COMMERCIAL ENGINES 2018

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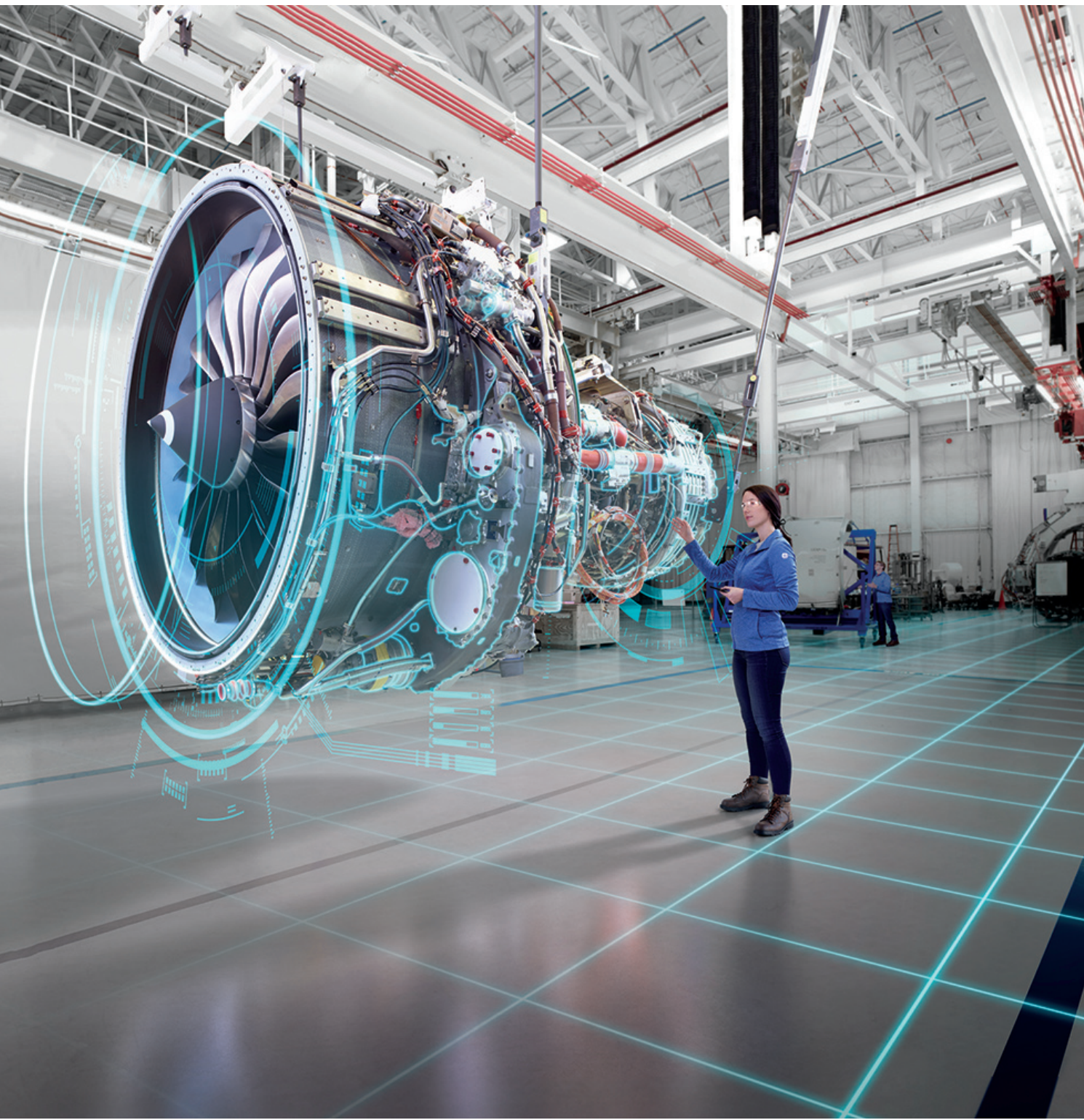

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COMMERCIAL ENGINES 2018

ENGINE EVENTS

May 2017

May 2017
Boeing delivers first Leap-1B-powered 737 Max 8 to Malindo

Boeing

Jun

May 2017
Maiden flight for the Leap-1C-powered C919

Comac

Jul

Aug

Sep

Oct

October 2017
Trent 7000-powered A330neo takes off on maiden flight


Airbus

Nov

November 2017
Rolls-Royce Trent 1000 TEN enters service on Boeing 787s

Rolls-Royce

Dec

Jan

Feb

February 2018
Qatar Airways takes delivery of first XWB-97-powered A350-1000

Mar

March 2018
GE9X enters flight test phase

Apr

April 2018
Embraer delivers first PW19000G-powered E190-E2 to Wideroe

Wideroe

May 2018

May 2018
First test flight for Trent XWB-powered Cathay Pacific A350-1000

May 2018
Power-on for the first CJ-1000AX demonstrator engine achieved

FUTURE ENTRY INTO SERVICE

AIRCRAFT	ENGINE	YEAR
Airbus A330neo	Rolls-Royce Trent 7000	2018
Boeing 787-10	Rolls-Royce Trent 1000	2018
Embraer E-Jet E195-E2	Pratt & Whitney PW1900G	2019
Irkut MC-21	Pratt & Whitney PW1400G	2020
Irkut MC-21	Aviadvigatel PD-14	2020
Mitsubishi MRJ	Pratt & Whitney PW1200G	2020
Boeing 777X	GE Aviation GE9X	2020
Embraer E-Jet E175-E2	Pratt & Whitney PW1700G	2021
Comac C919	CFM International Leap-1C	2020-21
Comac C919	ACAE CJ-1000AX	2022

Lifting expectations

Last year saw the Leap-1B enter service on the Boeing 737 Max, as CFM International cemented its domination of the global market by number of powerplants delivered. The Rolls-Royce Trent 7000 meanwhile powered the first A330neo flight, in a year when overall deliveries again rose to keep pace with record numbers of aircraft joining commercial airline fleets. In the regional sector, GE and Pratt & Whitney continued to dominate

A330 engine manufacturer share

	2017 deliveries		Backlog*	
Manufacturer	Aircraft	Share	Aircraft	Share
General Electric	11	18%	9	3%
Pratt & Whitney	2	3%	-	-
Rolls-Royce	49	79%	245	82%
Undecided	-	-	45	15%
Total	**62**		**299**	

Source: Flight Fleets Analyzer Notes: *At 31 December 2017. Excludes corporate and military operators. Includes A330neo

A380 engine manufacturer share

	2017 deliveries		Backlog*	
Manufacturer	Aircraft	Share	Aircraft	Share
Engine Alliance	5	33%	4	4%
Rolls-Royce	10	67%	61	64%
Undecided	-	-	30	32%
Total	**15**		**95**	

Source: Flight Fleets Analyzer Notes: *At 31 December 2017. Excludes corporate and military operators

767 engine manufacturer share

	2017 deliveries		Backlog*	
Manufacturer	Aircraft	Share	Aircraft	Share
General Electric	10	-	60	100%
Pratt & Whitney	-	-	-	-
Total	**10**		**60**	

Source: Flight Fleets Analyzer Notes: *At 31 December 2017. Excludes corporate and military operators

Airbus

Rolls-Royce

Engine manufacturer ranking

		2017 deliveries		Backlog*	
Rank	Manufacturer	Engines	Share	Engines	Share
1	CFM International	1,714	58%	13,928	53%
2	General Electric	406	14%	1,634	6%
3	Rolls-Royce	390	13%	2,520	10%
4	International Aero Engines	278	9%	120	1%
5	Pratt & Whitney	150	5%	2,950	11%
6	Engine Alliance	20	1%	16	0.1%
	Undecided	-	-	5,096	19%
Total		**2,958**		**26,264**	

Source: Flight Fleets Analyzer Notes: *At 31 December 2017. Data for installed engines based on Airbus/Boeing types. Excludes corporate and military operators

A320 family engine manufacturer share

Notes: *At 31 December 2017. Excludes corporate and military operators. Source: Flight Fleets Analyzer

CFM International	International Aero Engines	Pratt & Whitney	Undecided	Total deliveries: 558 Total backlog: 6,130

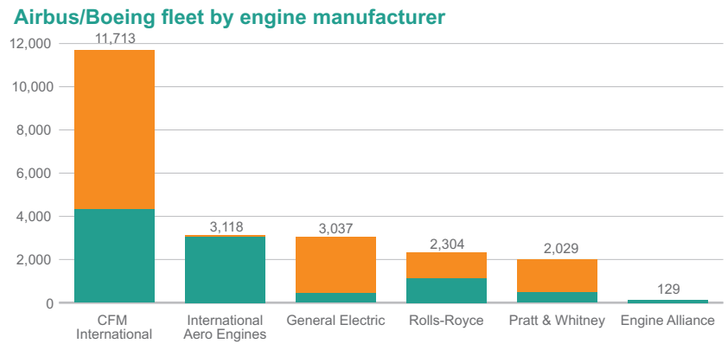
787 engine manufacturer share

Notes: *At 31 December 2017. Excludes corporate and military operators. Source: Flight Fleets Analyzer

Rolls-Royce	General Electric	Undecided	Total deliveries: 134 Total backlog: 656

Airbus

Airbus/Boeing fleet by engine manufacturer



Notes: In-service and parked fleet at 31 December 2017. Boeing data includes former MDC types. Excludes corporate and military operators. Source: Flight Fleets Analyzer

Airbus total: 9,552	Boeing total: 12,778	Grand total: 22,330

Regional aircraft engine manufacturer market share

Notes: *Airframe. **At 31 December 2017. Excludes corporate and military operators. ***Including P&W Canada. Data for firm orders for ATR, Bombardier, Comac, Embraer, Mitsubishi and Sukhoi. Source: Flight Fleets Analyzer

General Electric	Pratt & Whitney***	Powerjet	Total deliveries: 278 Total backlog: 1,242

BillyPix

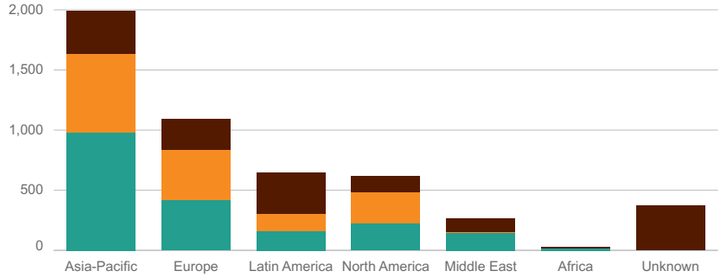
Bombardier

IAE

Powerbase

Engine options impact operating performance and airline economics. We use data from Flight Fleets Analyzer to detail the selection balance for Airbus and Boeing types

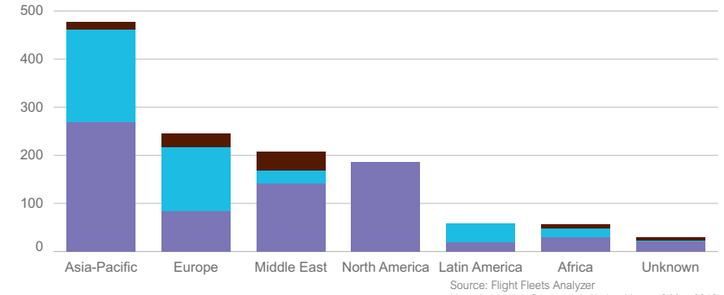
Airbus A320neo-family by engine manufacturer and region



Source: Flight Fleets Analyzer
Note: In-service fleet and order backlog at 9 May 2018

CFM International	Pratt & Whitney	Unannounced

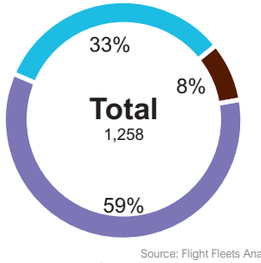
Boeing 787 by engine manufacturer and region



Source: Flight Fleets Analyzer
Note: In-service fleet and order backlog at 9 May 2018

GE Aviation	Rolls-Royce	Unannounced

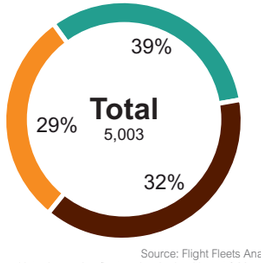
Boeing 787 by engine manufacturer



Source: Flight Fleets Analyzer
Note: In-service fleet and order backlog at 9 May 2018

GE Aviation	Rolls-Royce	Unannounced
746	413	99

Airbus A320neo-family by engine manufacturer



Source: Flight Fleets Analyzer
Note: In-service fleet and order backlog at 9 May 2018

CFM International	Pratt & Whitney	Unannounced
1,936	1,465	1,602

Boeing's 777X family will use efficiency gains from in-development GE9X

Boeing

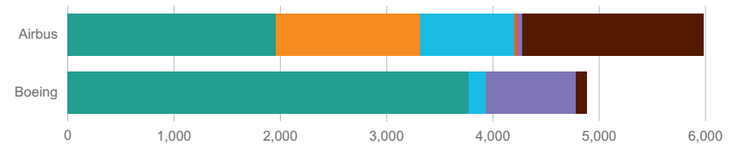
Qatar Airways' A380 fleet is exclusively driven by Engine Alliance GP7200s

R Grecco/Airbus

Delivered in March, 737 Max 8 is a great Leap forward for Kazakh carrier SCAT

Paul Gordon/Boeing

Airbus/Boeing order backlog by engine manufacturer



Source: Flight Fleets Analyzer (May 2018)

CFM International	Pratt & Whitney	Rolls-Royce
GE Aviation	International Aero Engines	Unannounced

Airbus/Boeing in service fleet by engine manufacturer

Source: Flight Fleets Analyzer
Note: In-service fleet at 9 May 2018; Boeing data includes former MDC types

CFM International	Pratt & Whitney	Rolls-Royce
GE Aviation	International Aero Engines	Engine Alliance

PW1100G is one of two options available to customers for re-engined A320neo

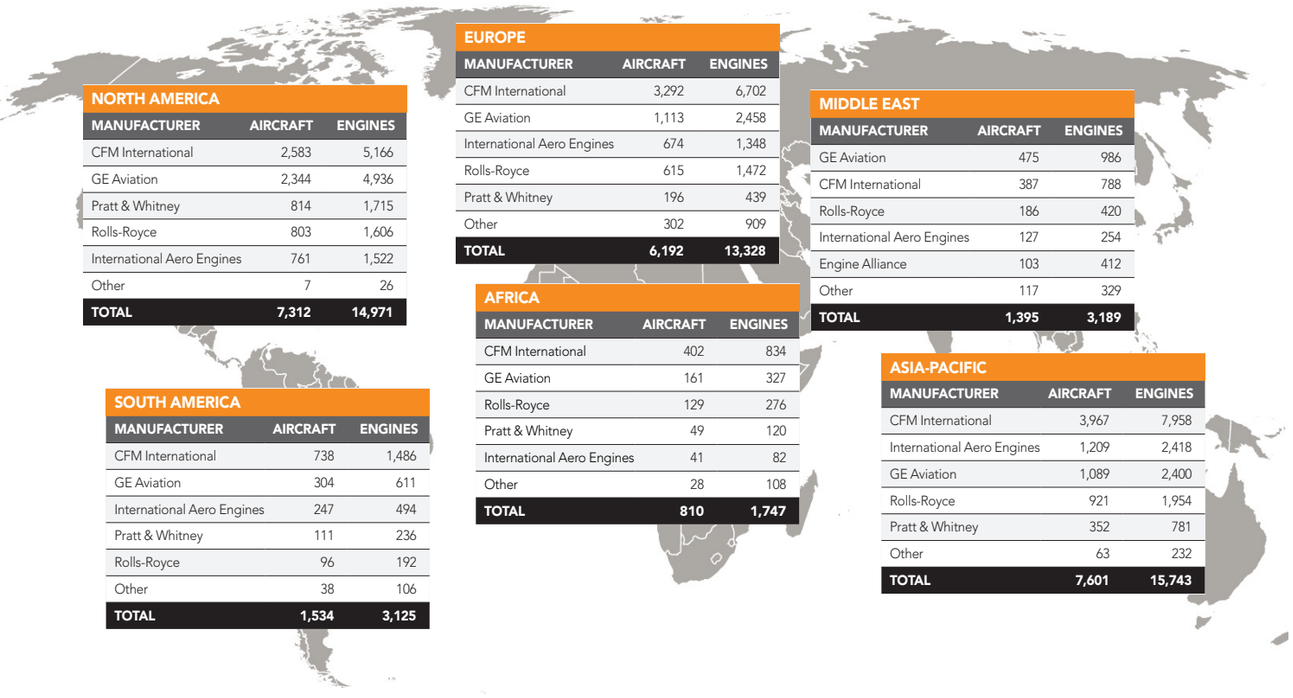
Airbus

Rolls-Royce has secured orders to equip one-third of global Dreamliner fleet

Boeing

AT A GLANCE

Commercial engines: manufacturer market share



NORTH AMERICA		
MANUFACTURER	AIRCRAFT	ENGINES
CFM International	2,583	5,166
GE Aviation	2,344	4,936
Pratt & Whitney	814	1,715
Rolls-Royce	803	1,606
International Aero Engines	761	1,522
Other	7	26
TOTAL	7,312	14,971

EUROPE		
MANUFACTURER	AIRCRAFT	ENGINES
CFM International	3,292	6,702
GE Aviation	1,113	2,458
International Aero Engines	674	1,348
Rolls-Royce	615	1,472
Pratt & Whitney	196	439
Other	302	909
TOTAL	6,192	13,328

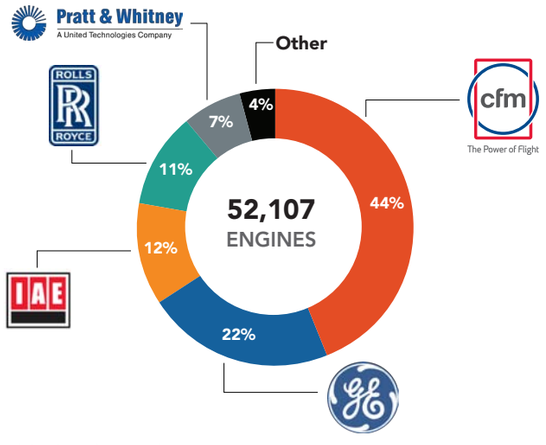
MIDDLE EAST		
MANUFACTURER	AIRCRAFT	ENGINES
GE Aviation	475	986
CFM International	387	788
Rolls-Royce	186	420
International Aero Engines	127	254
Engine Alliance	103	412
Other	117	329
TOTAL	1,395	3,189

AFRICA		
MANUFACTURER	AIRCRAFT	ENGINES
CFM International	402	834
GE Aviation	161	327
Rolls-Royce	129	276
Pratt & Whitney	49	120
International Aero Engines	41	82
Other	28	108
TOTAL	810	1,747

SOUTH AMERICA		
MANUFACTURER	AIRCRAFT	ENGINES
CFM International	738	1,486
GE Aviation	304	611
International Aero Engines	247	494
Pratt & Whitney	111	236
Rolls-Royce	96	192
Other	38	106
TOTAL	1,534	3,125

ASIA-PACIFIC		
MANUFACTURER	AIRCRAFT	ENGINES
CFM International	3,967	7,958
International Aero Engines	1,209	2,418
GE Aviation	1,089	2,400
Rolls-Royce	921	1,954
Pratt & Whitney	352	781
Other	63	232
TOTAL	7,601	15,743

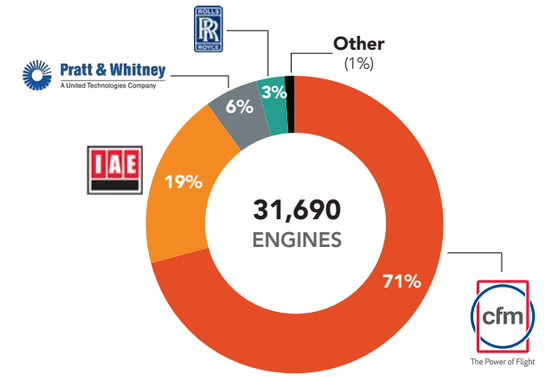
WORLD COMMERCIAL JET AIRCRAFT		
MANUFACTURER	AIRCRAFT	ENGINES
CFM International	11,369	22,934
GE Aviation	5,486	11,718
International Aero Engines	3,059	6,118
Rolls-Royce	2,750	5,920
Pratt & Whitney	1,595	3,466
Other	586	1,951
TOTAL	24,845	52,107



