late May unveiled the first Max painted in its livery.

Dominican Republic-based Arajet, the corporate successor to now-defunct Flycana, ordered 20 737 Max 8-200s and took options to purchase an additional 15 examples. Boeing disclosed the deal in March but finalised the purchase order in January. Qatar Airways meanwhile signed a provisional deal for up to 50 Boeing 737 Max in January, while IAG has agreed to take 50 Max aircraft and options for another 100 – reaffirming a tentative commitment made back in 2019.

In June 2021, United Airlines signed up for 200 more of the Boeing narrowbodies, including 150 Max-10s, as part of its "United Next" project. That commitment also includes 70 A321neos, for which United has still to make an engine choice.

A number of airlines have taken delivery of their first Leap-1B-powered Max aircraft over the past year, most notably Ryanair. The Irish low-cost carrier received the first of 210 on-order Max jets last June and expects to operate 70 of them this summer.

Other new Max operators over the past year include Korean Air, Caribbean Airlines and start-ups Flyr and Lynx Air.

New A220 operators score hit for P&W

Alongside fresh orders and commitments for Pratt & Whitney (P&W)-powered Airbus A220s from Qantas and Aviation Capital, US carrier JetBlue Airways placed a follow-on order for 30 more A220s, on which the PW1500G is the exclusive engine.

JetBlue launched services with its first A220-300 in April last year and has 10 of the type in service. The airline has a further 90 on order.

Another US operator, Breeze Airways, began its first services with A220s this year. The airline has agreements with P&W for geared turbofans covering 80 A220-300s. Breeze chief executive David Neeleman says: "With industry-leading fuel efficiency, Pratt & Whitney's engines will help us fly more passengers, farther, quieter and more sustainably, at lower fares."

Aircraft lessors Air Lease and Azorra signed for 25 and 22 A220s respectively, the latter including a pair of ACJ TwoTwenty business jet variants.

Air France meanwhile took delivery of the first of 60 A220-300s. Other new A220 operators include Iraqi Airways, which this year took delivery of the first two of five A220-300s it ordered in 2013; Reunion-based Air Austral, which is taking three A220-300s, and Kyrgyzstan-based Air Manas.

Qantas chief executive Alan Joyce (*left*) and Airbus chief commercial officer Christian Scherer at the signing for the carrier's 12 Trent XWB-97-powered Airbus A350-1000s

Airbus

Freighter and Qantas sunrise deal expand Rolls-Royce A350 horizons

Rolls-Royce (R-R) has been boosted by Airbus's decision to launch a freighter version of its A350 widebody, which, like the passenger variant, will be powered by the manufacturer's Trent XWB engines.

Airbus unveiled lessor Air Lease as its first customer for the freighter version at November's Dubai air show. Air France-KLM, logistics specialist CMA CGM and Singapore Airlines have since followed, taking formal commitments for the A350F to 22.

Middle Eastern operator Etihad Airways has also signalled that it will acquire the cargo model. Airbus is planning entry into service for 2025 for the type.

On the passenger side, Qantas at the start of May committed to a deal for 12 Trent XWB-97 powered Airbus A350-1000s. The aircraft will support its ultra-long-haul Project Sunrise initiative, with the first flights from Sydney to New York and London due for a late-2025 launch.

Ewen McDonald, chief customer officer, Rolls-Royce Civil Aerospace, said: "We have been powering Qantas aircraft for more than 40 years and we are delighted to be making more history with Qantas on Project Sunrise."

The UK engine manufacturer has also secured new business from European carriers Condor and ITA Airways for its Trent 7000 engines, which is the sole powerplant option for Airbus A330neo widebodies.

New Italian carrier ITA Airways, which has been established as a successor to Alitalia, signed for 10 A330neos. ITA is also taking A350-900s as part of its fleet revamp, the first of which entered service in April.

> "We have been powering Qantas aircraft for more than 40 years and we are delighted to be making more history with Qantas on Project Sunrise"
>
> **Ewen McDonald Chief customer officer, Rolls-Royce**

German leisure carrier Condor last summer outlined its plan to take 16 A330neos, ordering seven directly from Airbus and leasing a further nine.

Deliveries of the Trent 7000-powered aircraft begin in the autumn.

Taiwanese start-up carrier Starlux Airlines had earlier this year taken its first Trent 7000-powered A330neo. Starlux was set to debut the type in May, while three further A330neos are also due for delivery this year.

Starlux Airlines founder and chairman KW Chang says: "The efficiency of the A330neo is outstanding by bringing together enhanced technologies and highly efficient Rolls-Royce Trent 7000 engines."

The airline is taking its A330neos from lessor Air Lease, but also has orders with Airbus for Trent XWB-powered A350s.

Bamboo Dreamliner win and Boeing 777-8F launch give GE widebody lift

Vietnamese carrier Bamboo Airways in September signed a memorandum of understanding with GE Aviation covering the purchase of GEnx engines for its on-order Boeing 787-9s. Bamboo has 10 of the type on firm order, together with options on 20 more Dreamliners.

The GEnx is one of two engine options on the 787, alongside the Rolls-Royce Trent 1000; Bamboo already operates three leased GEnx-powered 787-9s.

Bamboo Airways chief executive Dang Tat Thang says: "The selection of the GEnx engines for our Boeing 787-9 aircraft will help increase the operational efficiency and service quality of Bamboo Airways on Vietnam-US nonstop flights, as well as many potential international routes."

Deliveries of the 787 were suspended for much of the last 18 months owing to manufacturing quality issues that have taken longer to rectify than originally planned. Boeing in late April said it had submitted a certification plan to the US Federal Aviation Administration (FAA).

Other new widebody business over the past year for GE Aviation includes an additional commitment from Singapore Airlines (SIA) for 22 GE9X engines to power its fleet of 777-9s. The order, which comes with a 12-year services contract, is valued at $2.8 billion at list price.

SIA already has orders for 31 777-9s, on which the GE9X is the sole engine. Boeing has announced a two-year delay on first deliveries of the programme until 2025, however. The airframer has been working with the FAA to address certification issues, including those that led Boeing to make some design changes.

The follow-up order for GE9X engines relates to SIA's move last year to switch an order for 14 787-10s to 11 777-9s during the pandemic.

On the cargo side, in January, Qatar Airways became launch customer for Boeing's next-generation 777-8F, with orders for 34 of the type – 20 of those were conversions of Qatar's existing orders for passenger-configured 777Xs. The new freighter is powered by GE9X engines. Qatar also ordered two more 777 freighters, which are powered by GE90s.

Qatar Airways Group chief executive Akbar Al Baker says: "We are confident that Qatar Airways' focus to drive towards a sustainable future will be very much supported by the efficiency of the GE9X engines."

Lufthansa meanwhile in May became the second customer for the 777-8F, when it placed an order for seven of the type. First delivery of the freighter is set for 2027. Ethiopian Airlines has also made a preliminary commitment for five.

Like Qatar, Lufthansa also ordered two more 777 freighters, while Ethiopian is taking five more of the cargo aircraft. They join Atlas Air, China Airlines, DHL Express, Emirates and Western Global Airlines in making fresh commitments for the 777F, while UPS signed for 19 Boeing 767 freighters.

50

Number of 777-8Fs launch customer Qatar Airways has made commitments for, including 34 firm orders

Boeing has secured orders from Lufthansa and Qatar Airways after launching its GE9X-powered 777-8F in January

Boeing

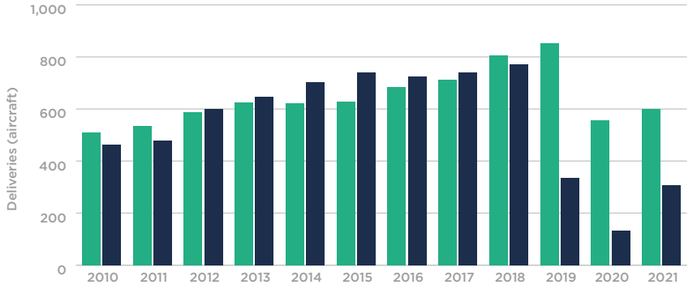
Deliveries on the rise

After the lows of 2020 as the pandemic resulted in a sharp industry slowdown, the gradual increase in demand as borders reopened and the return to service of Boeing's 737 Max helped manufacturers see an uplift in mainline jet deliveries last year – although still well below pre-crisis levels

Soos Jozsef/Shutterstock

IndiGo's Airbus A320neo-family mainline fleet now features Leap-1A and PW1100G engines

Mainline jet deliveries 2010-2021



Source: Cirium fleets data

● Airbus deliveries ● Boeing deliveries

Top 10 mainline aircraft customers 2021

Rank	Airline	Units
1	IndiGo	42
2=	Delta Air Lines, Ryanair	33
3	China Eastern Airlines	30
4	Southwest Airlines	28
5	Air China	28
6	United Airlines	27
7=	American Airlines, Wizz Air	25
8	Turkish Airlines	22
9=	Aeromexico, FedEx	21
10	Air Canada	19

Note: Data for Airbus and Boeing deliveries to airlines.
Source: Cirium fleets data