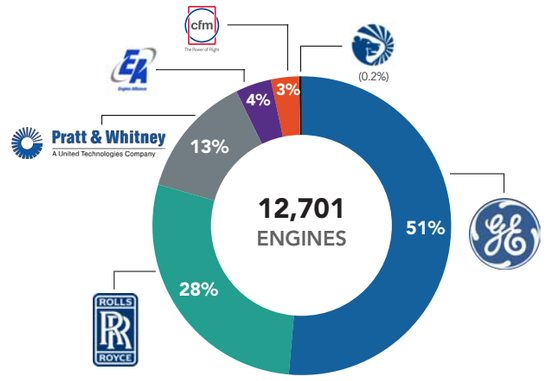
NOTE: Information for active commercial jets. Information includes narrowbody, widebody and regional jets in passenger, freighter, combi and quick change roles SOURCE: Flight Fleets Analyzer (May 2018)

Engine market share by market group

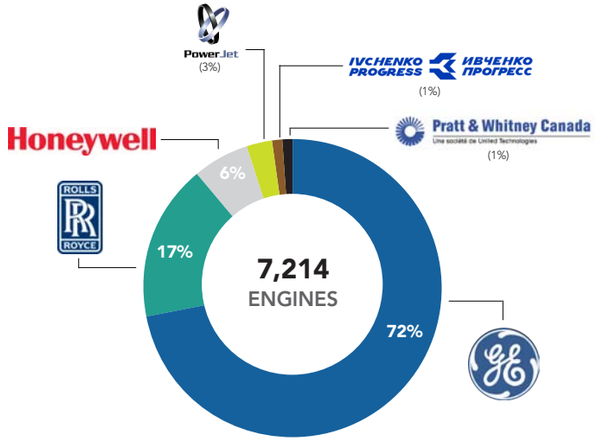
COMMERCIAL NARROWBODY AIRCRAFT		
MANUFACTURER	AIRCRAFT	ENGINES
CFM International	11,271	22,542
International Aero Engines	3,059	6,118
Pratt & Whitney	856	1,759
Rolls-Royce	546	1,092
Other	65	179
TOTAL	15,797	31,690



COMMERCIAL WIDEBODY AIRCRAFT		
MANUFACTURER	AIRCRAFT	ENGINES
GE Aviation	2,879	6,504
Rolls-Royce	1,588	3,596
Pratt & Whitney	738	1,705
Engine Alliance	123	492
CFM International	98	392
Aviadvigatel	3	12
TOTAL	5,429	12,701



COMMERCIAL REGIONAL JET		
MANUFACTURER	AIRCRAFT	ENGINES
GE Aviation	2,607	5,214
Rolls-Royce	616	1,232
Honeywell	113	452
Powerjet	102	204
Ivchenko-Progress	22	66
Other	23	46
TOTAL	3,483	7,214



NOTE: Information for active commercial jets. Information includes narrowbody, widebody and regional jets in passenger, freighter, combi and quick change roles SOURCE: Flight Fleets Analyzer (May 2018)

Airbus

Airbus E-FanX demonstrator will be a BAe 146 adapted to fly on three ordinary gas turbines and one nacelle-mounted electric fan

Current affairs

A future in which even large airliners are powered by hybrid and eventually all-electric propulsion systems is becoming an industry expectation; Rolls-Royce details its vision

STEPHEN TRIMBLE LAS VEGAS

In Rolls-Royce's vision of aviation's future, the entire market will shift to electric power for propulsion in ways that will disrupt business models and even the design of gas turbine engines. Says Rolls-Royce Electrical global head Mike Mekhiche: "It's not a matter of if. It's a matter of when. The entire aerospace business is going to be electrified."

R-R has given itself a front-row seat as the transformation unfolds. When the US Defense Advanced Research Projects Agency launched the (now cancelled) Aurora Flight Sciences XV-24A Lightning Strike programme, R-R supplied the AE1107 gas turbine used to power the electric motors for the turboelectric, unmanned air system. When Airbus launched the E-FanX demonstrator last year to replace one of the four turbofan engines on a BAe 146 with a 2MW-propulsion system, R-R signed up to adapt the Siemens-supplied electric motor to the existing nacelle and supply a turbine engine to function as an electric power generator.

BRIDGE TO THE FUTURE

The company plans to continue to be an active participant as the technology develops. In a recent presentation, Mekhiche showed an image of a new technology called the Embedded Electric Starter Generator (E2SG). Such a technology presents a bridging step between today's technology and an electric future. Using an Adour engine demonstrator, an R-R team installed a power-dense E2SG into the inhospitable core of a jet engine, converting the shaft power directly into electric power. By removing the need for a bleed-air offtake from the compressor to an accessory gearbox, installing the E2SG in a future engine is another step in the electrification of current aircraft systems, Mekhiche says.

"We're looking at a variety of architectures and systems solutions," he says. "We're looking into critical technologies: motors and batteries and most importantly the control system that allows us to optimise the power flow between the engine and the loads. The [E2SG] is one important programme. But it is not the only one."

R-R's vision of the future is one that it largely shares with its peers. GE Aviation has already revealed details of an aggressive push to develop new megawatt-class motors and electrical systems for future military and commercial aircraft. Pratt & Whitney has also disclosed a similar effort, including a demonstration of a large electric motor driven by a turbofan engine. Honeywell had signed up to supply the 1MW-class electric motor for the XV-24A, which was to be integrated with the R-R turboshaft engine to power that aircraft.

R-R has not yet released similar details of in-house demonstrations of megawatt-class electric motors and integrated hybrid-electric propulsion systems, but the company's vision for the technology seems consistent with a large investment in research and development. In addition to electrifying current aircraft power systems, Mekhiche sees three new classes of electric-powered air vehicles for transportation.

First, a new class of on-demand mobility platforms will provide intra-urban transports for one to four passengers seeking to avoid road traffic congestion. Aurora has pledged to divert the XV-24A's distributed electric propulsion system to this emerging market, with a goal of fielding a commercial product as soon as 2023.

A second category in the market is 20-40-passenger commuter aircraft with relatively short ranges, Mekhiche says. "The opportunity there is to actually take away some of the business jet or regional jet market. It is very possible and plausible that an electrified platform offers a much more attractive value proposition than, say, a business jet or regional jet," he says.

Finally, the large transport market is also a candidate for electrification, at least on large short-range trips with hybrid-electric propulsion systems.

INTEGRATED SYSTEMS

In the largest category, the transition will be more gradual, but in many ways has already started. By introducing new technologies such as the E2SG, R-R can make today's gas-powered aircraft produce electricity more efficiently, which allows designers to convert more onboard systems to electric power. Another upgrade exists in the rotorcraft market, with small electric motors providing back-up power in short bursts during, for example, a situation with an engine failure.

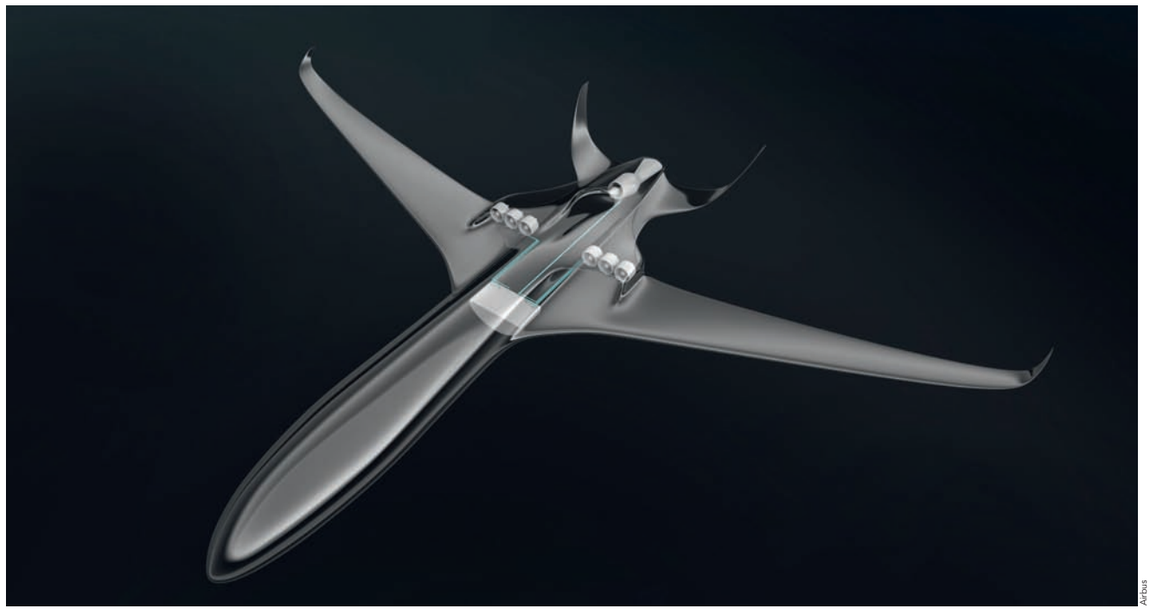
Airbus

Urban transport vehicles like CityAirbus are the likely first application for breakthrough

The next stage of electrification is coming soon, as suggested by Airbus's plan to fly the E-FanX demonstrator in 2020. It uses a turboelectric propulsion system, with a gas turbine generating electricity for electric motors that provide the thrust. "Your propulsion and your engine are now connected only by cables. They are not connected to mechanical structures," Mekhiche says.

A key limitation of a turboelectric system is the absence of an integrated battery for energy storage, he adds. Pushing beyond a turboelectric system with integrated batteries opens new paths to improving overall fuel efficiency.

"We're looking at what electrification [means] to the engine design," Mekhiche says. »



Airbus

Airbus/Rolls-Royce e-Thrust hybrid concept combines gas turbine power generation and backup batteries with electric fans for thrust

» "How does the engine design change because it is now going to be part of an electric powerplant? That is extremely relevant… to understanding our value stream and how we operate going forward in this electrified market. When we started doing electrification of cars and heavy-duty vehicles, we realised a lot of benefits. But actually, it was not until we had engines that were designed to be optimised for an electric propulsion system that we were able to realise the full capability of that type of system."

In what is called a parallel hybrid architecture, R-R envisions packaging a gas turbine and batteries to deliver thrust to an electric motor. By augmenting electric power with batteries during take-off and step climbs, the propulsion supplier is able to reduce the maximum thrust rating for the gas turbine without sacrificing performance, he says.

"There's an entire paradigm shift around what the engine does and when does it do it and how that can be realised," Mekhiche says. ■

STRATEGY **STEPHEN TRIMBLE** CHICAGO

European electric systems expertise makes transatlantic journey for Siemens

Current CFM56's 5:1 power-to-weight ratio is Siemens' benchmark

Boeing

Since its founding 170 years ago, German conglomerate Siemens has built a global industrial empire, making electric power components for cars, hospitals and power stations. It has gained a toehold in the aerospace industry as a provider of product lifecycle management (PLM) software for aircraft designers and automated systems for aircraft assemblers.

Now, Siemens has found a way to enter the aviation market as a tier one supplier, leveraging its decades-old expertise in electric power systems in an industry on the verge of a major transformation in propulsion system technology.

It began with a chance encounter between a Siemens and Airbus executive in 2008. A decade later, Siemens has opened a US facility in Waco, Texas, dedicated to introducing innovators in the US market to a potential new partner in several key systems for an electric-powered aircraft.

"What we really wanted to do here in the USA is stand up a team. We need to be close to innovators. If you're not in the US aviation market, you're not really in the market, so this team was stood up to be extension of the European team," says Teri Hamlin, Siemens' vice-president of electric and hybrid-electric propulsion.

The Waco-based team, which is co-located with Texas State Technical College, is focused on aircraft at the lower end of the power scale. These include unmanned air vehicles for the defence market, auxiliary power systems for large commercial aircraft and an emerging class of electric-powered urban air taxis, Hamlin says: "We're on some projects right now that should be announced real soon – hopefully, by this summer."

The US operation is building on a decade-long pursuit by their colleagues in Europe of a new role for Siemens in the aviation supply chain. As the market electrifies, Siemens is attempting to take a position now occupied by the likes of United Technologies' UTC Aerospace Systems, Honeywell and GE Aviation's electric power systems division.

Siemens' quest to obtain this role began in 2008 during a chance encounter between Siemens executive Frank Anton and then-Airbus chief technology officer Jean Botti at a Siemens' in-house innovation day. According to Siemens, Anton and Botti were both amateur pilots filled with dread about the future of gas-powered aviation. As emission regulations become more strict over the next four decades, Anton could envisage a day when it would no longer be possible to fly conventional aircraft on regional routes.

SPARK OF AN IDEA

For Siemens, the only possible solution to the problem called for electrifying aircraft propulsion systems. It seemed an impractical vision at the time, given the state of electrical power technology. At that time, the only electric motors on the market were used for terrestrial applications, lacking the aviation industry's demand for the lightest possible weight. A conventional electric motor produces about 1kW for every pound of weight, resulting in a roughly 1:1 power-to-weight ratio. By comparison, a CFM International CFM56-7B has a power-to-weight ratio above 5:1.

As Siemens set out to conquer this problem, it drew on its industrial digitalisation strategy. The company's PLM software allows designers to create a virtual copy of a physical product, using simulation tools and computational analysis to make rapid improvements.

The result of that approach led to the design of a new 260kW motor for the aviation market, boasting a 5:1 power-to-weight ratio. That improvement was possible because of advances in the efficiency of the motor's power cycle. It was also enhanced by Siemens' use of its PLM software suite to make certain components substantially lighter. A bearing shield on the front of the motor normally weighs 11.3kg (25lb), but that figure was reduced to 4kg.

"Siemens is not intending to become an aircraft OEM. We have no intention to move into that space," Hamlin says. "We're focusing on what we're good at and that is the electric propulsion and the electrification of complex systems, including motors, generators, power and signal distribution, inverters and complete end-to-end drive trains of these electric components. This is where Siemens shines. We have decades and decades, 100-plus years of experience in complex electrical systems. We're coming at this market from that level of expertise." ■

High stakes blade game

For Rolls-Royce, designing and delivering modifications to resolve Trent 1000 reliability problems are a drain on engineering resources, cash and customer confidence

MICHAEL GUBISCH LONDON

What starts as a trickle can end up a torrent: when, in 2016, Rolls-Royce first announced a durability issue with blades in the Trent 1000's intermediate-pressure turbine (IPT), there was no indication that the modification programme would grow in scope and complexity, causing significant disruption for some Boeing 787 operators.

Airlines had to park Dreamliners as engines required unscheduled maintenance to replace IPT blades, and aircraft could not be returned to service amid a shortage of available spare Trent 1000s – some carriers had to lease additional capacity. It became clear that on certain Trent 1000s the durability issues also extended to the high-pressure turbine (HPT) and intermediate-pressure compressor (IPC).

The costs are already mounting: R-R disclosed in March that in 2017 it incurred a charge of £227 million ($311 million) related to addressing technical issues on Trent 1000s and the Trent 900s powering Airbus A380s. And the UK engine maker said that this year, the upgrade programme's annual cash impact would "broadly double" from last year's £170 million, before dipping in 2019 as work drops off.

However, that was before the revelation in April of "additional disruption" – and higher costs – from further inspections required to address IPC blade durability issues on Trent 1000 Package C engines.

Of course, previous engine programmes – of both R-R and other manufacturers – have required updates to address premature part deterioration, particularly in the hot section. And R-R says it is "not uncommon for long-term engine programmes to experience technical issues during their life". »

Trent 1000 modifications have disrupted operations for multiple 787 customers

Rolls-Royce

AirTeamImages

ANA grounded some of its 787s in 2016 due to corrosion-related part failures, prompting redesign of intermediate-pressure turbine blades

» Teal Group vice-president analysis Richard Aboulafia, however, considers the Trent 1000 modification effort to be "somewhat worse than normal".

ENGINEERING RESOURCES

Aboulafia wonders whether R-R's issues with the Trent 1000 – and Pratt & Whitney's problems with its PW1000G-series geared turbofan – might be a result of having "greater ambitions than resources".

The technical challenges and required engineering effort to develop more efficient engines have hugely increased from previous generations of equipment. More broadly, Aboulafia thinks the Trent 1000 problems show that "we are on the very limits of squeezing performance improvement out of existing turbine architectures" and that highly engineered parts come with a "certain set of vulnerabilities".

Especially on Airbus and Boeing's latest aircraft programmes – the A320neo, A330neo, 737 Max and 777X – fuel-efficiency gains have been mainly, if not entirely, achieved through new engine technology. As a result, the airframers have redistributed much of the research and development effort, and therefore risk, for new programmes to the engine manufacturers; at the same time, Airbus and Boeing have put engine suppliers under pricing pressure and driven production to record levels.

"The ability to add resources at the engine companies was constrained at exactly the moment when so much was expected of them," Aboulafia says.

Boeing 787 chief engineer Bob Whittington revealed in January that "all" operators of Trent 1000-powered Dreamliners were affected by "some of the wear-out issues in the Rolls-Royce engine", which entered service in 2011.

The initial IPT blade replacement programme for the Trent 1000 was disclosed after All Nippon Airways had temporarily grounded some of its 787s in 2016 as a result of premature, corrosion-related part failures.

R-R redesigned the IPT blade and introduced it on the latest version of the Trent 1000, the 1000 TEN, and on the Trent 7000 derivative that powers the A330neo. The new part is being retrofitted to earlier Trent 1000s and, says R-R, should resolve the durability issue. But the modification programme nevertheless caused a wave of shop visits as some engines required urgent blade replacement.

There has been inevitable disruption for operators: Air New Zealand temporarily grounded several Dreamliners after experiencing in-flight failures on two of its 787-9s in December 2017. The carrier resorted to wet-leasing aircraft to support its schedule.

Virgin Atlantic in January disclosed plans to add four A330s to its fleet and return to service a stored A340-600 in a bid to improve the "resilience" of its operation "in light of an industry-wide shortage of Trent 1000 engines".

The IPC blade issue was first disclosed after an engine failure aboard a Scoot 787-9 in late 2016. Singapore's Transport Safety Investigation Bureau determined that the failure was caused by an IPC blade having broken off – probably as a result of material fatigue – and linked two further shutdown events on Scoot 787-9s last year to the same issue.

R-R says the cracking problem applies to the Trent 1000's Package C configuration and that neither the TEN nor the Package B version is affected. The manufacturer is in the process of preparing redesigned blades for the IPC – and for the HPT where erosion is an issue on existing blades.

The new parts are scheduled to become available by year-end and will be retrofitted to affected engines. R-R believes that the modification effort can be completed during planned rather than unscheduled shop visits.

Whether that retrofit programme will cover certain TEN engines is not entirely clear. R-R says Trent 1000 TEN compressors "are of different designs to the Package C", and that "a new standard" HPT blade is installed on the TEN.

However, the manufacturer does not rule out retrofitting a new IPC and the latest HPT blades to the TEN. "We will continue to positively confirm that none of the issues we are experiencing on the Trent 1000 Package C engines will apply to the Trent 1000 TEN," the manufacturer says.

And earlier this year, R-R said it was "possible that a population of early Trent 1000 TEN and Trent 7000 engines may benefit from proactive maintenance to embody parts in their first shop visit that weren't available at the point of production".

ETOPS LIMITATIONS

Regulatory pressure is compounding the disruption for operators.

Following the April disclosure relating to the IPC, the European Aviation Safety Agency mandated that operators conduct repetitive on-wing borescope inspections for all Package C engines, and introduced additional inspections for powerplants employed for extended twin-engine operations (ETOPS).

Meanwhile, the US Federal Aviation Administration more than halved the time that Trent 1000 Package C-powered 787s can fly under ETOPS regulations, to 140min, from a previous maximum of 330min.

The US regulator says that if an engine were to fail and the remaining powerplant already had cracked IPC blades, the "likelihood of the remaining engine failing will further increase before a diversion can be safely completed".

Bloomberg Intelligence warns that the ETOPS restriction could put R-R at a disadvantage on the 787 versus rival GE Aviation and its GEnx engine.

In a research note, Bloomberg senior aerospace analyst George Ferguson asserts that airlines will be required to "adjust operations to remain closer to diversion airports", and that this "reduces efficiency and range, especially for extreme long-haul operations, which are most appealing for 787 buyers".

He describes the FAA directive as a "blow" to R-R and operators of Trent 1000 Package-C-powered 787s, which will "probably hurt sales and value for the airplane".

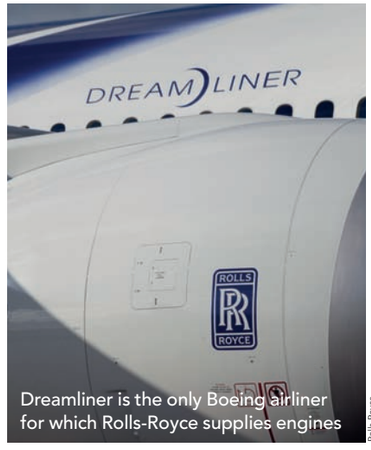
ANZ subsequently disclosed that it needed to introduce refuelling stops on certain 787 flights as new weight restrictions apply to aircraft with affected engines. ANA and British Airways, meanwhile, say the ETOPS changes have had a minor effect on their operations.

Norwegian's chief executive Bjørn Kjos acknowledged in April that the increased inspection regime will affect operations, but says "it is too early to predict the scale of the issue".

R-R's effort to resolve the Trent 1000 problems and modify the in-service fleet "takes an awful lot of resources", which will likely have an impact on the company's ability to concentrate engineering staff on other projects like future engine development, Aboulafia suggests.

He says the development and implementation of modifications for issues on in-service engines is "fairly labour-intensive stuff", while the ramping-up of production for new engine programmes, such as the Trent XWB for the A350, is largely a matter of capital expenditure.

R-R says it had to redeploy "engineering resource" to tackle the Trent 1000 issues, but notes: "[We] expect this to be a temporary measure." The manufacturer says its developmental Advance and UltraFan engine programmes "continue to progress as expected".



Dreamliner is the only Boeing airliner for which Rolls-Royce supplies engines

Rolls-Royce

Rolls-Royce

Engineers have been redeployed from other projects to help resolve Trent 1000 issues

Aboulafia does not believe that airlines and aircraft manufacturers have lost faith in R-R as a result of the Trent 1000 woes. Operators which have ordered Trent 1000-powered 787s have not yet switched to the GEnx. But he warns that the problems have not done R-R "any favours" either and that "a lot of it depends how quickly they can make it good".

R-R concedes: "Of course these issues must affect perception of the Trent 1000 by customers." But the engine maker says it is "confident" that the family's latest version and current production standard, the TEN, is a "great engine" for the 787.

SOLUTIONS

"It is our job to show them [airline and airframe customers] they can continue to trust in us and the engine," R-R says. It foresees that solutions for the existing issues will be implemented throughout the fleet by 2022.

However, Aboulafia suggests the Trent 1000 problems could have an effect on future orders: "I think where it might hurt is where people are looking at A350-1000 XWB versus 777X and... A330neo versus 787." Both of the Airbus programmes are exclusively powered by R-R engines.

"The big issue here for Rolls-Royce is that the 787 is their only connection with Boeing right now," says Aboulafia.

GE, P&W and R-R have all submitted engine proposals for Boeing's proposed New Mid-market Airplane (NMA), which could enter service around 2025. If Boeing were to launch the NMA programme without R-R on board, it would leave the UK manufacturer having almost the entirety of its large engine business – all in-production models except the Trent 1000 – tied to Airbus.

That is already the case today, as the Trent 700, 900, 7000 and XWB are exclusively employed on Airbus long-haul aircraft. But Aboulafia thinks a further re-enforcement of that alliance in the long-haul segment is a "very risky concept" for R-R.

GE is, likewise, the sole engine supplier to Boeing's 777 and 747-8 programmes. However, the US engine maker also has, via its CFM International joint venture with Safran, a strong position in the high-volume narrowbody market. Since it withdrew from the International Aero Engines consortium with P&W, Japanese Aero Engines and MTU, R-R has no active participation in the single-aisle segment.

R-R, for its part, argues that the prospect of a potential selection as NMA engine supplier is "unrelated" to the Trent 1000 problems: "We continue to invest in our future engine programmes irrespective of this [Trent 1000] challenge and will continue to evaluate any opportunities to have our engines selected as they come up." ■

GE Aviation

Installing the powerplant on inboard pylon of 747-400 flying testbed's left wing – carried out in record time – was a major engineering feat

Thrusting onwards

With its giant GE9X a critical element of the 777X update to Boeing's popular big twin, GE Aviation is powering ahead with testing and production of its most advanced engine

STEPHEN TRIMBLE WASHINGTON DC

In the second week of May, the crew of an Antonov An-124 operated by Russian cargo airline Volga-Dnepr got to work on the flightline at Victorville, California, loading a pallet measuring 3.96m (13ft) wide and 7.77m long into the cargo bay of the chartered widebody freighter for emergency shipment to Columbus, Ohio. The size of the payload and the route were dead give-aways: GE Aviation's first GE9X flight-test engine was coming home to Evendale, Ohio.

In early May, GE wrapped up the first phase of a two-stage flight-test effort on the 105,000lb-thrust (467kN) GE9X. Phase 1 included 18 flights on board the company's Victorville-based Boeing 747-400 flying testbed, GE9X programme manager Ted Ingling tells FlightGlobal.

GE is on a tight schedule. Boeing needs the GE9X ready to begin flight testing for certification on board the first 777-9 in 2019, allowing the aircraft to enter service in 2020. So the new powerplant for the 777-9 needed to return to Evendale to prepare for phase 2, which is scheduled to begin in the third quarter.

"It will be months of work to bring the engine down and back up again. The majority of the activities are around the instrumentation that we have on this vehicle. There's over 1,600 pieces of discrete information through sensors that get bundled onto this engine and routed into the aircraft," Ingling says.

"We want to preserve that instrumentation for the missions that follow. As a result, what would normally be a quick turn-around for incorporation of the hardware changes takes us much longer to bring the engine down and back up and make sure all the instrumentation is working," he adds.

GETTING STARTED

The first phase of flight-testing with the GE9X kicked off on 13 March, with the engine designated as No. 4 within the programme lifting off in Victorville. In nearly two months, the 747-400 flying testbed logged 110h overall during the 18 flights. "A portion [of the flight tests are reserved] for check-out of the aircraft and systems and the rest of it was dedicated to achieving the objectives of the flight test mission," Ingling says. Flight-test crews also explored the high-altitude envelope for the GE9X, evaluating how its cruise performance compared with ground test data.

"We are very encouraged about the engine. All indications from fight test is that the engine is doing exactly what we want it to do and we're on track to meet our objectives on performance," Ingling says. "The engine is really performing well and we couldn't be happier with that."

The engine is installed on the inboard station of the left wing of the 747-400, which was itself an engineering challenge, he adds. "We put the engine on wing in record time and with little drama. Boeing designed the pylon for us… and how it attaches to the engine is really the same as how it would do on the 777X, so Boeing's been involved in our [flying testbed] since the beginning. The installation was really remarkably quiet and flawless. Engine and instrumentation systems came together perfectly."

But the start of testing was delayed by more than two months, after GE engineers made a late discovery. Inside the compressor of the GE9X are 11 stages of rotating blades, with stationary vanes located in between each set of spinning rotors. These stator vanes slow down the airflow, thereby raising its pressure as it moves upstream to the combustor. To optimise the pressure of the airflow in take-off and cruise conditions, the engine's computer-operated controls can adjust the position of the stator vanes relative to the airflow.

Lever arms mounted externally on the engine case set the pitch of the vanes, but GE discovered a problem last December. The mechanical design and materials used to build the lever arms were correct, but the device wore out faster than it had expected.

"We didn't alter the material of the lever arms or anything," Ingling says. "It was just the design was not as robust as we needed it to be. It didn't affect the engine from a [specific fuel consumption] standpoint."

It was too late to incorporate the new lever arm design in the first GE9X flight-test engine, so the first phase of flight tests began in March using the existing configuration. The redesigned lever arms for the variable stator vanes will be installed as part of the tear-down prior to the restart of flight tests in phase 2, Ingling says.

GE Aviation

First phase of flight testing with the GE9X-105B was launched from Victorville in March

SECOND FRONT

Meanwhile, ground testing is continuing at GE's test centre in Peebles, Ohio. GE delivered the first engine to test (FETT) for the GE9X programme in 2016. This features its most advanced engine core, with a compression ratio of 27:1, versus 23:1 in the GE90-115B. The GE9X is loaded with new technology. Its $42 million list price makes a set of two engines on each 777X nearly equal to the advertised cost of a 737-700. For that price, GE has promised that the engine will burn 10% less fuel than the GE90 in flight and 5% less than a Rolls-Royce Trent XWB-97 on a test stand.

Driven by concerns about moving too quickly, GE afforded itself a 13-month window between delivering the FETT and the second engine to test (SETT) with certification-ready hardware. Since entering ground testing at Peebles 12 months ago, the SETT has been joined by four more test engines.

"We've made some fantastic progress on the certification programme," Ingling says. "We're through a little more than 25% of all required certification testing. Icing tests were completed in the first quarter. We completed all the crosswind testing, [as well as] inlet compatibility, aero-mechanics of the fan and booster, and aero-mechanics and thermal surveying of the high-pressure turbine."

The GE9X actually represents an entire family of engines. The 777-9 will be powered by the version designated GE9X-105B, with the numeral in the suffix representing the 105,000lb-thrust power rating. GE also plans to develop a 102,000lb-thrust version of the engine, along with another with a 93,000lb-thrust output, according to a regulatory document filed with the US Federal Aviation Administration in November 2017. The reduced ratings will likely power future variants of the 777X family, including the long-range 777-8 and a potential freighter version.

For now, however, GE is focused on getting the GE9X engine certificated.

"We're in the middle of building the very first compliance engine in Durham, [North Carolina]. The long-lead hardware on production engines are coming in," Ingling says. "So, we're ramping the production process using the Durham facility. The development engines are built in Evendale. Compliance and production [engines] will be assembled in Durham and tested out of Peebles.

"We're building the very first compliance engine and we're accumulating hardware up to the third engine, so more than 50% of hardware is accumulated depending on which engine you're looking at," he adds. ■

GE Aviation

An array of instrumentation captures performance information across 1,600 parameters

P&W-POWERED JETS TRICKLE BACK INTO AIRBUS DELIVERY FIGURES

Published on 8 May 2018

Airbus handed over two Pratt & Whitney-powered A320neo-family jets in April, ending a 55-day suspension of deliveries with the PW1100G engine.

Both deliveries – an A321neo on 24 April and an A320neo on 30 April – were to lessor AerCap, with the jets each bound for Mexican operator Volaris.

Airbus lists its last previous PW1100G delivery as taking place on 28 February, with an A321neo for China Southern Airlines, while the one prior to that, for Air China, was a month earlier on 1 February.

These had been the only other PW1100G deliveries to have taken place this year, as Airbus and Pratt & Whitney sought to overcome further technical snags with the powerplant.

Airbus's resumption of deliveries in the last week of April contributed to overall output of 17 A320neo-family jets for the month, including three A321neos.

This brought total A320neo deliveries so far this year to 47, of which 43 were fitted with CFM International Leap-1A powerplants.

Airbus's latest backlog figures show that re-engined jets accounted for 36% of the airframer's single-aisle deliveries over the first four months of 2018.

AMBITIOUS AIRBUS RESUMES P&W A320NEO DELIVERIES

Published on 27 April 2018

Airbus remains committed to meeting a full-year delivery target of 800 aircraft, but admits that the figure is becoming increasingly ambitious as it continues to tackle A320neo engine issues.

The airframer has resumed deliveries of Pratt & Whitney PW1100G-powered jets, after a suspension of several weeks.

Flight Fleets Analyzer lists an A321neo, fitted with PW1100G engines, as having been delivered to Volaris via AerCap on 25 April. AerCap has confirmed that it has newly delivered the second of six A321neos to the airline.

Airbus has not clarified whether this aircraft, MSN8087, was the first handover since the February suspension.

But the airframer says that PW1100G-powered aircraft deliveries "have resumed", and Airbus states that it is "committed" to delivering "in line with" its overall 800-aircraft target for 2018.

It admits, however, that the situation leaves the manufacturer with "a lot to do in the second half".

Airbus says that CFM International is also "working to catch up" after its Leap-1A production encountered delays.

Over the first quarter of this year Airbus delivered 30 A320neo-family jets, including six A321neos. Only two of these aircraft – one for Air China and one for China Southern Airlines – were fitted with PW1100G engines.

Airbus chief executive Tom Enders says the airframer's first-quarter performance "reflect the shortage of A320neo engines" and the consequent back-loading of deliveries.

"It's a challenging situation for all," he adds. "But based on the confidence expressed by the engine makers, and their ability to deliver on commitments, we can confirm our full-year outlook."

Airbus's first-quarter commercial aircraft revenues were down by 12% to €7.2 billion, while its adjusted earnings showed a €41 million loss – although this was an improvement on the previous loss of €103 million.

P&W PLANS TO DELIVER E190-E2 COMBUSTOR LINER FIX IN Q4

Published on 12 April 2018

Pratt & Whitney plans to certificate a durability upgrade for the combustor liner on the engine powering Embraer's E190-E2 flight by September, the engine manufacturer tells FlightGlobal.

If the US Federal Aviation Administration (FAA) comes through on schedule, P&W can begin delivering the improved PW1900G geared turbofan to Embraer's customers starting as early as October, P&W says.

Embraer has said that the engines now on the wings of E190-E2s can be replaced with upgraded PW1900Gs in an overnight procedure.

The Brazilian airframer delivered the first E190-E2 to launch operator Wideroe on 4 April with engines that include P&W's existing configuration for the combustor liner.

Operational experience on other versions of the geared turbofan engine has revealed that combustor liner gets exposed to hot spots in unexpected locations. As a result, the pattern of cooling holes in the original design of the combustor liner is inadequate, which reduces the service life of the combustor liner.

The problem surfaced originally on the PW1100G engine installed on Airbus A320neo aircraft, but it has also affected the PW1500G on the Bombardier CSeries and the PW1900G on the E190-E2.

P&W certificated the redesigned liner for the PW1100G in December and started delivering engines with the upgraded component in January. The fix redistributes the pattern of cooling holes within the liner to eliminate the unexpected hot spots and increase service life.

SUKHOI CONSIDERING PW1000G POWER FOR SUPERJET SHRINK

Published on 6 February 2018

Sukhoi Civil Aircraft (SCAC) has launched a major "shrink" derivative of the Superjet – and the variant could be powered by Pratt & Whitney's PW1000G geared turbofan when it enters service in 2022.

SCAC president Alexander Rubtsov revealed to FlightGlobal at the Singapore air show that a launch decision for the 75-seat derivative was made "last week" following a 100-aircraft commitment from an undisclosed Russian airline.

Rubtsov says the programme will require an investment of "several hundred million dollars", adding that SCAC is now evaluating choices around the wing structure – aluminium or composite – and the engines.

The Superjet's current 18,000lb-thrust (80kN) PowerJet SaM146 engine is "a bit too big", says Rubtsov, "so we could detune it or use other engines, either Russian or non-Russian, to optimise the aircraft".

Potential engines under evaluation include the Aviadvigatel PD-7 derivative of the Irkut MC-21's PD-14, and the 17,000lb-thrust Pratt & Whitney PW1200G which powers the Mitsubishi MRJ.

"We are talking to engine suppliers and will make a decision this year," says Rubtsov.

The derivative will use a shortened version of the 95-seat Superjet's five-abreast fuselage married to a smaller, optimised wing. As part of efforts to reduce the weight, SCAC is examining adopting composite for the wing in place of aluminium. It will also update the cockpit, incorporating systems from the MC-21 which could also aid pilot cross-training.

"For marketing purposes, the 75-seater may be called the 'MC-21-75', but it's not decided yet," says Rubtsov.

Because of the strong interest in a smaller Superjet, SCAC has shelved plans to develop a stretch. A larger Superjet variant would take it into the Bombardier CSeries market, says Rubtsov, "and I don't think it is the right time to reproduce the CSeries".

CFM ISSUES NEW INSPECTION PROTOCOL FOR 737 ENGINE FAN BLADES

Published on 20 April 2018

CFM International has sent an alert to Boeing 737 operators recommending ultrasonic inspections within the next 20 days to fan blades on CFM56-7B engines with more than 30,000 cycles since they were delivered.

The service bulletin released on 20 April also calls on operators to perform inspections on fan blades with more than 20,000 cycles by August and on all fan blades as soon as they reach 20,000 cycles.

About 680 engines are covered under the 30,000-cycle inspection deadline and 2,500 engines fall under the August deadline, says CFM, a joint company formed by GE Aviation and Safran.

The inspections target the oldest engines in the global fleet of CFM56-7B engines, which has accumulated 350 million flight hours since entering service 21 years ago, CFM says.
The inspection should then be repeated for all engines with more than 20,000 cycles on intervals of 3,000 cycles, representing about two years of average airline service, says CFM.

The service bulletin comes three days after a fan blade blew out of a CFM56-7B engine with 40,000 cycles on a Boeing 737-700 operated by Southwest Airlines. Pieces of the engine or cowling penetrated the wing and fuselage, blowing out a window and killing one passenger.

A quick inspection of the damage by the US National Transportation Safety Board found signs of metal fatigue where blade fractured at the hub. That early finding echoed the NTSB's preliminary report on a similar blade-out failure of the same engine in August 2016, which also led to engine shrapnel puncturing the fuselage and wing of a Southwest 737-700.

CFM's newly-released service bulletin stops short of a mandatory inspection, but airlines, such as Southwest and United, have already moved to scrutinise metallic fan blades on older CFM56-7Bs.

The US Federal Aviation Administration announced on 19 April that a directive with a mandatory fan blade inspection procedure will be released within two weeks. The FAA's airworthiness directives are often patterned on related service bulletins issued by manufacturers.

CFM DELIVERS 186 ENGINES IN Q1 BUT MISSES TARGET BY 25%

Published on 20 April 2018

CFM International delivered 186 Leap engines to Airbus and Boeing during the first quarter, but that was about 25% shy of the three-month goal, says GE Aviation chief executive John Flannery.

Despite the slow start, the joint company formed by GE and Safran remains on track to deliver 1,100 to 1,200 Leap engines this year, Flannery told analysts on a first quarter earnings call on 20 April.

CFM had planned to deliver about 250 engines in the first quarter, but missed the target by about 70 units, Flannery says.

Since late 2017, CFM executives acknowledged falling about six weeks behind on delivery commitments to the A320neo and 737 Max aircraft family programmes.

The company has planned to catch up on deliveries by the third quarter this year.

"The team is really, really focused on it into the supply chain and exactly what we need to do, what our suppliers need to do to really move Leap execution," Flannery says. "Right now, we are tracking to be back on track by the end of third quarter."

The Leap engine exclusive powers the 737 Max and is one of two options available for the A320neo. Another version of the engine will be offered on the Comac C919, which enters service after 2020.

FAA AND CFM SEEK TO ADDRESS COMPLEX FAN BLADE ISSUE

Published on 19 April 2018

Federal regulators in 2017 proposed inspections aimed at preventing engine failures like the one that damaged a Southwest Airlines Boeing 737-700 and killed one passenger on 17 April.

Since then, the document has worked through a lengthy federal review process and been subject to comments from airlines, some of which requested more time to complete proposed engine inspections.

The FAA, already under pressure following a critical 60 Minutes report last week, now says it will issue a final airworthiness directive (AD) in the coming weeks.

But it remains unclear if that proposal, had it been issued earlier, might have prevented the Southwest incident, which was caused by the poorly-understood and exceedingly-rare problem of internal cracks in the fan blades of CFM International CFM56-7B engines.

"They can't get a good handle on this," former National Transportation Safety Board member John Goglia tells FlightGlobal. "It's not well understood. We can see the physical results behind [failures], but the cause and the actual mechanism that led to the failure is not so plain to see."

He adds that today's high-bypass engines have larger fan blades than previous-generation engines; when modern blades fail, they can cause more damage.

"As we go to bigger and bigger high-bypass engines and bigger, more-efficient blades, we have been getting more mass in that rotation, which means more damage if [a blade] becomes separated," Goglia says.

On 17 April, Southwest pilots made an emergency landing after their Boeing 737-700's left-side CFM56-7B22 powerplant exploded, damaging the aircraft with shrapnel and breaking a window, which killed one passenger. The aircraft had been operating flight 1380 from LaGuardia to Dallas, but diverted to Philadelphia.