Top 5 regional aircraft customers 2021

Rank	Airline	Units
1	SkyWest Airlines	19
2	Rossiya Airlines	14
3	IndiGo	10
4	Red Wings Airlines	9
5	KLM Cityhopper	7

Note: Includes ATR, Bombardier (CRJ), Comac (ARJ), De Havilland Canada, Embraer, Sukhoi and Viking Air types. Excludes corporate and military customers
Source: Cirium fleets data

Airbus

Emirates in December took the last production A380, featuring Rolls-Royce Trent 900 engines

Bradley Caslin/Shutterstock

Boeing handed over Ryanair's first CFM Leap-1B-powered 737 Max last summer

Engine manufacturer rankings 2021

Rank	Manufacturer	2021 deliveries Engines	Share	Backlog Engines	Share
1	CFM International	1,066	59%	13,100	54%
2	Pratt & Whitney	478	26%	4,128	17%
3	Rolls-Royce	146	8%	1,670	7%
4	GE Aviation	122	7%	1,528	6%
	Undecided			3,810	16%
	Total	1,812		24,236	

Source: Cirium fleets data. Notes: At 31 December 2021. Data for installed engines based on Airbus/Boeing types. Excludes corporate and military operators

A320 family engine manufacturer share

Manufacturer	2021 deliveries Aircraft	Share	Backlog Aircraft	Share
CFM International	290	61%	2,453	42%
Pratt & Whitney	189	39%	1,595	27%
Undecided			1,791	31%
Total	479		5,839	

Source: Cirium fleets data. Notes: At 31 December 2021. Excludes corporate and military operators

Backlog for other mainline jets

Manufacturer	C919	MC-21
CFM International	303	-
Aviadvigatel (Soloviev)	-	60
Pratt & Whitney	-	83
Undecided	-	32
Total	303	175

Source: Cirium fleets data. Note: At 31 December 2021. Data is number of aircraft

Airbus/Boeing fleet by manufacturer

Manufacturer	Airbus	Boeing	Total
CFM International	5,311	8,042	13,353
GE Aviation	402	2,967	3,369
International Aero Engines	2,989	4	2,993
Rolls-Royce	1,543	1,174	2,717
Pratt & Whitney	1,463	1,224	2,687
Engine Alliance	127	0	127
Total	11,835	13,411	25,246

Source: Cirium fleets data. Notes: In-service and parked fleet at 31 December 2021. Boeing data includes former MDC types. Excludes corporate and military operators. Data is number of aircraft

787 engine manufacturer share

Manufacturer	2021 deliveries Aircraft	Share	Backlog Aircraft	Share
GE Aviation	12	86%	299	62%
Rolls-Royce	2	14%	89	18%
Undecided			99	20%
Total	14		487	

Source: Cirium fleets data. Notes: At 31 December 2021. Excludes corporate and military operators

Regional aircraft engine manufacturer share

Manufacturer	2021 deliveries Aircraft	Share	Backlog Aircraft	Share
Pratt & Whitney*	60	44%	374	39%
GE Aviation	51	37%	503	53%
Powerjet	26	19%	79	8%
Total	137		956	

Source: Cirium fleets data. Notes: At 31 December 2021. Excludes corporate and military operators. *Including P&W Canada. Data for firm orders for ATR, Bombardier, Comac, De Havilland Canada, Embraer, Mitsubishi, Sukhoi and Viking Air

While recovery efforts dominate near-term horizons, commercial engine manufacturers have their sights on developing technology to address the longer-term challenge of sustainable flying

Forward thinking

Tatyana Belyakova/Shutterstock

Blue-sky thinking on cutting emissions has risen up the industry's agenda during the pandemic

Mark Pilling London

Today, every self-respecting aerospace engine manufacturing executive has a cool road-map to hand, charting the pathway, over the coming two decades, towards a decarbonised air transport industry. The grand mission is to achieve net zero carbon emissions by 2050.

Important waypoints along the journey are a massive increase in the use of sustainable aviation fuel (SAF) and to make decisive progress on "disruptive technologies", such as hydrogen. These are vital ingredients, in parallel with the ever-present desire to reduce fuel burn and deliver engines with improved efficiency.

As Eric Dalbies, senior executive vice-president research & technology and innovation at Safran told the EU's Clean Aviation Summit in March: "For the coming decade the focus is on ultra-efficient aircraft... reducing fuel burn is a no-regret choice."

The speed at which sustainability has rocketed to the very top of the aerospace agenda is astonishing. Equally remarkable is the fact that it has taken place during a global pandemic that saw the air transport industry grind to a halt.

The world's urgent need to tackle climate change may be argued to have been a welcome call to arms for aviation when it was at its lowest ebb.