NTSB investigators already traced the failure to a broken fan blade. They found an "internal" crack in the blade near where the blade meets the engine hub.

The FAA responded on 18 April, saying it "will issue an airworthiness directive within the next two weeks that will require inspections of certain CFM56-7B engines."

"The directive will require an ultrasonic inspection of fan blades when they reach a certain number of takeoffs and landings. Any blades that fail the inspection will have to be replaced," the statement said.

Engine maker CFM is also working with the FAA and airlines as it writes an updated service bulletin – one that likewise recommends inspections, that company says.

"We are meeting with the FAA today on timing," CFM tells FlightGlobal. "You can expect a [service bulletin] with immediate FAA endorsement through an AD."

"The actual numbers are being reviewed finalised with the FAA," CFM adds. "The major airlines know it is coming, so those with the largest fleets are prepared."

KNOWN PROBLEM

Those responses build on previous work to address an issue that became salient after the August 2016 inflight failure of a CFM56-7B22 on a Southwest 737-800 over the Gulf of Mexico. The aircraft lost the engine cowling, and the pilots landed safely with no passenger injuries.

Though the NTSB has not issued its final findings, the 2016 event caught everyone's attention.

In a service bulletin issued in March 2017 and updated in June 2017, CFM recommended airlines "as soon as possible" ultrasonically inspect blades in CFM56-7Bs that had accumulated more than 15,000 cycles since a shop visit.

"Investigation has identified a crack that initiated and propagated in fan blade dovetail," says the June update. The dovetail is the end of the blade that fits into the engine hub.

As a matter of proportion, the CFM56-7 has accumulated 350 million flight hours with few problems, according to CFM.

The FAA responded in August 2017 with the proposed airworthiness directive. It proposed requiring airlines, within six months, to ultrasonically inspect fan blades on CFM56-7Bs that had accumulated more than 15,000 cycles since a last shop visit. Engines with less than 15,000 cycles would need inspections within 18 months, the FAA proposed.

The agency estimated 220 engines in service with US airlines would be affected.

"This proposed AD was prompted by a report of an in-flight fan blade failure and uncontained forward release of debris on a CFM56-7B turbofan engine," says the proposal. "The fracture in the blade initiated from the fan blade dovetail."

The industry took no major issue with the 2017 proposal, though some airlines requested longer compliance times. They said the rule would affect more than 220 engines because airlines often swap blades between engines.

CFM actually asked the FAA to reduce from 18 months to 12 months the inspection deadline for engines with less than 15,000 cycles since a shop visit.

Southwest disagreed with CFM, asking for 18 months to inspect 732 affected engines; American Airlines asked for 20 months.

The FAA says the document had been working through the lengthy federal regulatory review process for months, and that it had been weeks away from becoming an AD even before the 17 April Southwest incident.

But the AD might not have applied to the Southwest aircraft anyway. On the day of the accident, Southwest chief executive Gary Kelly said the engine had accumulated 10,000 cycles since a shop visit – below the FAA's proposed 15,000-cycle threshold for urgent inspections.

Following the accident, Southwest said it would inspect all its engines, but the company has not said if it had started or completed any checks prior to the accident.

"FORWARD RELEASE"

Like in 2016 incident, the 17 April engine explosion may not technically qualify as an "uncontained failure" – a term meaning a blade penetrated the casing around the fan, says Goglia.

"You can see the containment ring, and it's still on the engine," Goglia says after viewing NTSB photographs of Southwest flight 1380. "Further back… you see the containment ring. It's totally intact."

The blade broke near the hub, according to the NSTB. It apparently flew forward, hitting the forward part of the cowling and causing the cowling to disintegrate into shrapnel that damaged the aircraft, Goglia suspects.

Investigators retrieved parts of the cowling on the ground 65nm (120km) from Philadelphia, the NTSB said.

"Everybody has been saying it's an uncontained engine failure. It isn't by the FAA definition," Goglia says.

Experts studying such failures believe the forward trajectory results from pressure behind the blades, he adds.

But the extreme rarity of such failures and complexity of forces involved make testing, understanding and predicting blade failures difficult.

The blades whirl thousands of times per minute, forcing cold outside air into hot aft sections, Goglia notes. And incidents like bird strikes, even those years ago, might theoretically degrade blade strength.

"[Engine makers] are using the very best materials they can get their hands on, but we are still learning," he says. "In order to get that knowledge, there is got to be a lot of testing on blades to get them to break on the ground."

Fixing the problem now rests with the FAA, CFM and airlines. One possible solution could be to require airlines to replace blades after a specified number of cycles – throw them out and replace them with new blades, Goglia says.

But blades are "brutally expensive", and airlines would likely be wary of a "knee jerk" reaction to a poorly-understood problem, he says.

NTSB

UNITED INSPECTING 737 ENGINES FOLLOWING SERVICE BULLETIN

Published on 18 April 2018

United Airlines is inspecting 698 CFM International engines on its Boeing 737 fleet following a recent service bulletin from the manufacturer, says chief operating officer Greg Hart.

The bulletin, which was released during the week of 9 April, follows an incident aboard a 737 in 2016, says Hart without specifying the incident during a quarterly earnings call today.

United has already begun inspections and plans to "comply fully" with the service bulletin, adds chief executive Oscar Munoz during the call.

The Chicago-based carrier operates 329 737-700, -800 and -900ERs with CFM56 engines, Flight Fleets Analyzer shows.

The comments come a day after a passenger died aboard a Southwest Airlines Boeing 737-700 when a CFM56-7B engine failed inflight with shrapnel puncturing both the fuselage and wing of the aircraft. The flight, Southwest 1380, enroute to Dallas Love Field from New York LaGuardia landed safely at Philadelphia International airport.

The National Transportation Safety Board (NTSB) said on 17 April that a preliminary inspection found signs of metal fatigue where a fan blade separated from the engine.

A similar incident occurred in August 2016 when another Southwest 737-700 with CFM56 engines suffered a fan blade separation, forcing an emergency landing in Pensacola.

Following the 2016 incident, the US Federal Aviation Administration issued an airworthiness directive mandating ultrasonic inspections of certain CFM56 engines last year.

United stands "shoulder-to-shoulder" with Southwest following the incident yesterday, says Munoz.

The death aboard Southwest 1380 is the first passenger death onboard a US passenger carrier since 2009, and the first ever for the Dallas-based airline.

CFM'S HYDERABAD TRAINING CENTRE ADDS LEAP CAPABILITY

Published on 9 March 2018

CFM International's training centre in Hyderabad has added capability to train engineers on Leap-1A and -1B engines.

The centre, which opened in 2010, has provided hands-on training for CFM56-7B and -5B engines, and adding the Leap courses will enable it to support operators of Airbus A320neos and Boeing 737 Max jets in the region powered by the new engines.

CFM International says that the facility has capacity to train 500 engineers each year, and mirrors similar facilities in China, France and the United States.

Safran

CFM SETS NEW ENGINE DELIVERY RECORD DESPITE LEAP SHORTFALL

Published on 25 January 2018

CFM International delivered a total of 459 Leap engines to three manufacturers in 2017, but the joint venture struggled to keep pace with demand while coping with parts shortages and teething problems in service, executives said on 25 January.

The number of Leap engine deliveries last year represented a six-fold increase over the 77 Leap-1A engines delivered to the Airbus A320neo family in 2016 and formed about one-fourth of the 1,900 engines that CFM delivered overall to set a new annual record in 2017, says CFM executive vice-president Francois Bastin.

Despite the swift production ramp-up, CFM still fell short of demand from Airbus and Boeing. The joint venture between GE Aviation and Safran Aircraft Engines is running about four to five weeks behind on engine deliveries, Bastin says, speaking to journalists on a teleconference hosted by CFM on 25 January ahead of the Singapore air show.

The delivery shortfall means CFM is under pressure to continue meeting demand in 2018, with a planned 250% jump in production to 1,100 to 1,200 engine deliveries this year, Bastin says.

"We are a handful of weeks behind demand," he says. "It's that much and only that much. The demand is a tremendous ramp-up that was set years ago."

CFM's Leap-1A first entered service on the A320neo in August 2016, followed by the Leap-1B on the 737 Max 8 about nine months later. After delivering 77 Leap engines in 2016 and 459 in 2017, CFM plans to deliver up 1,200 more this year, 1,800 more in 2019 and more than 2,000 in 2020, Bastin says. At the same time, CFM is continuing to build large numbers of CFM56 engines.

The production ramp-up is part of a rapid growth spurt in the single-aisle market, as Airbus and Boeing race to double production capacity within a decade, with announced deliveries reaching nearly 60 a month for A320neo and 737 Max families by next year. Meanwhile, CFM and Pratt & Whitney also are supporting several other aircraft types, with the former providing the Leap-1C for the Comac C919 and the latter building versions of the geared turbofan for the Airbus A320neo, Bombardier CSeries, Embraer E-Jet E2, Irkut MC-21 and Mitsubishi Regional Jet.

"It's not a walk in the park," Bastin acknowledges. "We have some disruptions. We are working to address them."

The first sign of teething issues appeared last May when Boeing grounded the 737 Max 8 test fleet on the eve of entry-into-service to address a flaw in turbine discs within about 30 or 40 Leap-1B engines. A few months later, CFM also discovered another disc forging problem that caused the joint venture to remove 70 Leap-1As for inspections, of which about half are completed, says Alan Paxson, CFM's second executive vice-president.

Around the same time, CFM also detected a problem with a coating for a turbine shroud. The coating was flaking off the ceramic matrix composite (CMC) shrouds, leading to an increase in exhaust gas temperatures. CFM is implementing several repairs to keep Leap engines with the defective coating in operation longer despite the metal-fatiguing temperature increase, while also working to develop a more effective coating for the CMC shrouds, Bastin says.

Finally, the company also is working to increase supply chain capacity to keep up with demand during the production ramp-up, Bastin says. The company decided to work with two sources for each major component in the engine, so the rate of deliveries would never be threatened if one supplier ran into trouble. But that strategy also made it more complicated to ramp up production with a larger number of suppliers. Despite those challenges, CFM expects to complete its two-source capacity strategy by the end of this year, Bastin says.

ROLLS-ROYCE FURTHER BROADENS TRENT 1000 CHECKS

Published on 11 June 2018

Rolls-Royce is extending its inspection regime on Trent 1000 engines to include other models of the powerplant which may be affected by the blade durability issue.

While the analysis and examinations have focused on the Package C version of the Trent 1000, the manufacturer says it has found a "similar" issue with the intermediate pressure compressor on Package B engines.

The manufacturer is taking precautionary preventive measures to redesign specific parts in the Package B version as well as its latest Trent 1000 TEN engine.

Rolls-Royce's Package B version has been in service on Boeing 787s since 2012 and comprises 166 powerplants. The manufacturer states that the durability issue has been identified on a "small number" of high-life engines.

"We have therefore agreed with the relevant regulatory authorities, with concurrence from Boeing, to carry out a one-off inspection of our Trent 1000 Package B fleet," it says.

Rolls-Royce says this measure will "further inform our understanding" of the problems involved. It had originally said, when it broadened the extent of Package C checks in April, that neither the Package B nor the TEN would be affected.

But it now admits it is taking the "precautionary" measure of commencing redesign of specific components in the Package B model as well as the Trent 1000 TEN – which has not shown any durability problems, although the TEN engine fleet is young.

The European Aviation Safety Agency is to issue an airworthiness directive covering the extended Package B inspection regime.

"We anticipate there will be a limited impact on customer operations to enable this programme of one-off inspections to take place," says Rolls-Royce. "Engines will be inspected on-wing using existing techniques."

Civil aerospace president Chris Cholerton insists the company is "committed to eliminating" the durability problem from the Trent 1000 intermediate compressor. The company points out that it has "successfully" run a redesigned compressor for the Package C engine.

ROLLS-ROYCE TO UPDATE TRENT 7000 PARTS IN WAKE OF TRENT 1000 ISSUES

Published on 29 March 2018

Rolls-Royce expects the Trent 7000 engines powering the in-development Airbus A330neo to require modification as a result of the technical issues seen on Trent 1000s.

The Trent 7000 – set to enter service in mid-2018 as the sole engine available for the A330neo – is derived from the Trent 1000, an option on the 787.

Although R-R has been forced to redesign the intermediate-pressure (IP) turbine blade on the Trent 7000 and the latest version of the Trent 1000, the -TEN, due to durability issues, the manufacturer has no concerns about the new part's longevity.

"Neither the Trent 1000-TEN nor the Trent 7000 are affected by the issues we have experienced with [IP] turbine blades within the Trent 1000, which have caused unscheduled shop visits," the engine maker says.

However, the durability issues on Trent 1000s also cover the engines' high-pressure (HP) turbine and IP compressor.

R-R is in the process of preparing redesigned blades for both the HP turbine and IP compressor, a source familiar with the situation tells FlightGlobal.

The Trent 7000's HP turbine blade is slightly different from that on the Trent 1000, and disparities also exist between the two engines' IP compressor blades. But the source confirms that R-R will introduce redesigned HP turbine and IP compressor blades for the Trent 7000, which will need to be retrofitted to in-service engines.

The new blades are scheduled to become available by year-end, and will be installed during "targeted", rather than unscheduled, maintenance events, the source says.

R-R states: "Early Trent 1000-TEN and Trent 7000 engines may benefit from proactive maintenance to embody parts… that weren't available at the point of production."

The engine manufacturer does not anticipate a disruptive modification programme as seen on the Trent 1000, because the pool of Trent 7000s and Trent 1000-TENs is smaller and new blades are being prepared earlier in the engines' lifecycles.

R-R says it is "normal practice at the very start of a new engine programme" that parts are updated to address potential in-service issues.

Airbus

ROLLS-ROYCE 'CONFIDENT' XWB WILL NOT SUFFER TRENT 1000 ISSUES

Published on 21 February 2018

Rolls-Royce is confident that its Trent XWB powerplant for the Airbus A350 will not be afflicted by similar technical problems which have emerged on the Trent 1000.

The A350 family is exclusively powered by the Trent XWB – the -900 variant is fitted with the XWB-84 and the larger -1000 has the higher-thrust XWB-97.

Speaking during the delivery of the first A350-1000 to Qatar Airways, newly-appointed Rolls-Royce civil aerospace chief Chris Cholerton said the XWB engine had "performed superbly" over the three years since service entry.

Cholerton was the programme director for the XWB-84 and says the engine has completed 1.3 million flight hours, around 25% of which were with Qatar Airways.

This shows the powerplant has "demonstrated that reliability in some pretty arduous environments", he says, putting dispatch reliability at 99.9%.

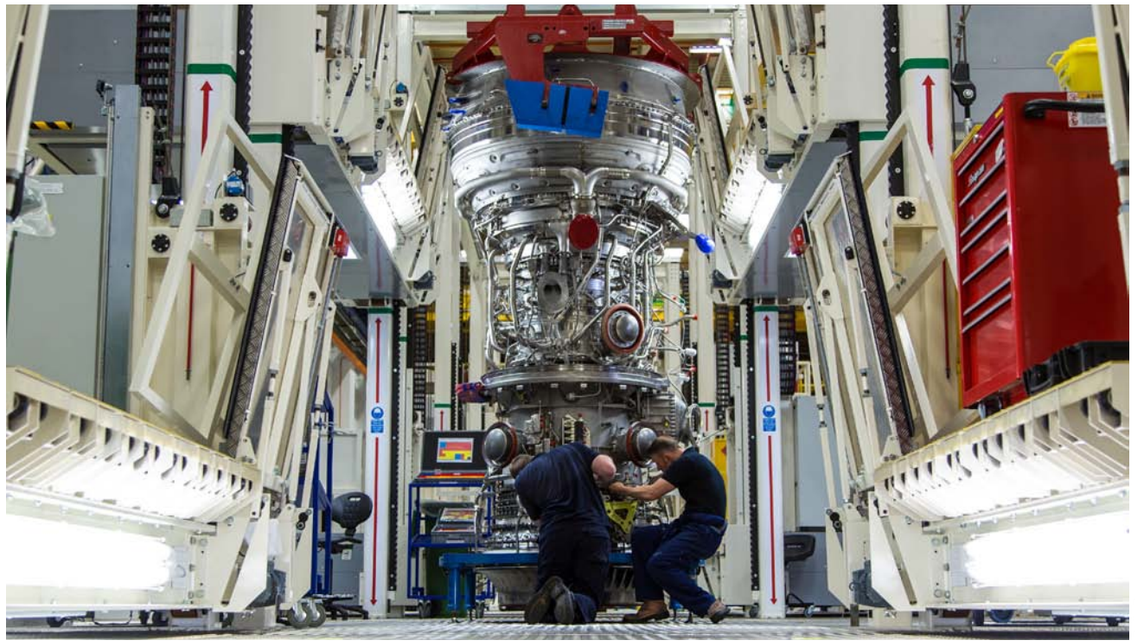
While acknowledging the difficulties experienced by some operators of Trent 1000 engines on Boeing 787s, relating to compressor blade durability, Cholerton says he has "very high confidence" that the Trent XWB will not face similar or related issues.

He says that the XWB has a different architecture, and adds: "[The] magnitude of testing, the magnitude of experience we have, and the experience to date in the fleet – of those 1.3 million flying hours – has been exceptional."

For the -1000 the XWB-97 incorporates an improved, higher-speed fan, a larger core, and new materials and coatings for protection.

The manufacturer ran 10 XWB-97 development engines over 3.5 years, exposing them to extreme conditions in five countries, and logging over 11,000 simulated flight cycles, as well as 1,600h of flight tests.

Cholerton claims the XWB has "set a new record for reliability" for entry into service of a large commercial air transport engine. Rolls-Royce says the engine type accounts for about 40% of its order book.



Rolls-Royce

ROLLS-ROYCE PARTNERS WITH AIRBUS FOR ULTRAFAN FLIGHT TESTS

Published on 26 April 2018

Rolls-Royce will co-operate with Airbus to develop a nacelle and pylon for flight tests of the UK manufacturer's under-development UltraFan demonstrator engine.

The European airframer has been recruited to provide "both nacelle and engine/aircraft integration architecture and technology enablers" for ground and flight tests under the future engine programme, R-R says.

"Airbus integration solutions will play an important part in achieving the overall fuel-efficiency improvement," the engine maker says, with this achieved through "innovative architecture and associated technologies".

It notes the trial will be conducted on "a Rolls-Royce flying test-bed"; the Derby-headquartered manufacturer uses a Boeing 747 for test flights of its engines.

Airbus's head of research and technology, Axel Flaig, says the co-operation represents "a key project to pave the way towards the next-generation integrated propulsion systems that will be needed by airline customers towards the end of the next decade".

The partnership will enable Airbus to "fully integrate the overall powerplant system – composed of engine, pylon and nacelle – onto future long-range aircraft products" and to facilitate "scalability for future short-range aircraft", the airframer says.

Advanced manufacturing technologies, including high-deposition-rate 3D printing, welded assembly and high production-rate thermoplastics, are to be employed for the project.

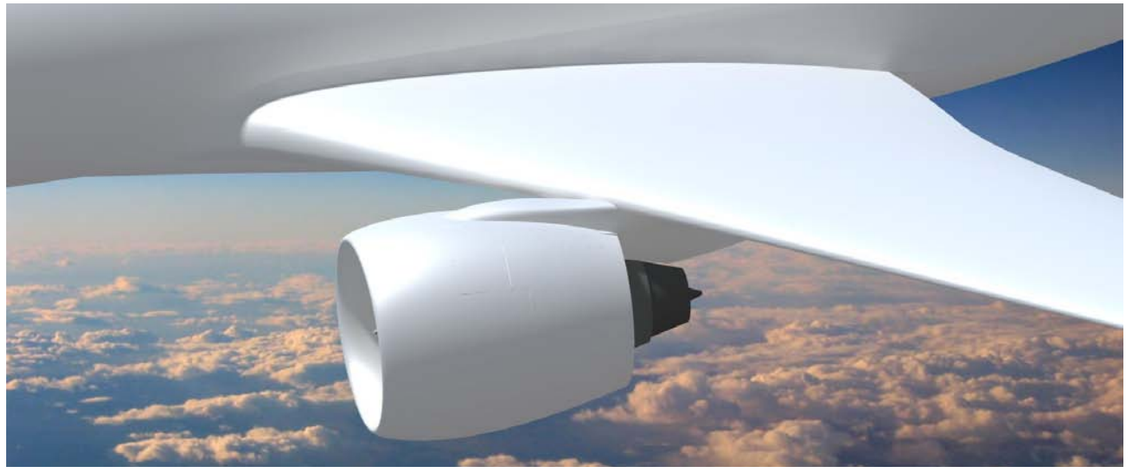
Under the UltraFan programme, R-R will develop a geared turbofan that will utilise an engine core that is being developed in a separate future technology effort named Advance.