Pre-pandemic, the air transport industry was in rude health, bathing in a decade of unbridled growth. However, at the end of the 2010s decade, the industry was showing signs of significant growing pains. In 2019, FlightGlobal's annual Commercial Engines Report saw the manufacturers facing criticism over design issues and in-service problems. In addition, with bulging orderbooks, the engine makers were in a steep production ramp-up, putting strain on the supply chain and contributing to delivery delays.

Each of the big three had significant issues in the years running up to the end of the decade. However, by 2019, Rolls-Royce (R-R) was coming to grips with the premature turbine blade deterioration problems suffered by the Trent 1000 engine, which is an option on Boeing 787s. Similarly, Pratt & Whitney's Geared Turbofan (GTF), the manufacturer's big bet on returning to the narrowbody powerplant market, was, after three years in service, overcoming its early high-profile engine issues.

At GE Aviation, the story was different, but no less troublesome. Its GE9X engine was selected by Boeing as the sole powerplant choice for the 777X in 2013. Issues with components in the high-pressure compressor, which came to light in 2019, caused a redesign that delayed the first flight of the 777X. That was scheduled for 2019 with first deliveries to airlines of the initial 777-9 version in 2020. While GE has fixed the engine issue, Boeing itself now expects the aircraft to enter service in 2025 under the current certification timetable.

Despite these hiccups, the engine makers entered 2020 in good health, with record orderbooks and strong aftermarket revenue flows. That changed abruptly with the onset of the global pandemic in March that year. As revenues from the all-important service contracts, which are based on how much engines are flown, fell off a cliff, all the manufacturers shed staff, raised liquidity, and restructured their businesses to cut losses and preserve cash.

> "We are excited about building our arsenal of technologies for the future with sustainability as our north star"
>
> **Mohamed Ali Vice-president engineering, GE Aviation**

However after two years of unprecedented business trauma, the recovery in air travel is very welcome as the engine majors seek a return to normality. Revenues are flowing again as flying hours rise and maintenance shop visits return. As business revives and the discipline of delivering hundreds of highly sophisticated engines annually returns, the strategic landscape has changed for the propulsion experts.

The decarbonisation challenge has become an overwhelming obligation. Every manufacturer was deeply absorbed in R&D to find more efficient, lower emissions engines prior to the pandemic. Now that occupation has turned into an obsession. The manufacturers are quick to stress that despite the pandemic, none cut back their expenditure on R&D to any great extent. The technologies under scrutiny include electric, hybrid-electric, and engines powered by liquid hydrogen or hydrogen fuel cells.

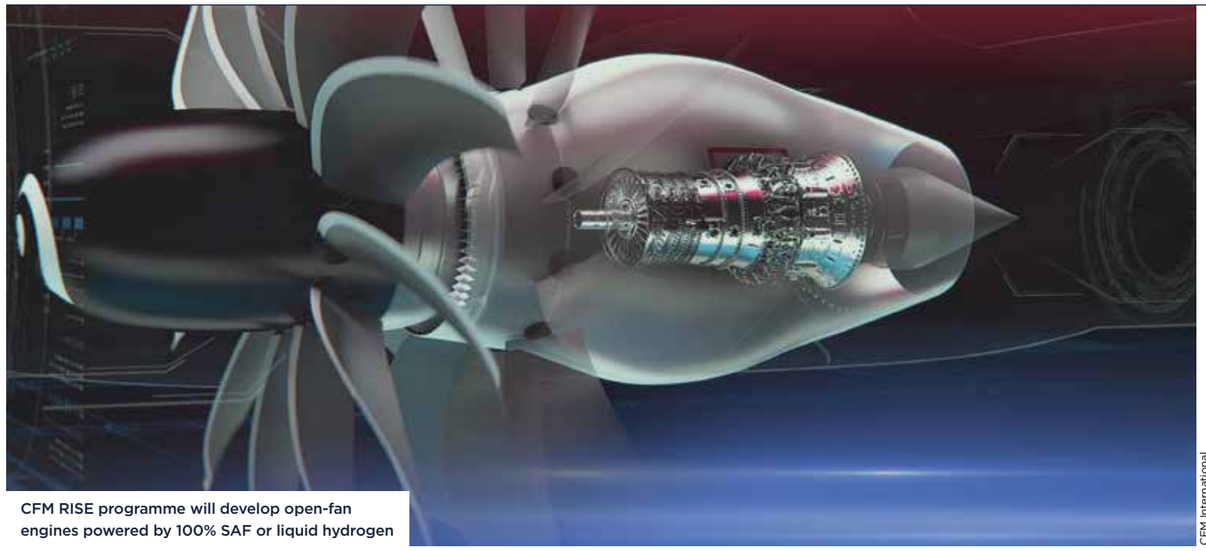
Breakthrough technologies

Speaking at GE's investor day in March, Mohamed Ali, vice-president of engineering, talked about the great strides made in breakthrough technologies and materials to enable next-generation engines like the GEnx and Leap. Ali highlighted the introduction of composite fan blades to replace metals on the GE90, the creation of highly durable ceramic components for Leap, and the invention of additive manufacturing technology to produce hitherto "impossible-to-make" lightweight parts.