The new engine is set to reduce fuel consumption by 25% versus the Trent 700, and is scheduled to become available for service entry from 2025.

R-R is in the process of testing individual sections and components of UltraFan, including a demonstrator version of the Advance engine core.

In February, R-R's chief engineer of civil aerospace future programmes, Phil Curnock, said the manufacturer intended to build an UltraFan demonstrator in "a few years' time".

UltraFan has not yet been selected for any aircraft programme, and R-R has previously not associated the future engine with any particular airframer. However, the manufacturer has offered a variant of the developmental powerplant for Boeing's New Mid-market Airplane.



Airbus

ROLLS-ROYCE PONDERS GERMAN MOVE TO ENSURE EASA RULE

Published on 26 April 2018

Rolls-Royce is considering a transfer of engine certification processes to Germany to guarantee that powerplants can be approved under European regulations post Brexit.

"We have to consider what contingency measures we may need to take to ensure our operations in the UK and elsewhere can continue [after Brexit]," the engine manufacturer says.

It adds: "These may in the future include the transfer of the design approval for our large jet engines from the UK to Germany."

Prime Minister Theresa May indicated in March that the UK could seek associate membership of the European Aviation Safety Agency in future. But with the country to leave the EU in March 2019, there is still no definite plan for UK aviation regulation after that date.

Without a succession agreement in place, the UK would no longer be covered by EASA regulations.

R-R says it is in "regular dialogue" with the UK government "to ensure there is no interruption in our service to customers as a result of Brexit".

The manufacturer already handles certification for business jet engines from Germany, as the powerplants are assembled at Rolls-Royce's Dahlewitz site near Berlin.

That facility also builds Trent XWB engines for the Airbus A350, in addition to R-R's assembly line at its Derby headquarters.

Transferring certification of large engines to Germany would be a "technical measure", and the company says: "We do not anticipate such a move would lead to the transfer of any jobs from the UK."

The move is one of several options being considered as potential post-Brexit contingency plans. R-R insists "no final decision" has been taken on whether to "activate this precautionary measure".

ROLLS-ROYCE STARTS BUILDING ADDITIONAL TESTBED IN DERBY

Published on 22 March 2018

Rolls-Royce has begun construction of a new engine testbed at its Derby headquarters.

Plans for the testbed, which is to become operational in 2020, were disclosed by the engine maker in 2017, as part of a £150 million ($210 million) programme of investments in UK aerospace facilities.

Additional testing capacity is required amid increased output of engines, says R-R, citing the Trent 1000 and Trent XWB, which power the Boeing 787 and Airbus A350 respectively.

"It comes at a pivotal moment... as we ramp up production to record levels," states the engine maker's president of civil aerospace Chris Cholerton.

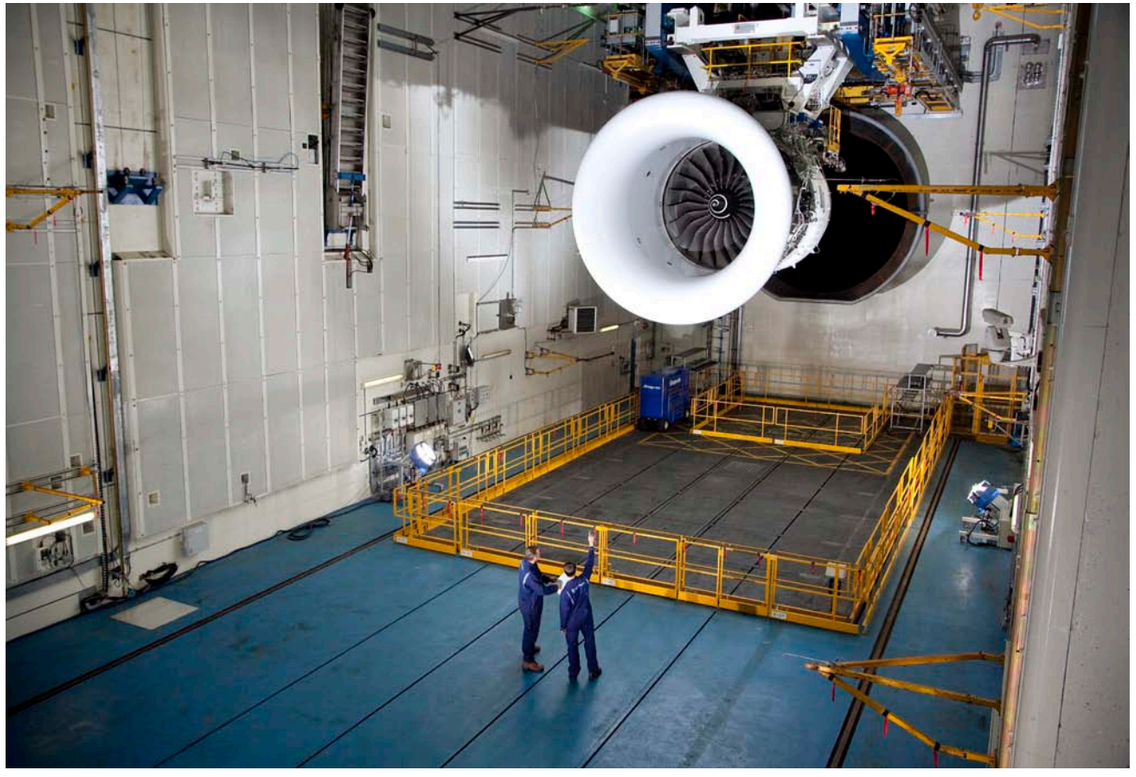
The facility will be additionally employed for testing of the UltraFan future engine programme.

R-R says the testbed will be the "largest indoor facility of its type in the world" and will be used for a range of assessments, including water ingestion and endurance trials.

It is to be equipped with the "latest digital technology", including X-ray systems to assess the engines' internals during operation.

The UK's business secretary Greg Clark describes the project as "a reminder of Rolls-Royce's commitment to Derby and the UK" and part of efforts to ensure the country "remains at the pinnacle of engineering and aerospace excellence".

He states that the facility represents "exactly the type of investment our modern industrial strategy will continue to attract".



Rolls-Royce

INTERVIEW: R-R ENGINE EXPERT DISCUSSES FUTURE FIGHTER TECHNOLOGY

Published on 16 February 2018

Rolls-Royce believes that advanced engines will be the single most important design factor for future fighter aircraft.

Conrad Banks is R-R's chief engineer for defence future programmes. In his 30-year career he has worked on projects such the Pegasus for the BAE Systems Harrier and the EJ200 for the Eurofighter Typhoon. Now his role is to look towards the future.

"My job is to get the best technology developed, so whichever platform goes forward – future fighter, UCAVs, combinations of, growth variants – we are in a position to exploit and develop the best system," he says.

"We're putting advanced technology on the shelf. When the politicians agree to collaborate on certain programmes we are ready to press the button. When sixth technology [fighter] programmes are launched, we'll be ready with solutions."

Banks believes that the physical characteristics of fighters, whether manned or unmanned, will largely be driven by the shape of the propulsion system – which comprises the engine as well as the intake and exhaust.

This is a departure from the past, where airframers would develop an aircraft, and call on engine-makers to provide an engine of a certain thrust. The change is largely driven by the premium placed on stealth, which demands that engines be buried deep in an aircraft. S-shaped inlets fore and aft ensure that radar waves cannot reach engine parts without bouncing around the intake or exhaust. Shaping, however, while crucial, is not enough: radar absorbent materials (RAM) are also necessary to absorb radar waves.

"By the time you've got these S-shaped intakes front and back, the length of the propulsion system is very long," says Banks. "The airframers want it to be as short as possible because then the aircraft does not have to be unnecessarily large, and they've got more space for weapons and fuel."

THE LEGACY OF TARANIS

Should the intake be scrunched up too much, the engine could be prone to surges. Banks says a great deal about the relationship between engine, airframe, and aerodynamics was learned from the secretive BAE Systems Taranis technology demonstrator, which is powered by an off-the-shelf Adour engine. Jointly funded by the UK's Ministry of Defence and industrial partners including BAE Systems and Rolls-Royce, the unmanned Taranis remains shrouded in secrecy since its first flight in 2013.

A key focus area for R-R is the development of distortion-tolerant military fans, which are better able to deal with separation of air flow issues. Banks says the length of the intake in front of the engine is determined by fan-size. If the length is less than four times the fan diameter, "very, very high distortion levels" occur.

"What you want to do is crumple [the intake] up as much as possible, and do the same with the exhaust," says Banks. "The more you crumple this up, the shorter the length of the propulsion system, and the more flexibility the airframer has to design the aircraft."

POWER HUNGRY

Another focus area is an embedded starter-generator that could save space and provide the large amount of electrical power required by future fighters. Banks says power demand on fighters will rise exponentially, with electricity needed for powerful radars, electrically-actuated control surfaces and directed energy weapons.

Existing aircraft engines generate power through a gearbox underneath the engine, which drives a generator. In addition to adding moving parts and complexity, the space required outside the engine for the gearbox and generator makes the airframe larger, which is undesirable in a stealthy platform.
"By the time you've embedded all of this underneath, it increases the diameter of the installation," says Banks.

So R-R is working on fusing magnets to the rotating shaft of the engine, which can reach 15,000 rotations per minute. The placement of wires outside this creates an electric motor. "If you have magnetics rotating, and you have wires, you generate electricity."

In addition to generating power for the aircraft, the system can also serve as a starter generator. By energising the shaft with, say, power from a battery or a ground power unit, the engine winds up. Magnets can be applied to both the high and low pressure shafts, effectively creating two separate power generators.

"I can take more energy from one shaft, rather than the other," says Banks. "If have a surge issue at high altitude because the air is rarefied, I can unload the fan and direct energy from one shaft to the other, providing more surge margin. You can intelligently siphon off energy."

GOODBYE GEARBOX

"We can remove all of the gearbox underneath the gas turbine. Now we tell the airframer that all we need is a battery or electrical power source, and that starts your engine for you… it's a win-win. Everything is beneficial."

The company is also continuing to develop advanced composites that can reduce weight inside the engine.

Work is underway on these systems at Rolls-Royce's lab in Bristol. Banks stresses that the technologies are not being developed with a specific aircraft in mind, but for futuristic programmes in general. One of these, of course, is the prospective British-French Future Combat Air System (FCAS).

"If we can offer a slimline, power dense, propulsion system because we've cracked distortion tolerance, and with electrical energy that's generated at the heart of the gas turbine – and not generated via generators mounted on the pad like at the moment – then everyone wins and you have a much more efficient system," he says.

ROLLS-ROYCE UNVEILS 'INTELLIGENT ENGINE' INITIATIVE

Published on 5 February 2018

Rolls-Royce has launched its "IntelligentEngine" concept, focused on the use of digital data in the development and operation of future powerplants.

The UK manufacturer's senior vice-president of marketing for civil aerospace Richard Goodhead says the concept – based on the premise that engines will be increasingly connected to their operating environments, via data links – represents a mindset change that is "as big a shift as going from the piston engine to the gas turbine engine".

Prior to the introduction of the Trent series in the 1990s, Rolls-Royce concentrated on manufacturing engines and, separately, providing overhaul services, notes Goodhead. With the launch of the manufacturer's hour-based support programmes, however, aftermarket services became more central and began to increasingly overlap with engine production as more models were added to the Trent range.

Goodhead believes that the confluence will be "supercharged" by digital services, and that engine development, production and in-service support will be "inextricably linked... not too far in the future".

He says engines will be connected not just to the manufacturer's support organisation, but also to the operator's infrastructure and every other engine across the fleet in a "totally connected, Internet of Things-type environment". Whereas automatic data downloads from the engine used to provide information about conditions inside the powerplant, Goodhead says engines are now being "contextualised". A much broader range of information about the equipment's individual operating environment and history is available, and can be used to optimise the engine's efficiency and reliability.

Engines will also be "comprehending" in future – "self-aware" and able to learn through artificial intelligence to optimise operations, Goodhead predicts.

"This is more visionary... But ultimately we could see an engine that has diagnosed what's wrong with it and is able to fix itself," he says, noting that robots are being developed to conduct autonomous repairs inside an engine.

He stresses that the "IntelligentEngine" is not a new powerplant or aftermarket programme, but represents a "new way of thinking". The concept will be applied to "any engine going forward", and is particularly relevant to the development of new propulsion systems – including electric and hybrid-electric powerplants – and to aircraft with greater integration between the airframe and engine.

R-R SEES POSSIBILITY FOR ULTRAFAN ON A350, 787

Published on 7 February 2018

Rolls-Royce foresees opportunities to re-engine the Airbus A350 and Boeing 787 as a potential avenue for its UltraFan future engine programme.

Chief technology officer Paul Stein suggested during a briefing at the Singapore air show that airframers might now opt more quickly to re-engine existing aircraft types to keep their equipment relevant.

Asked if the 787 might represent such an opportunity in 20 years, Stein said: "Yes… maybe not in 20 years' time. I think re-engining of aircraft is probably coming more frequently."

He confirms that the A350 is also a target alongside "any other types of aircraft by any other manufacturer".

The A350 is exclusively powered by the UK manufacturer's Trent XWB, while the 787 is available with Trent 1000 or the GE Aviation GEnx engine.

Rolls-Royce expects the first engine of its UltraFan generation to enter service between 2025 and 2027. UltraFan – which will feature a new engine-core architecture and a geared carbon-composite fan – is currently a demonstrator programme that is not tied to a particular aircraft.

Stein notes that some aircraft may not have sufficient room under the wing to accommodate the future engine, which is set to have a fan diameter of up to 356cm (140in). "It is possible with a very short… blended pylon arrangement that UltraFan could be fitted under some existing aircraft programmes," he says.

He also points out that airframers might need to opt for a gull-wing design to create enough ground clearance for larger engines on future aircraft.

MRJ TEST FLEET GROUNDED AFTER PW1200G FLAMEOUT

Published on 24 August 2017

Mitsubishi Aircraft has grounded its MRJ regional jet flight test fleet, following an engine "flameout" on one of its test prototypes on 21 August.

The Japanese manufacturer tells FlightGlobal that there was an "uncommanded shut down" of FTA-2's left Pratt & Whitney PW1200G engine during a test flight.

Mitsubishi would not say what tests the aircraft was conducting when the flameout occurred, but said the incident happened in training airspace over the ocean, about 170km west of Portland. Pilots were alerted to the issue only when the left engine shut down.

The aircraft had taken off from Moses Lake at 14:00 local time and had to make an unscheduled landing at Portland International airport at 17:12 local time.

"After a quick investigation with the borescope, we confirmed that there was partial damage inside the engine. We're still investigating the cause," says the manufacturer, adding that a Pratt & Whitney team is also onsite in Portland, aiding with the investigation.

Mitsubishi has since grounded its flight test fleet. It will only decide when to resume flight tests after the cause of the incident is determined. It was unable to say how this would affect its programme schedule.

Mitsubishi has four flight-test aircraft, and is working to deliver its first MRJ90 to launch customer All Nippon Airways in mid-2020.

Pratt & Whitney has suffered a series of minor crises with the related PW1100G engine (which powers the Airbus A320neo) including bowed rotors, parts shortages, prematurely deteriorating components and an in-flight shutdown.

The PW1000G series powers other types such as the Bombardier CSeries, Embraer E-Jets E2. and Irkut MC21.

ROLLS-ROYCE TESTS LEAN-BURN COMBUSTOR IN ICING CONDITIONS

Published on 26 March 2018

Rolls-Royce has conducted icing tests on a demonstrator engine equipped with a lean-burn combustor to be used in the manufacturer's Advance and UltraFan future powerplant programmes.

The UK manufacturer says that the modified Trent 1000 engine – dubbed ALECSys, or advanced low-emission combustion system – underwent cold-weather rig trials in Canadian province Manitoba at temperatures of -20°C (-4°F) a month after initial ground tests at R-R headquarters in Derby.

R-R told FlightGlobal in January that the ground tests had been completed that month.

The combustor features two different fuel-distribution systems to facilitate more efficient mixing of air and fuel during take-off, climb and cruise.

"Tests have so far shown a halving of NOx [emissions] at cruise, compared to today's levels," says R-R.

Andy Geer, the manufacturer's chief engineer and head of technology programmes, says that while computer simulation has provided "in-depth understanding" of the system's operation in extreme temperatures, the cold-weather trials were required to validate the data.

The lean-burn combustor has been included in R-R's Advance3 demonstrator engine, the purpose of which is to assess a new and more efficient core for a future-generation turbofan, and of which ground tests began in Derby in November 2017.

The ALECSys development effort is part-funded by the EU's Clean Sky future technology research programme, R-R notes.

ROLLS-ROYCE EXPANDS SUPPLIER DEAL WITH INDIA'S GODREJ AEROSPACE

Published on 26 March 2018

Indian firm Godrej Aerospace has secured a $30 million contract from Rolls-Royce to manufacture components for the engine maker at its new facility in Mumbai over the next five years.

Under the new agreement, Godrej will manufacture unison rings, external brackets and undertake other complex fabrication work. The contract will see the shipment of 600 different parts spread across R-R's civil engine range.

The new agreement is an expansion of an earlier contract signed in 2014 to manufacture unison rings for the engine manufacturer. Since then, Godrej has also started complex sheet metal fabrication.

The company has invested Rs500 million ($6 million) into a new facility in Mumbai that it has "opened itself to a global market size in excess of Rs15 billion".

"The expansion of partnership with Godrej for manufacturing of aero engine components showcases our commitment to developing an aerospace ecosystem in the country. We are constantly developing and rationalising strategic partnerships across our supply chain. With the expansion of this partnership... our focus will be to meet our customers' strategic requirements in quality, cost and delivery," says Kishore Jayaraman, president of Rolls-Royce India and South Asia.

Godrej has been manufacturing aerospace components since 2005 and, and is also a supplier to General Electric and Safran.

GE9X ENTERS FLIGHT TEST PHASE

Published on 15 March 2018

GE Aviation's GE9X turbofan flew for the first time on 13 March, launching a months-long engine certification campaign for the largest turbofan engine in history.

The 340cm (134in)-diameter fan mounted on the inboard station of the left wing of GE's Boeing 747-400 flying test bed took off from Victorville, California.

"Today's flight starts the beginning of the GE9X flight test campaign that will last for several months, allowing us to accumulate data on how the engine performs at altitude and during various phases of flight," says GE programme manager Ted Ingling.

The GE9X will power the Boeing 777-9 and 777-8, which are scheduled to enter service in 2020 and 2022, respectively.

The 105,000lb-thrust engine produces less thrust than the older 115,000lb-thrust GE90 for the 777-300ER, but is 10cm wider. The additional width increases the bypass ratio to about 10:1, a key metric in GE's plan to reduce fuel burn compared to the GE90 by about 10%.

The first flight comes more than two months behind schedule. GE planned to begin flying the first flight test engine – designated within the programme as the No. 4 engine – by the end of last year.

GE decided in mid-December to redesign the external lever arm that actuates to move the variable stator valves. The redesign of the lever arm is ongoing, but flight test has started using the previous design, GE Says.

The GE9X programme also has completed icing tests at GE's facility in Winnipeg, Canada. Crosswind tests are continuing at the Peebles Test Operation in Ohio.

Meanwhile, Boeing has started assembling the first 777-9 aircraft in Everett, Washington. In addition to the GE9X engines, the 777X family will feature a 71.8m-span composite wing with folding wingtips and a longer fuselage.

C919'S LOCAL ENGINE ALTERNATIVE POWERED UP

Published on 18 May 2018

China has successfully achieved power-on for the first CJ-1000AX demonstrator engine, the alternative powerplant for the in-development Comac C919.

The high-bypass turbofan engine's core reached a maximum speed of 6,600 rpms, disclosed China's Ministry of Industry and Information Technology.