"We are excited about building our arsenal of technologies for the future with sustainability as our north star," says Ali. These advances will enable GE to reduce fuel burn by more than 20%, whether the fuel is kerosene, SAF or hydrogen, he adds.

The key component of bringing GE's roadmap to fruition is a batch of "breakthrough technology demonstrators" with ground and flight tests to show technology readiness this decade, says Ali. This is the critical timeline to meet the count back in years for Airbus and Boeing's ambitions for next-generation aircraft using "disruptive" technology in service from 2035.

GE has three demonstration programmes lined up. The first is a partnership with NASA and Boeing,



CFM RISE programme will develop open-fan engines powered by 100% SAF or liquid hydrogen

CFM International

with BAE Systems recently added to provide electricity management systems. Through NASA's Electrified Powertrain Flight Demonstration (EPFD) project, GE will test hybrid-electric configurations on a modified Saab 340B with GE CT7-9B engines to prove out the technology. It says the programme will fly a full hybrid-electric aircraft by the mid-2020s.

"Anybody can do a motor – a hybrid-electric motor or an electric motor and test it on the ground," says Ali. "Anybody can fly perhaps even up to 10,000ft. Above 10,000ft, high-voltage electric machines behave very differently. We are testing in collaboration with NASA at the NASA facility, a megawatt electric motor in a 40,000ft environment... and we believe we have the technology to enable that."

In February, Airbus and CFM International announced one of the most significant moves by the aerospace majors to date on the hydrogen front. Airbus will use an A380 as the flight-test demonstrator for a future hydrogen-fuelled engine. The aim is for first flight by the end of 2026, says Sabine Klauke, chief technical officer at Airbus.

CFM will modify the combustor, fuel and control system of a GE Passport turbofan to run on hydrogen. The engine was selected because of its physical size, advanced turbo machinery and fuel flow capability. It will be mounted along the rear fuselage of the A380 testbed to allow engine emissions, including contrails, to be monitored separately from those of the engines powering the aircraft.

"There is still life in the gas turbine. Whether fuelled by kerosene, SAF or hydrogen, we need to invest in the basic efficiency of the gas turbine"

Alan Newby Director of aerospace technology and future programmes, Rolls-Royce

The physical property of hydrogen means it has many challenges to become a viable liquid fuel for either gas turbine combustion engines or to make electricity in a fuel cell. However, many believe it has a future role in the decarbonisation picture. "Hydrogen combustion does get to zero carbon emissions, so it is a logical thing to look at," says Arjan Hegeman, general manager advanced technologies at GE.

As the first ground testing on this programme begins this year, GE's third demonstrator using technology called adaptive cycling is already running. This is being conducted in collaboration with the US Air Force (USAF) to develop the XA100 adaptive cycle engine for the F-35 fighter. The latest phase of tests began in March at the USAF Arnold Engineering Development Complex in Tennessee.

"An adaptive cycle means the engine actually changes its geometry depending on which part of the mission it is in to maximize the fuel burn advantage for that mission," says Ali. It has the potential to give the "best of both worlds", switching between high thrust and efficiency with the promise of 10% more thrust and 25% better fuel efficiency compared with today's engines.

He adds: "We are going to be taking all of these technologies and putting them in what we call the RISE demo, where RISE stands for revolutionary innovations for sustainable engines." This demonstration programme, launched in June 2021 by CFM, aims to develop open-fan powerplants that can be fuelled by 100% SAF or liquid hydrogen and include hybrid-electric capability for the next generation of single-aisle aircraft from 2035. The target is to reduce fuel consumption and carbon dioxide (CO_2) emissions by more than 20% with a flight demonstration engine planned for mid-decade.

Greener business

Pratt & Whitney (P&W) has identified three core themes in its roadmap to net zero: smarter technology; clean fuels and greener business.

Under the smarter technology banner come projects such as the Hybrid Thermally Efficient Core (HyTEC).

P&W was selected by NASA in October 2021 for HyTEC to develop advanced high-pressure turbine technologies for next-generation single-aisle aircraft.

These include ceramic matrix composite (CMC) materials that are capable of operating at higher temperatures than current CMCs, environmental barrier coatings and advanced cooling and aerodynamic approaches that will make new component designs and efficiencies possible, according to P&W.

HyTEC is part of NASA's Sustainable Flight National Partnership, which is intended to enable breakthrough innovations and help accomplish the industry's decarbonisation goals.

Using a raft of advanced fan technologies, new core development, increased use of hybrid-electric to augment the engine, and more efficient propulsion-airframe integration, P&W will build the future GTF, the firm's first chief sustainability officer, Graham Webb, explained at the Sustainable Skies World Summit, hosted by Farnborough International Airshow in early April.

In December, P&W launched the GTF Advantage configuration, the next iteration of the engine, which has technology enhancements throughout the core. After completing a year of ground and flight testing it will be available for A320neo-family aircraft from January 2024, offering greater thrust and a 1% increase in fuel efficiency.

25%

Fuel-efficiency gain that could be achievable using adaptive-cycle engine management technology

P&W's key demonstrator in the hybrid field is work led by Pratt & Whitney Canada, which is partnering with De Havilland to equip a Dash 8-100 turboprop with a hybrid-electric propulsion system. P&W's roadmap sees hybrid-electric technology coming into service from 2030.

Flight tests with the Dash 8 are scheduled to start in 2024 with ground tests planned this year, says Webb. The target is a 30% reduction in fuel burn and CO_2 emissions compared with today's turboprops. A key partner in this project is P&W's Raytheon Technologies stable mate Collins Aerospace, which is providing the electric motor and controller.

P&W says this project will provide technology and component learnings that will directly feed into to larger applications. Although it has not announced

Airbus

Airbus and CFM will experiment with hydrogen fuel contained in internal tanks at the rear of an A380 flying testbed

a specific programme yet to augment the GTF with hybrid-electric power, it is in the plan. The thinking is to marry an electric engine capable of delivering 18MW with the GTF to "enhance the flight operations" of a single-aisle airliner, says Webb. This is an order of magnitude larger than the 2MW being delivered for the Dash 8 project.

P&W's roadmap, which is naturally in sync with the Airbus vision of a zero emissions aircraft in service, sees it ready to field a hydrogen-fuelled engine for a 100-plus-seat airliner from 2035. Like its competitors, the company is accelerating its hydrogen research.

In February, it was awarded a US Department of Energy project called the Hydrogen Steam Injected, Inter-Cooled Turbine Engine (HySIITE).

It is described as a revolutionary hydrogen combustion system that uses water vapour recovered from the exhaust stream to increase engine efficiency, promising a reduction in fuel consumption for next-generation narrowbody airliners of 35% compared with the GTF. There are certainly challenges with delivering on liquid hydrogen as a fuel for aviation, but Webb sees the opportunity too. "There is a lot more work and study to be done but we look at hydrogen as a promising fuel," says Webb.

While hydrogen fuel grabs many headlines, the industry's drive to increase SAF use is critical to achieve net zero.

In March, P&W tested the GTF Advantage configuration with 100% SAF in what it describes as a key milestone towards 100% operation of GTF-powered aircraft with these fuels. Today, SAF is approved in blends of up to 50% with regular kerosene.

Step change

The three big themes in the Rolls-Royce (R-R) strategic drive to net zero are a step change in the efficiency of gas turbines, leading SAF demonstrators and adoption, and developing third-generation technologies, the company's chief technology officer Grazia Vittadini explained at the Clean Aviation Summit. "Engines are at the core of the decarbonisation challenge... and are the most impactful," she says.

Of the engine majors, R-R is exploring the widest range of potential power and propulsion technologies and applications, from small propeller aircraft and advanced air mobility vehicles, right up to widebody airliners and large business jet aircraft.

All-electric power will be viable for smaller aircraft with short range requirements and is a relatively mature technology, says R-R.

In November, it flew the *Spirit of Innovation*, a high-speed demonstrator that set two new world speed records for an all-electric aircraft.

This effort was part of the UK Government's Accelerating the Electrification of Flight project and the advanced battery and propulsion technology developed has applications for the advanced air mobility market, says R-R.

On the electric front, the company is also the engine partner with Italy's Tecnam on the 11-seat P-Volt utility aircraft. It will feature two R-R electric powerplants of 320kW each with Norwegian regional airline Wideroe set to take the first examples in 2026.

R-R has created a division dedicated to furthering its efforts in the electric engine space. In addition to its work with Tecnam, another key programme for R-R's electrical division is providing the technology to power Vertical Aerospace's four-seat VX4 vertical take-off and landing vehicle. This is expected to be certificated in 2024 with service entry soon after.