It adds that since the assembly of the demonstrator engine was completed last December, Chinese manufacturer AECC Commercial Aircraft Engine has overcome numerous issues in connections and debugging. All adjustments were finally completed on 30 March.

With the engine power-on, conducted in a test cell in Shanghai, the ministry says the functionality of its various components and systems have preliminary verification. Subsequent tests will determine the performance of the engine in its entirety.

The CJ-1000AX has a diameter of 1.95m (76.8in) and a length of 3.29m (10.7ft). China plans to build 24 more CJ-1000 prototype engines to support an airworthiness campaign, with entry into service targeted after 2021.

The C919 will initially be powered by CFM International Leap-1C powerplants.

ENGINE OPTIONS BY COMMERCIAL AIRCRAFT

Aircraft type	No of engines	Engine option 1	Engine option 2	Engine option 3
AIRBUS				
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	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	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		

Aircraft type	No of engines	Engine option 1	Engine option 2	Engine option 3
BOMBARDIER				
CSeries	2	PW1500G		
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	
IRKUT				
MC-21	2	PW1400G	PD-14	
LOCKHEED				
L-1011*	3	RB211		
MITSUBISHI REGIONAL JET				
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

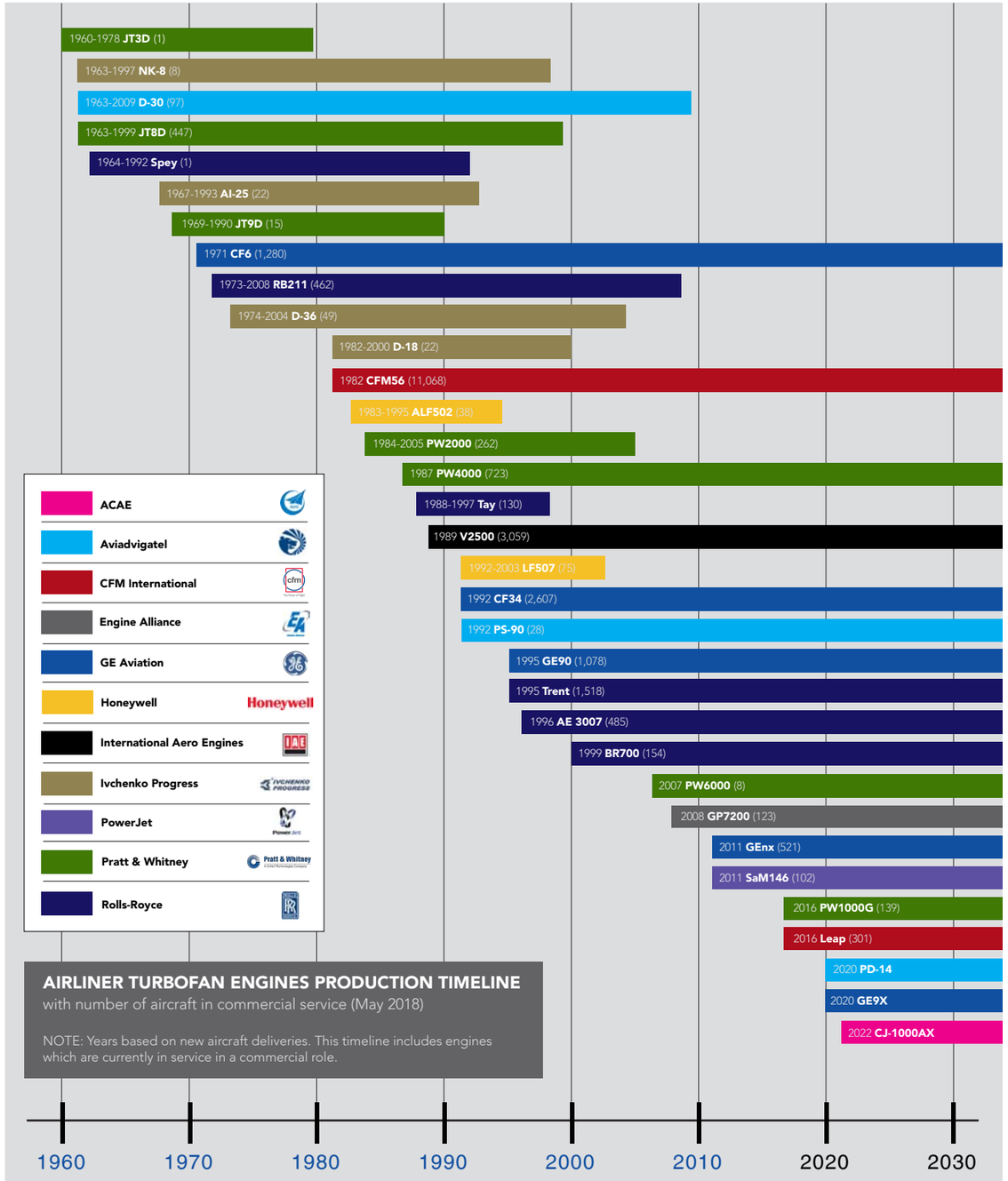
COMMERCIAL AIRCRAFT BY ENGINE TYPE

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
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

Engine type	Aircraft type
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	A320neo family, CSeries, 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	A330, A330neo, A340*, A350, A380, 777, 787
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

TURBOFAN ENGINES: PRODUCTION TIMELINE



AVIADVIGATEL

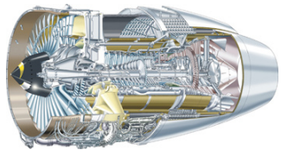
Founded: 1934
Ownership: United Engine Corporation
Number of commercial aircraft powered: 125
Number of aircraft on order: 14

D-30

Production: 1963-2009
Variants: KP, KU, KU-154
Applications: Il-62, Il-76, Tu-134, Tu-154
Aircraft in service: 97

PS-90

Production: 1992-present
Variants: A, A-76, A1, A2, A-42, A3
Applications: Il-76, Il-96, Tu-204
Aircraft in service: 28



PD-14

Production: due in 2018
Application: MC-21
Aircraft on order: 14

CFM INTERNATIONAL

Founded: 1974
Ownership: Joint venture between GE Aviation and Safran Aircraft Engines
Headquarters: France and Cincinnati, Ohio, USA
Number of commercial aircraft powered: 11,369
Number of aircraft on order: 5,792

CFM56

Production: 1982-present
Variants: -2, -3, -5A, -5B, -5C, -7B
Applications: A320 family, A340, 737 family, DC-8
Aircraft in service: 11,068
Aircraft on order: 486

LEAP

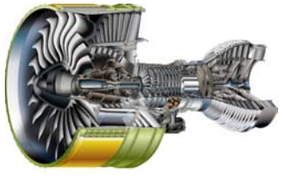
Production: 2016-present
Variants: -1A, -1B, -1C
Applications: A320neo family, 737 Max, C919
Aircraft in service: 301
Aircraft on order: 5,306

ENGINE ALLIANCE

Founded: 1996
Ownership: Joint venture between GE Aviation and Pratt & Whitney
Headquarter: East Hartford, Connecticut, USA
Number of commercial aircraft powered: 123

GP7200

Production: 2008-present
Variants: GP7270, GP7277
Application: A380
Aircraft in service: 123



GE AVIATION

Founded: 1917
Ownership: Subsidiary of General Electric
Headquarter: Evendale, Ohio, USA
Number of commercial aircraft powered: 5,486
Number of aircraft on order: 1,135

CF6

Production: 1971-present
Variants: -6, -50, -80
Applications: A300, A310, A330, 747, 767, DC-10, MD-11
Aircraft in service: 1,280
Aircraft on order: 69

CF34

Production: 1992-present
Variants: -1, -3A, -3B, -8C, -8E, -10A, -10E
Applications: ARJ21, CRJ, E-Jet
Aircraft in service: 2,607
Aircraft on order: 282

GE90

Production: 1995-present
Variants: -76B, -77B, -85B, -90B, -92B, -94B, -110B1, -115B
Application: 777
Aircraft in service: 1,078
Aircraft on order: 94

GEnx

Production: 2011-present
Variants: -1B, -2B
Applications: 747-8, 787
Aircraft in service: 521
Aircraft on order: 364

GE9X

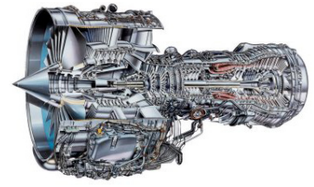
Production: due in 2020
Applications: 777-8X/9X
Aircraft on order: 326

INTERNATIONAL AERO ENGINES

Founded: 1983
Ownership: Joint venture between P&W, MTU Aero Engines and Japanese Aero Engine Corporation
Number of commercial aircraft powered: 3,059
Number of aircraft on order: 41

GP7200

Production: 1989-present
Variants: -A1, -A5, -D5, -E5
Applications: A319, A320, A321, MD-90
Aircraft in service: 3,059
Aircraft on order: 41



POWERJET

Founded: 2004
Ownership: Joint venture between Safran Aircraft Engines and NPO Saturn
Headquarter: Paris, France
Number of commercial aircraft powered: 102
Number of aircraft on order: 34

SaM146

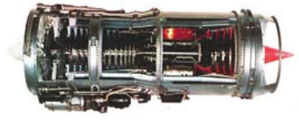
Production: 2011-present
Application: Superjet 100
Aircraft in service: 102
Aircraft on order: 34

PRATT & WHITNEY

Founded: 1925
Ownership: Subsidiary of United Technologies (UTC)
Headquarter: East Hartford, Connecticut, USA
Number of commercial aircraft powered: 1,595
Number of aircraft on order: 2,073

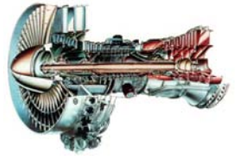
JT8D

Production: 1963-1999
Variants: -1, -7, -9, -11, -15, -17, -209, -217, -219
Applications: 727, 737-100/200, DC-9, MD-80
Aircraft in service: 447



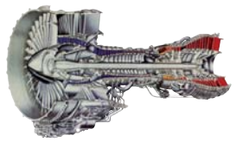
JT9D

Production: 1969-1990
Variants: -3, -7
Applications: A310, 747, 767
Aircraft in service: 15



PW2000

Production: 1984-2005
Variants: PW2037, PW2040, PW2043
Application: 757
Aircraft in service: 262

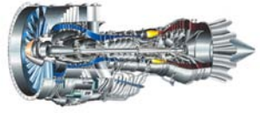


PW4000

Production: 1987-present
Variants: -94, -100, -112
Applications: A300, A310, A330, 747, 767, 777, MD-11
Aircraft in service: 723

PW6000

Production: 1987-present
Application: A318
Aircraft in service: 8



PW1000G

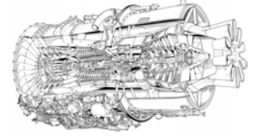
Production: 2016-present
Applications: A320neo, CSeries, MRJ, MC-21, E-Jet E2
Aircraft in service: 139
Aircraft on order: 2,073

ROLLS-ROYCE

Founded: 1904
Company structure: Public limited company
Headquarter: London, UK
Number of commercial aircraft powered: 2,750
Number of aircraft on order: 1,049

Spey

Production: 1964-1992
Variants: RB.163, RB.168, RB.183
Application: F28
Aircraft in service: 1

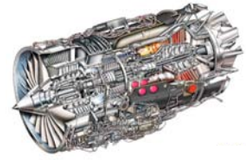


RB211

Production: 1973-2008
Variants: -524, -535
Applications: 747, 757, 767, Tu-204
Aircraft in service: 462

Tay

Production: 1988-1997
Variants: 611, 620, 650
Applications: Fokker 70/100
Aircraft in service: 130

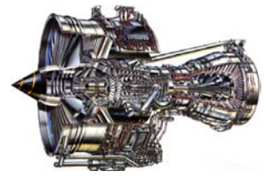


BR700

Production: 1999-present
Variants: -710, -715, -725
Application: 717
Aircraft in service: 154

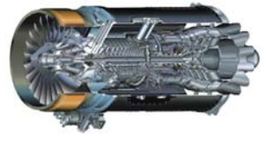
Trent

Production: 1995-present
Variants: -500, -700, -800, -900, -1000, -XWB, -7000
Applications: A330, A330neo, A340, A350, A380, 777, 787
Aircraft in service: 1,518
Aircraft on order: 1,049



AE3007

Production: 1996-present
Variants: -C, -H, -A
Application: ERJ-145 family
Aircraft in service: 485



ENGINE CENSUS

Operator listing by commercial engine type

EXPLANATORY NOTES

This census data covers all engines powering commercial jet aircraft in service or on firm order with commercial operations worldwide.

The information has been compiled using Flight Fleets Analyzer.

The information is correct up to 9 May 2018 and excludes non-commercial companies, such as business and military operators.

Engines are listed in alphabetical order, first by manufacturer and then type. The figures are for fitted engines only and don't include spares.

Operators are listed by region. Fleet data comprises the number of installed engines on the in-service fleet and, where applicable, the number of installed engines for the outstanding firm aircraft orders in parentheses in the right-hand column. The census does not include any parked aircraft/engines at the time of the data extraction.

The region is listed by operator base and does not necessarily indicate the area of operation. Options and letters of intent (where a firm contract has not been signed) are not included. Orders by leasing companies have been included where end-user is unknown.

Operators' fleets include leased aircraft/engines. Aircraft/engines being operated on wet-lease are generally listed with the company for which they are being operated, and not the airline flying the aircraft on their behalf.

The outstanding firm orders information also includes airline holding companies.

AVIADVIGATEL D-30	TOTAL 370
Africa	**Total 44**
Alfa Airlines	4
BADR Airlines	8
CEIBA Intercontinental	4
El Dinder Aviation	4
Global Aviation Services	4
Green Flag Aviation	4
Kush Aviation	4
Libyan Air Cargo	8
Lina Congo	4
Asia-Pacific	**Total 68**
Air Koryo	24
Air Manas	4
Khatlon Air	8
Sigma Airlines	8
TAPC Aviatrans	4
Turkmenistan Airlines	12
Uzbekistan Airways	8
Europe	**Total 224**
223rd State Airline Flight Unit	8
Abakan Air	28
Air Stork	8
Aircompany ZetAvia	24
Alpha Air	12
ALROSA Air Company	14
Aviacon Zitotrans	16
Azal Avia Cargo	4
Europa Air	20
Kosmos Airlines	6
Maximus Airlines	4
Oscar Jet	12
Rada Airlines	4
Ruby Star Airlines	16
Silk Way Airlines	20
TransAVIAexport Airlines	24
Yuzhmashavia	4
Middle East	**Total 34**
Al-Rafedain Falcon	4
Click Airways	4
Jordan International Air Cargo	4
Pouya Air	8
Syrianair	14
AVIADVIGATEL PD-14	TOTAL (28)
Europe	**Total (28)**
IrAero	(20)
Red Wings Airlines	(8)
AVIADVIGATEL PS-90	TOTAL 80
Asia-Pacific	**Total 4**
Air Koryo	4
Europe	**Total 60**
Aviastar-TU	8
Red Wings Airlines	10
Rossiya Special Flight Detachment	14
Silk Way Airlines	8
Volga-Dnepr Airlines	20
Latin America	**Total 8**
Cubana	8
Middle East	**Total 8**
Jordan International Air Cargo	8
CFM INTERNATIONAL CFM56	TOTAL 22,332 (740)
Africa	**Total 832 (6)**
Aero Contractors	8
Africa Charter Airline	8
Afriqiyah Airways	6
Air Algerie	62
Air Arabia Egypt	4
Air Arabia Maroc	16
Air Austral	4
Air Cairo	14
Air Cote D'Ivoire	12
Air Ghana	2
Air Madagascar	6
Air Mauritius	28
Air Namibia	8
Air Peace	24
Alexandria Airlines	2
Allied Air Cargo	6
Almasria Universal Airlines	4
AMC Airlines	8
Arik Air	10
ASKY	10
Azman Air	8
BADR Airlines	8
Buraq Air	6
CAA - Compagnie Africaine d'Aviation	2
Camair-Co	4
CEIBA Intercontinental	6
Comair (South Africa)	34
Congo Airways	6
Egyptair	58
Eritrean Airlines	2
Ethiopian Airlines	36
Express Air Cargo	4
FirstNation Airways	2
Fly Mid Africa	2
flyEgypt	10
Gomair	4
Karinou Airlines	2
Kenya Airways	26
Kulula	20
Libyan Airlines	4
Libyan Wings	4
Linhas Aereas de Mocambique	4
Malawian Airlines	2
Mango	22
Mauritania Airlines	8
Med View Airlines	6
Nile Air	4
Nouvelair	14
Nova Airways	2
Royal Air Maroc	74
RwandAir	12
Safair	28
Serve Air	6
SkyAir corp	4
SonAir	4
South African Airways	46
Star Air	12
Sudan Airways	4
TAAG Angola Airlines	10
Tarco Air	14
Tassili Airlines	8 (6)

Trans Air Congo	8
Tunisair	50
Asia-Pacific	**Total 7,734 (134)**
9 Air	30
Air Changan	16
Air China	436
Air China Inner Mongolia	8
Air Do	18
Air Guilin	6
Air Incheon	4
Air India	102
Air India Express	46
Air Kyrgyzstan	2
Air Manas	4
Air Niugini	6
Air Tahiti Nui	20
Air Vanuatu	2
AirAsia	132 (26)
AirAsia (India)	36
AirAsia Japan	4 (2)
Airblue	22
Airwork (NZ)	16
ANA Wings	28
ANA-All Nippon Airways	108 (8)
Ariana Afghan Airlines	4
Asia Cargo Express	4
Avia Traffic Company	8
Bassaka Air	4
Batik Air	108
Bhutan Airlines	4
Biman Bangladesh Airlines	8
Cambodia Angkor Air	2
Capital Airlines	48
Cardig Air	4
Cebu Pacific Air	78 (6)
Chengdu Airlines	62
China Airlines	36
China Eastern Airlines	432 (4)
China Eastern Airlines Jiangsu	66
China Eastern Yunnan	128
China Express Airlines	6
China Postal Airlines	44
China Southern Airlines	524 (6)
China United Airlines	88 (2)
China Xinhua Airlines	10
Chongqing Airlines	8
Citilink Indonesia	78
Dalian Airlines	22
Donghai Airlines	38
Druk Air	6
Eastar Jet	36
EVA Air	44
Express Air	10
Express Freighters Australia	10
Fiji Airways	10
Fuzhou Airlines	32
Garuda Indonesia	146
GoAir	38
Grand China Air	6
GX Airlines	12
Hainan Airlines	310
Hebei Airlines	34 (2)
Himalaya Airlines	6
Hong Kong Airlines	22 (2)
Hongtu Airlines	6
IndiGo	22
Indonesia AirAsia	36
Indonesia AirAsia Extra	10
Japan Airlines	100
Japan TransOcean Air	26 (2)
JC International Airlines	10
Jeju Air	68
Jet Airways	164
JetConnect	10
Jiangxi Air	16
Jin Air	40
Juneyao Airlines	102 (2)
Kam Air	14
K-Mile Air	6
Korean Air	70
Kunming Airlines	52
Lao Airlines	8
Lion Air	192 (14)
Longhao Airlines	6
LongJiang Airlines	4
Loong Air	62
Lucky Air	86
Malaysia Airlines	96
Maldivian	4
Malindo Air	58
Mandarin Airlines	2
MIAT - Mongolian Airlines	6
My Indo Airlines	6
MY Jet Xpress	2
Myanmar Airways International	8
Myanmar National Airlines	8
Nam Air	20
Nauru Airlines	10
NewGen Airways	22
Nok Air	36
Okay Airways	50 (4)
Pakistan International Airlines	22
PAL Express	18
Palau Pacific Airways	2
Peach	40 (14)
Philippine Airlines	40
Philippines AirAsia	38
Qantas	140
Qingdao Airlines	28 (2)
Raya Airways	2
Regent Airways	12
Ruili Airlines	32 (10)
Samoa Airways	2
SCAT	14
Serene Air	6
SF Airlines	34
Shandong Airlines	232 (2)
Shanghai Airlines	166
Shenzhen Airlines	272 (2)
Sichuan Airlines	64
SilkAir	34
Sky Angkor Airlines	4
Skymark Airlines	52
Small Planet Airlines (Cambodia)	2
Solaseed Air	24 (2)
Somon Air	12
SpiceJet	78
Spring Airlines	158 (4)
Spring Airlines Japan	12
SriLankan Airlines	6
Sriwijaya Air	82
Star Flyer	20
Sunkar Air	4
Suparna Airlines	40
Tajik Air	4
Thai AirAsia	100
Thai Airways International	4
Thai Lion Air	56
Thai VietJet Air	10
Tianjin Airlines	20
Tibet Airlines	46
Tigerair Australia	6
Toll Priority	2
Tri MG Airlines	6
Trigana Air	8
Turkmenistan Airlines	22
T'way Air	40
UNI Air	4
Urumqi Airlines	24 (2)
US-Bangla Airlines	8
Uzbekistan Airways	18
Vanilla Air	30 (2)
VietJet Air	100 (12)
Virgin Australia	134
Virgin Australia International	30
Vision Air International	6
West Air (China)	30
Xiamen Airlines	296 (2)
YTO Express Airlines	14
Zhuhai Airlines	4
Europe	**Total 6,566 (232)**
Adria Airways	2
Aer Lingus	74
Aeroflot Russian Airlines	306 (30)
Aigle Azur	16
Air Belgium	8
Air Bucharest	2
Air Corsica	10
Air Europa	38 (4)
Air France	236
Air Horizont	6
Air Italy	18
Air Malta	18
Air Mediterranean	6
Air Moldova	6
airBaltic	22
AirExplore	2
Airzena - Georgian Airways	6
Alanna	2
Alba Star	10