R-R's research into potential propulsion pathways encompasses hybrid-electric, hydrogen fuel cells, and gas turbines burning hydrogen, with likely applications up to regional and narrowbody aircraft. As the aircraft move up in size, from narrowbody and to widebody territory, the gas turbine is the clear favourite.

"There is still life in the gas turbine. Whether fuelled by kerosene, SAF or hydrogen, we need to invest in the basic efficiency of the gas turbine," Alan Newby, director of aerospace technology & future programmes at Rolls-Royce, said at Clean Aviation.

The key demonstrator in the R-R gas turbine world is its UltraFan engine design. UltraFan features a new-engine architecture, material, and a new power gearbox to prove "all the building blocks that will go into a next-generation engine". Engine UF001 is now being built and will be tested with 100% SAF this year, says Newby.

R-R says the engine will be available in the second half of the 2020s and will be 25% more fuel efficient than a first-generation Trent powerplant. Although initially sized for a widebody jet, UltraFan would be scalable for narrowbody aircraft.

Summing up the efforts of engineers at the engine manufacturers, Vittadini describes the technologies being explored as a "buffet" from which engine makers will choose the tastiest to meet the low-emission aircraft applications coming down the line.

"Revolutionary breakthroughs are required for aviation," Vittadini says. "There is quite a series of daunting challenges."

By the end of this decade, we will know which buffet items have the most promise for these pioneering aircraft. The biggest unknown is whether "disruptive" technologies such as hydrogen will be one of the ingredients or whether super-efficient gas turbines burning SAF will be the right choice.

Rolls-Royce

R-R broke world speed records for an all-electric aircraft with its Spirit of Innovation demonstrator

Pratt & Whitney

In March, P&W undertook tests on the new GTF Advantage engine configuration with 100% SAF

MTU leads charge with flying fuel cell

In parallel with its work alongside partner P&W on next-generation geared turbofan technology, MTU Aero Engines is developing a fuel cell powered by hydrogen as one of the answers to create engines with game-changing emissions reduction.

MTU's approach has been to develop a complete product-relevant electric powertrain from the hydrogen fuel system to the gearbox for technology demonstration purposes. The MTU Flying Fuel Cell (FFC) team is already 70 strong and growing.

MTU is working with German aerospace research centre DLR on converting a Dornier 228 twin-turboprop into a hydrogen fuel cell demonstrator. One of the Do 228's Honeywell TPE 331 engines will be replaced with a 600kW fuel cell-powered electric motor. The Do 228 will be a flying testbed used to validate the technologies being developed and integrated, but it will not be a product.

However, proving the technology will, MTU believes, put it in a leading position to be the engine partner with an airframer seeking to launch a zero-emissions 19-seater aircraft.

One of the main challenges for hydrogen fuel cell technology is certification. "We are in talks with EASA and Germany's civil aviation authority, the Luftfahrt-Bundesamt, because clearly a fuel cell of this type has not been through the full certification process," explains the chief engineer at MTU's FFC unit, Barnaby Law. The cryogenic fuel tanks to carry liquid hydrogen are another important technology and MTU has an unannounced partner on board to work in this area.

The aim is for the Do 228's first flight in the middle of the decade with the platform used to test individual system components prior to installation of the complete powertrain.

If this is successful, MTU believes it will be positioned to have serious discussions with airframers on providing an entire electric powertrain for a new aircraft product.