ALBAWINGS	4
Alitalia	144
ALROSA Air Company	10
Anadolu Jet	68
Armenia	2
ASL Airlines Belgium	40
ASL Airlines France	30
ASL Airlines Hungary	4
ASL Airlines Ireland	16
Astra Airlines	2
Atlantic Airways (Faroe Islands)	6
Atlasglobal	12
Atlasglobal Ukraine	2
Atran	6
Aurora	20
Austrian	70
Aviolet	4
Avion Express	4
Azerbaijan Airlines	18
Azores Airlines	6
Azur Air	12
Azur Air Germany	2
Azur Air Ukraine	4
B&H Airlines	(4)
Belavia	36
Blue Air	54
Blue Bird Airways	4
Blue Panorama Airlines	16
Bluebird Nordic	16
Bravo Airways	4
British Airways	2
Brussels Airlines	82
Bul Air	4
Bulgaria Air	8
Cargo Air	14
Cello Aviation	2
Cobalt Air	6
Condor	42
Corendon Airlines	10
Corendon Airlines Europe	2
Corendon Dutch Airlines	6
Croatia Airlines	12
Cyprus Airways	2
Czech Airlines	20
EasyJet	340 (16)
EasyJet Europe	184
EasyJet Switzerland	48
Edelweiss Air	28
Ellinair	8
Enter Air	36
Ernest Airlines	2
European Air Transport	12
Eurowings	138
Eurowings Europe	18
Evelop Airlines	2
Finnair	48
FlyOne	4
Freebird Airlines	12
Gazpromavia	4
Germania	58
Germania Flug	6
Germanwings	12
GetJet Airlines	6
Globus	42
Gowair	2
Grand Cru Airlines	4
Hamburg International	-4
Hi Fly	4
Hi Fly Malta	12
Iberia	82
Iberia Express	44
Izair	12
Jet Time	10
Jet Time Finland	2
Jet2	140 (8)
Joon	30
KLM Royal Dutch Airlines	100
Laudamotion	6
LOT Polish Airlines	16
Lufthansa	244
Lufthansa CityLine	20
Luxair	12
Maleth Aero	4
Mistral Air	2
Montenegro Airlines	2
Myway Airlines	4
NEOS	10
Nordavia - Regional Airlines	20
Nordwind Airlines	16
Norwegian	96
Norwegian Air International	128
Norwegian Air Norway	8
Olympus Airways	2
Pegas Fly	8
Pegasus	100 (6)
Plus Ultra	12
Pobeda	38 (22)
Primera Air Nordic	14
Primera Air Scandinavia	4
Red Wings Airlines	2
Rossiya Airlines	92
Royal Flight	2
Ryanair	872 (46)
Ryanair Sun	2
S7 Airlines	86
SAS	166
Small Planet Airlines (Germany)	8
Small Planet Airlines (Lithuania)	6
Small Planet Airlines (Poland)	8
Smartwings	26
Star East	2
Sundair	4
SunExpress	60
SunExpress Germany	22
Swiftair	14
SWISS	90
Tailwind Airlines	10
Taimyr Air - NordStar	20
TAP Air Portugal	110
TAROM	28
Taron-Avia	4
Thomas Cook Airlines	54
Thomas Cook Airlines Scandinavia	14
Titan Airways	10
Transavia Airlines	82
Transavia France	66
Travel Service Airlines	26
Travel Service Hungary	2
Travel Service Poland	4
Travel Service Slovakia	2
TUI Airlines Nederland	14
TUI Airways	68
TUI fly	50
TUIfly	52
TUIFly Nordic	8
Turkish Airlines	182
Ukraine International Airlines	68
Ural Airlines	74 (14)
Utair	96 (76)
VIA Airways	2
VLM Airlines	2
Volotea	22
Vueling Airlines	108
West Atlantic	38
White	2
Windrose Airlines	4
WOW air	24 (2)
Yakutia Airlines	10
Yamal Airlines	8
YanAir	8
Latin America	**Total 1,406 (34)**
Aer Caribe	4
Aerolineas Argentinas	86
Aerolineas Estelar	8
Aeromexico	104
Air Costa Rica	2
Albatros Airlines	2
Andes Lineas Aereas	8
Aruba Airlines	2
Avianca	110
Avianca Brazil	64
Avianca Costa Rica	2
Avianca Ecuador	20
Avianca El Salvador	12
Avior Airlines	20
Bahamasair	6
BoA	38
Caribbean Airlines	24
Cayman Airways	8
Conviasa	2
Copa Airlines	148
Copa Airlines Colombia	2
Cubana	2
Estafeta Carga Aerea	8
Flybondi	6
Global Air	2
GOL	234
Interjet	106
LATAM Airlines Brazil	98 (2)
LATAM Airlines Chile	92 (2)

LATAM Airlines Colombia	12
LATAM Airlines Peru	12
LC Peru	8
Magnicharters	16
Modern Logistics	6
One Airlines	2
Peruvian Air Line	22
Sideral Air Cargo	24
Sky Airline	26
Surinam Airways	8
Turpial Airlines	6
Vensecar Internacional	4
Viva Air Peru	6
VivaColombia	20 (30)
Wingo	14
Middle East	**Total 772 (36)**
Air Arabia	78 (4)
Al Naser Wings Airlines	2
Arkia	2
ATA Airlines	10
AVE.COM	2
Caspian Airlines	6
Cham Wings	6
El Al	40
Felix Airways	2
Fly Baghdad	4
Fly Jordan	2
Flyadeal	14
flydubai	110
Flynas	58
Gulf Air	32
Iran Air	10 (14)
Iran Aseman Airlines	10
Iraqi Airways	32
Israir	2
Jazeera Airways	14
Jordan Aviation	8
Karun Air	4
Kish Air	10
Kuwait Airways	20
Mahan Air	20
Middle East Airlines	8
Oman Air	52
Qatar Airways	14
Qeshm Airlines	6
Royal Wings	2
SAHA Airlines	6
SalamAir	6
Saudia	130 (18)
Sepehran Airlines	6
Syrianair	4
Taban Airlines	4
Texel Air	4
Up	8
Wataniya Airways	6
Wings of Lebanon	2
Zagros Airlines	16
North America	**Total 5,022 (298)**
Air Canada	144
Air Canada Jetz	6
Air Canada Rouge	52
Air North	10
Air Transat	22
Alaska Airlines	436 (22)
Allegiant Air	114 (6)
Aloha Air Cargo	6
American Airlines	910
Atlas Air	10
Canadian North	20
Delta Air Lines	694 (232)
EG&G Special Projects	12
First Air	8
Flair Airlines	14
Frontier Airlines	112 (4)
Kalitta Charters II	8
Miami Air International	10
Nolinor Aviation	2
Northern Air Cargo	6
Sierra Pacific Airlines	4
Southwest Airlines	1,402 (34)
Sun Country Airlines	40
Sunwing Airlines	40
Swift Air	38
United Airlines	658
WestJet	230
Xtra Airways	14
CFM INTERNATIONAL LEAP	**TOTAL 602 (8,590)**
Africa	**Total 2 (122)**
Arik Air	(16)
Comair (South Africa)	(16)
Egyptair	(30)
Ethiopian Airlines	(60)
Mauritania Airlines	2
Asia-Pacific	**Total 224 (3,518)**
Air China	18 (12)
Air India	36 (16)
Air Niugini	(8)
AirAsia	40 (746)
Asiana Airlines	(50)
Cathay Dragon	(64)
China Eastern Airlines	6 (18)
China Southern Airlines	18 (98)
Citilink Indonesia	10 (10)
City Airways	(20)
Donghai Airlines	(50)
Druk Air	(2)
Fiji Airways	(10)
Garuda Indonesia	2 (98)
Hainan Airlines	8 (40)
Jet Airways	(266)
Jetstar	(198)
Korean Air	(60)
Lion Air	16 (738)
Loong Air	(2)
Lucky Air	(12)
Malaysia Airlines	(50)
MIAT - Mongolian Airlines	(8)
Myanmar National Airlines	(8)
Nok Air	(16)
Okay Airways	(26)
Royal Brunei Airlines	(14)
Ruili Airlines	(72)
SCAT	2
Shanghai Airlines	12
Sichuan Airlines	(40)
SilkAir	10 (64)
SpiceJet	(294)
Spring Airlines	(120)
SriLankan Airlines	10 (2)
Thai AirAsia	18 (4)
Thai Lion Air	4
VietJet Air	(200)
Virgin Australia	(80)
Vistara	14 (2)
Europe	**Total 136 (1,792)**
Air Europa	(40)
Air Italy	(2)
Air Malta	(4)
Atlantic Airways (Faroe Islands)	(2)
Azores Airlines	4 (8)
Blue Air	(24)
British Airways	4 (66)
Corendon Airlines	(2)
EasyJet	12 (248)
Enter Air	(12)
Globus	(18)
Iberia	(40)
Icelandair	6 (26)
La Compagnie	(4)
LOT Polish Airlines	4 (8)
Lufthansa	(82)
NEOS	(4)
Norwegian	4 (206)
Norwegian Air International	8 (2)
Novair	4
Pegasus	36 (164)
Primera Air Scandinavia	2 (42)
Ryanair	(220)
SAS	36 (24)
SkyUp	(10)
Smartwings	4 (2)
SunExpress	(64)
TAP Air Portugal	2 (78)
Travel Service Airlines	(42)
TUI Airlines Nederland	(2)
TUI Airways	(78)
TUI fly	4 (4)
TUI Travel PLC	(50)
TUIFly Nordic	2 (4)
Turkish Airlines	(150)
Utair	(60)
WOW air	4
Latin America	**Total 80 (766)**
Aerolineas Argentinas	8 (20)
Aeromexico	4 (116)
Avianca	10 (52)
Avianca Brazil	16 (8)
Avianca El Salvador	2
Azul	28 (98)
Cayman Airways	(8)

Copa Airlines	(122)
GOL	(250)
Interjet	12 (86)
Sky Airline	(6)
Middle East	**Total 16 (828)**
Air Arabia	(12)
Arkia	(8)
Etihad Airways	(52)
flydubai	12 (490)
Flynas	(158)
Gulf Air	(58)
Oman Air	4 (50)
North America	**Total 144 (1,564)**
Air Canada	26 (96)
Alaska Airlines	14 (130)
American Airlines	14 (386)
Frontier Airlines	42 (122)
Jetlines	(10)
Southwest Airlines	30 (450)
Sunwing Airlines	(8)
United Airlines	6 (264)
WestJet	12 (98)
ENGINE ALLIANCE GP7200	**TOTAL 492**
Asia-Pacific	**Total 40**
Korean Air	40
Europe	**Total 40**
Air France	40
Middle East	**Total 412**
Emirates Airline	332
Etihad Airways	40
Qatar Airways	40
GENERAL ELECTRIC CF34	**TOTAL 5,214 (522)**
Africa	**Total 156 (4)**
African Express Airways	2
Air Burkina	4
Airlink	12 (2)
Arik Air	6
CemAir	14
DAC Aviation East Africa	2
Egyptair Express	24
Fastjet Tanzania	4
Fly540	6
Fly-SAX	2
Kenya Airways	30
Libyan Airlines	4
Linhas Aereas de Mocambique	4
Nova Airways	2
Petroleum Air Services	4
Proflight Zambia	2
Royal Air Maroc	8
RwandAir	4
SA Express	20
Tunisair Express	2 (2)
Asia-Pacific	**Total 506 (228)**
7th Sky	2
Afghan Jet International Airlines	2
Air Astana	18
Air Pohang	4
Airnorth	10
Chengdu Airlines	10 (52)
China Express Airlines	68 (8)
China Southern Airlines	40
City Airways	(20)
Colorful Guizhou Airlines	18
FMI Air Charter	2
Fuji Dream Airlines	24 (4)
Garuda Indonesia	36
GX Airlines	34
Hebei Airlines	12 (2)
Henan Airlines	(100)
Ibex Airlines	20
J-Air	62 (2)
Mandarin Airlines	12
Myanmar Airways International	(4)
Myanmar National Airlines	4
Saurya Airlines	4
SCAT	12
Shandong Airlines	(20)
Shanghai Airlines	(10)
Shree Airlines	6
Tianjin Airlines	98 (6)
Urumqi Airlines	2
Zoom Air	6
Europe	**Total 1,004 (40)**
Adria Airways	16
Air Dolomiti	24
Air Europa Express	22
Air Moldova	6
Air Nostrum	64 (14)
Airzena - Georgian Airways	8
Alitalia Cityliner	40
Aurigny Air Services	2
Austrian	38
BA CityFlyer	44
Belavia	18 (14)
Binter Canarias	6
Bulgaria Air	8
Buta Airways	14 (4)
Croatia Airlines	4
Eastern Airways	2
Flybe	36 (8)
HOP!	100
IrAero	8
KLM Cityhopper	98
LOT Polish Airlines	46
Lufthansa CityLine	102
Luxair	2
Montenegro Airlines	4
Nextjet	4
Nordic Regional Airlines	24
Nordica	24
Pegas Fly	2
People's Vienna Line	4
Portugalia Airlines	26
Rusline	34
S7 Airlines	34
Saratov Airlines	4
SAS	50
Severstal Aircompany	12
Stobart Air	4
SWISS	14
TUI fly	8
Ukraine International Airlines	10
UVT Aero	14
West Atlantic Sweden	4
Yamal Airlines	20
Latin America	**Total 428**
Aerolineas SOSA	2
Aeromexico Connect	120
Aeronaves TSM	2
Amaszonas	14
Amaszonas del Paraguay	8
Amaszonas Uruguay	4
Aruba Airlines	2
Austral Lineas Aereas	52
Avianca El Salvador	16
Azul	132
BoA	4
Conviasa	16
Copa Airlines	30
Copa Airlines Colombia	8
Estafeta Carga Aerea	4
FlyEst	2
MCS Aero Carga	8
Satena	2
TAME	2
Middle East	**Total 44 (12)**
Arkia	10
Felix Airways	2 (12)
Fly Baghdad	2
Iraqi Airways	12
Oman Air	8
Royal Jordanian	10
North America	**Total 3,076 (238)**
Air Canada	50
Air Georgian	32
Air Wisconsin	124
American Airlines	40
Compass Airlines	112
Elite Airways	24
Endeavor Air	308
Envoy Air	132 (50)
ExpressJet Airlines	84
GoJet Airlines	108
Gulf & Caribbean Cargo	2
Horizon Air	26 (40)
Jazz	62
JetBlue Airways	120 (48)
Mesa Airlines	288
PSA Airlines	254 (30)
R1 Airlines	2
Republic Airline	378
Sky Regional Airlines Inc	50
SkyWest Airlines	870 (70)
Voyageur Airways	10
GE AVIATION CF6	**TOTAL 3,076 (132)**
Africa	**Total 55**
Aeronexus	2
Air Algerie	22
Air Mauritius	4

Allied Air Cargo	3
Almasria Universal Airlines	2
Astral Aviation	4
Egyptair	2
Libyan Airlines	4
Royal Air Maroc	12
Asia-Pacific	**Total 660 (10)**
Air Calin	4
Air Do	8
Air Hong Kong	18
Air Incheon	2
Air Japan	24
Air Niugini	2
ANA-All Nippon Airways	68
Ariana Afghan Airlines	4
Asiana Airlines	68
China Airlines	136
China Cargo Airlines	8
EVA Air	40
Express Freighters Australia	2
Galaxy Aviation	2
Japan Airlines	70
Jet Airways	16 (10)
MIAT - Mongolian Airlines	2
Nippon Cargo Airlines	12
Qantas	84
Raya Airways	2
SF Airlines	10
Shaheen Air International	8
Sunday Airlines	2
Suparna Airlines	16
Tajik Air	2
Thai Airways International	40
Uni-top Airlines	10
Europe	**Total 708 (6)**
Aer Lingus	24
Air Atlanta Icelandic	4
Air Europa	12
Air France	30
Air Italy	10
Air Serbia	2
AirBridgeCargo	28
Airbus Transport International	10
Alitalia	28
ASL Airlines Belgium	12
Azerbaijan Airlines	4
Azores Airlines	2
Azur Air	4
Blue Panorama Airlines	6
Brussels Airlines	6
CargoLogicAir	8
Cargolux	8
Condor	14
DHL Air	8
EuroAtlantic airways	4
Finnair	16
Geo Fly Airways	2
Hi Fly	2
Iberia	40
Icelandair	8
KLM Royal Dutch Airlines	74
LEVEL	4 (6)
Lufthansa	52
Lufthansa Cargo	36
Martinair	12
MNG Airlines	6
NEOS	6
Pegas Fly	4
Privilege Style	2
Rossiya Airlines	32
Royal Flight	4
Solinair	2
Star Air	28
SunExpress Germany	14
TAP Air Portugal	14
Titan Airways	2
TransAVIAexport Airlines	4
TUI Airlines Nederland	2
TUI Airways	8
TUI fly	2
Turkish Airlines	66
Utair	6
Virgin Atlantic Airways	32
West Atlantic Sweden	2
XL Airways France	2
Latin America	**Total 133**
Aerolineas Argentinas	12
AeroUnion	14
BoA	8
Fly Jamaica	2
LATAM Airlines Argentina	6
LATAM Airlines Brazil	28
LATAM Airlines Chile	38
LATAM Airlines Colombia	4
LATAM Cargo	2
LATAM Cargo Brazil	6
LATAM Cargo Chile	4
LATAM Cargo Colombia	4
TAB Airlines	3
Transcarga International Airways	2
Middle East	**Total 198**
C.A.L. Cargo Air Lines	4
DHL International Aviation EEMEA	6
Fars Qeshm Air Lines	8
Flynas	2
Global Charter Services	8
Iran Air	20
Iraqi Airways	10
Jordan Aviation	4
Mahan Air	44
Qatar Airways	48
Qeshm Airlines	8
Royal Jordanian	2
Saudia	32
Taban Airlines	2
North America	**Total 1,322 (116)**
21 Air	4
ABX Air	36
Air Canada	14
Air Canada Rouge	26
Air Transat	14
Aloha Air Cargo	2
American Airlines	48
Amerijet International	12
ATI - Air Transport International	4
Atlas Air	102
Cargojet Airways	20
Delta Air Lines	114
Eastern Airlines	2
FedEx	445 (108)
Hawaiian Airlines	2
Kalitta Air	50
KF Aerospace	6
National Airlines	8
Northern Air Cargo	2
Omni Air International	18
Polar Air Cargo	38
Prime Air	70
Sky Lease Cargo	7
United Airlines	32
UPS Airlines	203 (8)
Western Global	35
WestJet	8
GE AVIATION GE90	**TOTAL 2,156 (148)**
Africa	**Total 66 (8)**
Air Austral	6
CEIBA Intercontinental	2
Egyptair	10
Ethiopian Airlines	32 (8)
TAAG Angola Airlines	16
Asia-Pacific	**Total 758 (52)**
Air China	52 (2)
Air China Cargo	16
Air India	34
Air New Zealand	14
ANA-All Nippon Airways	44 (16)
Biman Bangladesh Airlines	8
Cathay Pacific	106
China Airlines	20
China Cargo Airlines	12
China Eastern Airlines	40
China Southern Airlines	46
EVA Air	72 (6)
Garuda Indonesia	20
Hong Kong Airlines	-12
Japan Airlines	48
Jet Airways	20
Korean Air	68 (6)
Pakistan International Airlines	22 (10)
Philippine Airlines	20
Singapore Airlines	54
Thai Airways International	28
Turkmenistan Airlines	4
Virgin Australia International	10
Europe	**Total 474 (26)**
Aeroflot Russian Airlines	32 (12)
AeroLogic	20
Air France	140
Alitalia	24
Austrian	12