Engine options by commercial aircraft

Aircraft type	No of engines	Engine option 1	Engine option 2	Engine option 3
Airbus				
A220	2	PW1000G		
A300*	2	CF6	PW4000	JT9D
A310*	2	CF6	PW4000	JT9D
A318	2	CFM56-5B	PW6000	
A319/A320/A321	2	CFM56-5B	V2500	
A319neo/A320neo/A321neo	2	Leap	PW1100G	
A330	2	CF6	PW4000	Trent 700
A330neo	2	Trent 7000		
A340-200/300*	4	CFM56-5B		
A340-500/600*	4	Trent 500		
A350-900/1000/F	2	Trent XWB		
A380*	4	GP7200	Trent 900	
Antonov				
An-72	2	D-36		
An-74	2	D-36		
An-124	4	D-18		
An-148	2	D-436		
An-158	2	D-436		
An-225	6	D-18		
BAE Systems				
BAe 146*	4	ALF502	LF507	
Avro RJ*	4	LF507		
Boeing				
717*	2	BR700		
727*	3	JT8D	Tay	
737-200*	2	JT8D		
737-300/400/500*	2	CFM56-3B		
737NG (-600/700/800/900)*	2	CFM56-7B		
737 Max (-7/8/9)	2	Leap		
747-100/SP*	4	JT9D	RB211	
747-200/300*	4	CF6	JT9D	RB211
747-400*	4	CF6	PW4000	RB211
747-8	4	GEnx-2B		
757*	2	RB211	PW2000	
767-200/300*	2	CF6	PW4000	JT9D
767-200ER/400ER*	2	CF6	PW4000	
767-300ER/300F	2	CF6	PW4000	RB211
777-200/200ER/300	2	GE90	PW4000	Trent 800
777-200LR/300ER/F	2	GE90		
777-8X/9X/F	2	GE9X		
787 Dreamliner	2	GEnx-1B	Trent 1000	
DC-8*	4	JT3D	JT4A	
DC-9*	2	JT8D		
DC-10*	3	CF6	JT9D	
MD-11*	3	CF6	PW4000	
MD-80*	2	JT8D		
MD-90*	2	V2500		
Bombardier				
CRJ (all variants)	2	CF34-8		
COMAC				
C919	2	Leap-1C	CJ-1000AX	
ARJ21	2	CF34-10		
Embraer				
E-170/175/190/195	2	CF34		
ERJ 145 family	2	AE 3007		
E-Jet E2 family	2	PW1700G/PW1900G		
Fairchild Dornier				
328JET*	2	PW300		
Fokker				
F28*	2	Spey		
Fokker 70/100*	2	Tay		
Ilyushin				
Il-62*	4	D-30		
Il-76*	4	D-30	PS-90	
Il-96*	4	PS -90	PW2000	
Il-114-300	2	TV7-117ST-01		
Irkut				
MC-21	2	PW1400G	PD-14	
Lockheed				
L-1011*	3	RB211		
Mitsubishi				
MRJ70/90	2	PW1200G		
Sukhoi				
Superjet 100	2	SaM146		
Tupolev				
Tu-134*	2	D-30		
Tu-154*	3	D-30	NK-8	
Tu-204	2	PS-90	RB211	
Yakovlev				
Yak-40*	3	AI-25		
Yak-42*	3	D-36		

Note: Aircraft listed are narrowbody, widebody and regional jets currently in service and/or in development, in a commercial role
*Aircraft no longer in production

Commercial aircraft by engine type

Engine type	Aircraft type
Aviadvigatel	
D-30	Il-62*, Il-76*, Tu-134*, Tu-154*
PS-90	Il-76*, Il-96*, Tu-204
PD-14	MC-21
CFM International	
CFM56	A320 family, A340*, 737 family*, DC-8*
Leap	A320neo family, 737 Max, C919
Engine Alliance	
GP7200	A380*
GE Aviation	
CF6	A300*, A310*, A330, 747, 767, DC-10*, MD-11*
CF34	ARJ21, CRJ, E-Jet
GE90	777
GEnx	747-8, 787
GE9X	777-8X/9X/F
Honeywell	
ALF502	BAe 146*
LF507	Avro RJ*, BAe 146*
International Aero Engines	
V2500	A319, A320, A321, MD-90*
Ivchenko Progress	
NK-8	Tu-154*
AI-25	Yak-40*
D-36	An-72, An-74, Yak-42*
D-18	An-124, An-225*
D-436	An-148, An-158
Klimov	
TV7-117ST-01	Il-114-300
PowerJet	
SaM146	Superjet 100
Pratt & Whitney	
JT3D	DC-8*
JT8D	727*, 737-100/200*, DC-9*, MD-80*
JT9D	A310*, 747, 767
PW2000	757*
PW4000	A300*, A310*, A330, 747, 767, 777, MD-11*
PW6000	A318
PW1000G	A220, A320neo family, MRJ, MC-21, E-Jet E2
Pratt & Whitney Canada	
PW300	328JET*
Rolls-Royce	
Spey	F28*
RB211	747, 757*, 767, Tu-204
Tay	Fokker 70/100*
BR700	717*
Trent 500	A340*
Trent 700/7000	A330, A330neo
Trent 800	Boeing 777
Trent 900	A380*
Trent 1000	Boeing 787
Trent XWB	A350-900/1000/F
AE3007	ERJ-145 family

Note: Aircraft listed are narrowbody, widebody and regional jets currently in service and/or in development, in a commercial role
*Aircraft no longer in production

SUSTAINABILITY
A CLEAR AMBITION

Sustainability is at the heart of our business. From the beginning, we have invested in technologies to make our engines cleaner, quieter and more efficient. Our clear ambition is to push the limits of innovation, demonstrating uncompromising technologies that will help pave the way for an ever more sustainable future. A common mission, extraordinary together.

cfmaeroengines.com/sustainability

CFM International is a 50/50 joint company between GE and Safran Aircraft Engines

cfm