British Airways	78
KLM Royal Dutch Airlines	58
Lufthansa Cargo	10 (4)
Nordwind Airlines	10
SWISS	20 (4)
Turkish Airlines	70 (6)
Latin America	**Total 18 (4)**
LATAM Airlines Brazil	18
LATAM Cargo Brazil	(4)
Middle East	**Total 574 (44)**
Emirates Airline	296 (22)
Etihad Airways	48 (2)
Iraqi Airways	2
Kuwait Airways	18
Qatar Airways	126 (20)
Saudia	84
North America	**Total 266 (14)**
Air Canada	50
American Airlines	40
Delta Air Lines	20
FedEx	68 (12)
Southern Air	10
United Airlines	78 (2)
GE AVIATION GE9X	**TOTAL (632)**
Asia-Pacific	**Total (122)**
ANA-All Nippon Airways	(40)
Cathay Pacific	(42)
Singapore Airlines	(40)
Europe	**Total (40)**
Lufthansa	(40)
Middle East	**Total (470)**
Emirates Airline	(300)
Etihad Airways	(50)
Qatar Airways	(120)
GE AVIATION GENX	**TOTAL 1,272 (730)**
Africa	**Total 50 (8)**
Ethiopian Airlines	26
Kenya Airways	14
Royal Air Maroc	10 (8)
Asia-Pacific	**Total 476 (244)**
Air China	28
Air India	54
Air Tahiti Nui	(8)
Biman Bangladesh Airlines	(8)
Cathay Pacific	56
China Eastern Yunnan	(10)
China Southern Airlines	22 (38)
EVA Air	(48)
Hainan Airlines	52 (10)
Japan Airlines	72 (26)
Jet Airways	(20)
Jetstar	22
Juneyao Airlines	(10)
Korean Air	78 (10)
Nippon Cargo Airlines	32
Qantas	8 (8)
Shanghai Airlines	(20)
Suparna Airlines	2 (2)
Uzbekistan Airways	4 (10)
Vietnam Airlines	22 (16)
Xiamen Airlines	24
Europe	**Total 272 (94)**
Air France	12 (2)
AirBridgeCargo	44
Azerbaijan Airlines	4
CargoLogicAir	4
Cargolux	56
KLM Royal Dutch Airlines	24 (36)
Lufthansa	76
Silk Way West Airlines	20
TUI Airlines Nederland	6
TUI Airways	22 (2)
TUI fly	4
TUI Travel PLC	(4)
Turkish Airlines	(50)
Latin America	**Total 32 (4)**
Aeromexico	32 (4)
Middle East	**Total 170 (128)**
Etihad Airways	40 (102)
Oman Air	14 (18)
Qatar Airways	68
Royal Jordanian	14 (8)
Saudia	34
North America	**Total 272 (252)**
Air Canada	68 (6)
American Airlines	70 (106)
Atlas Air	12
Polar Air Cargo	28
United Airlines	74 (28)
UPS Airlines	20 (92)
WestJet	(20)
HONEYWELL ALF502	**TOTAL 152**
Africa	**Total 16**
Air Libya	4
Cronos Airlines	8
Fair Aviation	4
Asia-Pacific	**Total 56**
Cobham Avtn Services Australia-Regional Services	24
Pionair Australia	16
Skyjet	12
TransNusa Air Services	4
Europe	**Total 36**
ASL Airlines Spain	12
Aviro Air	4
EasyJet Europe	12
Nextjet	4
WDL Aviation	4
Latin America	**Total 20**
Aerovias DAP	8
Star Peru	12
Middle East	**Total 24**
Mahan Air	24
HONEYWELL LF507	**TOTAL 300**
Africa	**Total 44**
Air Annobon	4
Air Libya	4
Airlink	36
Asia-Pacific	**Total 36**
Cobham Avtn Services Australia-Regional Services	28
Tez Jet Airlines	8
Europe	**Total 100**
Air France	4
BRA-Braathens Regional Airlines	48
CityJet	44
HOP!	4
Latin America	**Total 36**
Aerovias DAP	20
Eco Jet	16
Middle East	**Total 60**
Mahan Air	32
Qeshm Airlines	24
Taban Airlines	4
North America	**Total 24**
First Air	4
North Cariboo Air	8
Summit Air Charters	12
IAE V2500	**TOTAL 6,118 (82)**
Africa	**Total 82**
Air Cairo	2
Air Seychelles	4
Almasria Universal Airlines	2
Egyptair	12
flyEgypt	2
Global Aviation Operations	4
Jubba Airways (Somalia)	2
Mango	2
Nesma Airlines	8
Nile Air	10
South African Airways	34
Asia-Pacific	**Total 2,418 (2)**
Air Astana	24
Air Bishkek	2
Air Busan	46
Air Calin	4
Air China	108
Air Guilin	12
Air India	16
Air Macau	36
Air New Zealand	60
Air Seoul	12
Asiana Airlines	52
Avia Traffic Company	4
Bangkok Airways	46
Cambodia Angkor Air	6
Capital Airlines	88 (2)
Cathay Dragon	46
China Eastern Airlines	180
China Eastern Airlines Jiangsu	32
China Southern Airlines	328
Chongqing Airlines	28
Citilink Indonesia	10
HK Express	36
IndiGo	222
Jetstar	120
Jetstar Asia	36
Jetstar Japan	44
Jetstar Pacific	34
Juneyao Airlines	34
Lanmei Airlines	10
Nepal Airlines	4

Network Aviation	4
PAL Express	10
Pan Pacific Airlines	6
Philippine Airlines	38
Philippines AirAsia	4
Royal Brunei Airlines	12
Scoot	50
Shaheen Air International	26
Shenzhen Airlines	82
Sichuan Airlines	166
SilkAir	24
Sky Angkor Airlines	8
SriLankan Airlines	10
Thai Smile	40
Tianjin Airlines	40
Tigerair Australia	24
Tigerair Taiwan	22
Vietnam Airlines	114
Virgin Australia Regional Airlines	6
Vistara	26
West Air (China)	26
Europe	**Total 1,348 (34)**
Adria Airways	4
Aegean Airlines	94
Air Malta	2
Air Moldova	2
Air Serbia	20
Atlasglobal	20
Atlasglobal Ukraine	2
BH Air	4
British Airways	260
Bulgarian Air Charter	8
Cobalt Air	6
Condor	4
Corendon Airlines	2
Corendon Airlines Europe	2
Corendon Dutch Airlines	2
DAT - Danish Air Transport	10
EasyJet	4
Ellinair	4
Enter Air	2
Ernest Airlines	2
Eurowings	40
Eurowings Europe	12
Finnair	24
Grand Cru Airlines	2
Hi Fly	2
Jet2	2
Lufthansa	126
Nordwind Airlines	12
Olympus Airways	2
Onurair	30
Orange2fly	2
Red Wings Airlines	14
S7 Airlines	2
SAS	46
Small Planet Airlines (Germany)	6
Small Planet Airlines (Lithuania)	6
Small Planet Airlines (Poland)	12
Smartlynx Estonia	2
Thomas Cook Airlines	12
TUI fly	2
Turkish Airlines	194
Ural Airlines	16
Vueling Airlines	110
Windrose Airlines	6
Wizz Air	190 (30)
Wizz Air UK	2 (4)
WOW air	4
Yamal Airlines	16
Latin America	**Total 494 (12)**
Aruba Airlines	2
Avianca	4
Avianca Costa Rica	20
Avianca El Salvador	44
Avianca Peru	6
Cubana	2
JetSMART	10
LATAM Airlines Argentina	32
LATAM Airlines Brazil	120
LATAM Airlines Chile	20
LATAM Airlines Colombia	4
LATAM Airlines Ecuador	10
LATAM Airlines Paraguay	4
LATAM Airlines Peru	36
Mexicana	(8)
Sky Airline	4
Sunrise Airways	2
TAME	6
VivaAerobus	44 (4)
Volaris	118
Volaris Costa Rica	6
Middle East	**Total 254 (2)**
ATA Airlines	4
Cham Wings	2
Etihad Airways	64
Gulf Air	12
Iran Air	4
Iran Aseman Airlines	12
Iraqi Airways	4
Israir	6 (2)
Meraj Air	4
Middle East Airlines	18
Qatar Airways	70
Royal Jordanian	24
SaudiGulf	8
Syrianair	12
Wataniya Airways	2
Yemenia	4
Zagros Airlines	4
North America	**Total 1,522 (32)**
American Airlines	482
Delta Air Lines	112
JetBlue Airways	372 (14)
Spirit Airlines	228 (18)
United Airlines	328
IVCHENKO-PROGRESS AI-25	**TOTAL 66**
Asia-Pacific	**Total 18**
East Kazakhstan Region Air Enterprise	6
Zhetysu Aviakompania	6
ZhezAir	6
Europe	**Total 36**
Aerobratsk	3
Gazpromavia	9
Petropavlovsk-Kamchatsky Air Enterprise	9
Rossiya Special Flight Detachment	3
Severstal Aircompany	3
Vologda Air Enterprise	6
Zodiac Group	3
Middle East	**Total 12**
Syrianair	12
IVCHENKO-PROGRESS D-18T	**TOTAL 90**
Europe	**Total 90**
Antonov Airlines	34
Maximus Airlines	4
Silk Way Airlines	4
Volga-Dnepr Airlines	48
IVCHENKO-PROGRESS D-36	**TOTAL 125**
Africa	**Total 4**
Green Flag Aviation	4
Europe	**Total 105**
Antonov Airlines	2
Ayk Avia	2
Black Sea Airlines	6
Izhavia	30
KrasAvia	27
Mars Avia	4
Motor Sich Airlines	2
Saratov Airlines	12
Shar ink	6
Turuhan Aviacompany	6
UTair Cargo	8
Middle East	**Total 16**
Pouya Air	6
Skiva Air	6
South Airlines (Armenia)	4
IVCHENKO-PROGRESS D-436	**TOTAL 20 (22)**
Asia-Pacific	**Total 4**
Air Koryo	4
Europe	**Total 10 (22)**
Angara Airlines	10
Rossiya Special Flight Detachment	(2)
Silk Way West Airlines	(20)
Latin America	**Total 6**
Cubana	6
KUZNETSOV NK-8	**TOTAL 24**
Asia-Pacific	**Total 6**
Air Koryo	6
Europe	**Total 18**
223rd State Airline Flight Unit	18
POWERJET SAM-146	**TOTAL 204 (68)**
Europe	**Total 168 (52)**
Aeroflot Russian Airlines	74 (16)
Azimuth	14
Brussels Airlines	10
CityJet	2 (18)
Gazpromavia	20
IrAero	10
Severstal Aircompany	(10)
Utair	4

Yakutia Airlines	8
Yamal Airlines	26 (8)
Latin America	**Total 36 (16)**
Interjet	36 (16)
PRATT & WHITNEY JT3D	**TOTAL 4**
Africa	**Total 4**
Trans Air Cargo Services	4
PRATT & WHITNEY JT8D	**TOTAL 939**
Africa	**Total 63**
African Express Airways	6
Air Charter United	3
Air Zimbabwe	2
Allegiance Airways - Gabon	2
Astral Aviation	5
Canadian Airways Congo	6
DANA Air	6
Emirate Touch Aviation Services	3
Exclusive Alliance	2
FlyCongo	2
Fly-SAX	2
Global Aviation Operations	2
JedAir	2
Multiple Solutions	2
Safe Air Company	3
Serve Air	12
SKA Air and Logistics (Uganda)	3
Asia-Pacific	**Total 59**
AIRFAST Indonesia	8
Astro Air International	2
Express Air	2
Far Eastern Air Transport	16
Jayawijaya Dirgantara	6
Kam Air	6
My Indo Airlines	2
Raya Airways	6
Sigma Airlines	3
Sky Capital Airlines	2
South East Asian Airlines (SEAIR)	2
Vision Air International	4
Europe	**Total 37**
ALK Airlines	4
Anda Air Airlines	4
AviaStar Air Company	3
Bravo Airways	4
Bulgarian Air Charter	16
DAT - Danish Air Transport	4
Mistral Air	2
Latin America	**Total 160**
Aerolineas Estelar	2
Aeronaves TSM	36
Aerosucre Colombia	13
Aerovias DAP	6
Air Class Lineas Aereas	3
Andes Lineas Aereas	10
Aviatsa	2
Avior Airlines	8
Chilean Airways	2
EasySky	2
Global Air	2
InselAir	2
LASER	24
Lineas Aereas Suramericanas	12
Magnicharters	2
Peruvian Air Line	4
Rutaca	2
Sideral Air Cargo	6
TAM - Transporte Aereo Militar	2
Total Linhas Aereas	9
Uniworld Air Cargo	3
Venezolana	8
Middle East	**Total 99**
Airstream Aviation	2
ATA Airlines	16
Caspian Airlines	12
Iran Air	8
Iran Airtours	10
Iran Aseman Airlines	9
Kish Air	12
Taban Airlines	10
Taftan Air	4
Zagros Airlines	16
North America	**Total 521**
Air Inuit	8
Air North	2
Allegiant Air	72
American Airlines	88
Amerijet International	3
Ameristar Charters	12
Canadian North	4
Cargojet Airways	9
Delta Air Lines	212
Everts Air Alaska	14
Gulf & Caribbean Cargo	9
Interjet West	3
Kalitta Charters II	24
Nolinor Aviation	14
Northern Air Cargo	4
Sierra Pacific Airlines	2
SkyWay Enterprises	2
TransAir	10
USA Jet Airlines	17
World Atlantic Airlines	12
PRATT & WHITNEY JT9D	**TOTAL 46**
Africa	**Total 12**
MaxAir	12
Asia-Pacific	**Total 10**
Kam Air	2
Uni-top Airlines	8
Europe	**Total 12**
Fly Pro	4
Geo Sky	8
North America	**Total 12**
Atlas Air	8
Eastern Airlines	4
PRATT & WHITNEY PW1000G	**TOTAL 278 (4,018)**
Africa	**Total (28)**
Air Tanzania	(4)
Egyptair Express	(24)
Asia-Pacific	**Total 152 (1282)**
Air Astana	4 (40)
Air Calin	(4)
Air China	2 (4)
Air Costa	(100)
Air Mandalay	(12)
Air New Zealand	(34)
ANA-All Nippon Airways	10 (86)
Cebu Pacific Air	(64)
China Southern Airlines	16 (42)
GoAir	28 (116)
GX Airlines	(4)
HK Express	6 (14)
IndiGo	62 (296)
J-Air	(64)
Korean Air	8 (72)
Loong Air	(4)
Philippine Airlines	(42)
Qingdao Airlines	(2)
Scoot	(78)
Sichuan Airlines	8 (8)
Tianjin Airlines	6 (12)
VietJet Air	2 (144)
Vietnam Airlines	(36)
West Air (China)	(4)
Europe	**Total 84 (992)**
Aeroflot Russian Airlines	(50)
airBaltic	16 (24)
BRA-Braathens Regional Airlines	(20)
Czech Airlines	(2)
Germania	(50)
Lufthansa	20 (100)
Norwegian	(76)
Odyssey Airlines	(20)
Red Wings Airlines	(36)
S7 Airlines	8 (40)
SWISS	38 (52)
Turkish Airlines	(184)
Utair	(20)
Vueling Airlines	(94)
Wideroe	2 (4)
Wizz Air	(220)
Latin America	**Total 26 (326)**
Azul	(72)
LATAM Airlines Brazil	(38)
LATAM Airlines Chile	4 (62)
VivaAerobus	4 (76)
Volaris	18 (78)
Middle East	**Total (64)**
Gulf Air	(20)
Iraqi Airways	(10)
Jazeera Airways	(2)
SaudiGulf	(32)
North America	**Total 16 (1,326)**
Air Canada	(90)
Air Transat	(20)
Delta Air Lines	(350)
Hawaiian Airlines	6 (30)
JetBlue Airways	(170)
Republic Airways Holdings Inc	(80)
SkyWest Airlines	(400)
Spirit Airlines	10 (86)

Trans States Holdings	(100)
PRATT & WHITNEY PW2000	**TOTAL 524**
Africa	**Total 4**
Ethiopian Airlines	4
Asia-Pacific	**Total 18**
Asia Pacific Airlines	4
Raya Airways	2
Tajik Air	2
Uzbekistan Airways	10
Europe	**Total 38**
Aer Lingus	6
ASL Airlines Belgium	2
Azur Air	14
European Air Transport	12
OpenSkies	2
Royal Flight	2
Latin America	**Total 8**
DHL Aero Expreso	8
Middle East	**Total 2**
Taban Airlines	2
North America	**Total 454**
ATI - Air Transport International	10
Delta Air Lines	254
FedEx	90
United Airlines	30
UPS Airlines	70
PRATT & WHITNEY PW300	**TOTAL 24**
Europe	**Total 22**
Sun-Air of Scandinavia	22
North America	**Total 2**
Calm Air	2
PRATT & WHITNEY PW4000	**TOTAL 1,659**
Africa	**Total 37**
Afriqiyah Airways	2
Air Austral	2
Air Zimbabwe	2
Egyptair	8
Ethiopian Airlines	12
Global Africa Aviation	3
MaxAir	8
Asia-Pacific	**Total 542**
Air Astana	6
Air China	16
Air China Cargo	12
Air Hong Kong	12
Air India	16
Air Niugini	2
ANA-All Nippon Airways	56
Asia Atlantic Airlines	4
Asiana Airlines	48
Cathay Pacific	24
China Cargo Airlines	4
China Southern Airlines	60
Hong Kong Airlines	12
Japan Airlines	32
Jin Air	8
Korean Air	126
Malaysia Airlines	40
MIAT - Mongolian Airlines	2
Shanghai Airlines	8
Silk Road Cargo Business	2
Singapore Airlines	28
Uzbekistan Airways	16
Vietnam Airlines	8
Europe	**Total 268**
Aerotranscargo	16
Aigle Azur	2
Air Atlanta Icelandic	8
Air Cargo Global	8
Air Greenland	2
ASL Airlines Belgium	8
ASL Airlines Ireland	8
Austrian	12
Azores Airlines	2
Azur Air	10
Azur Air Germany	4
Azur Air Ukraine	2
Brussels Airlines	12
Condor	18
Corsair	12
Czech Airlines	2
European Air Transport	42
Evelop Airlines	2
Ifly	4
Martinair	4
MNG Airlines	4
Nordwind Airlines	4
Onurair	2
Pegas Fly	8
Rossiya Airlines	4
Ruby Star Airlines	4
Solinair	2
TAP Air Portugal	12
Turkish Airlines	16
Ukraine International Airlines	12
Virgin Atlantic Airways	6
Wamos Air	16
Latin America	**Total 26**
Aerolineas Argentinas	8
Air Caraibes	12
French Bee	2
LATAM Airlines Chile	4
Middle East	**Total 74**
C.A.L. Cargo Air Lines	8
El Al	32
Iraqi Airways	4
Mahan Air	2
Meraj Air	4
Saudia	22
Yemenia	2
North America	**Total 712**
ABX Air	6
Air Canada Rouge	24
American Airlines	18
Atlas Air	24
Delta Air Lines	128
FedEx	101
Hawaiian Airlines	14
Kalitta Air	32
Prime Air	2
Sky Lease Cargo	7
United Airlines	174
UPS Airlines	182
PRATT & WHITNEY PW6000	**TOTAL 16**
Latin America	**Total 16**
Avianca Brazil	16
ROLLS-ROYCE AE 3007	**TOTAL 970**
Africa	**Total 132**
Africa World Airlines	12
Air Katanga	2
Air Namibia	8
Air Peace Hopper	4
Airlink	48
ALS Limited	6
Cronos Airlines	8
Equaflight	2
FastJet Zimbabwe	6
Groupe Transair	4
Madagasikara Airways	2
Mauritania Airlines	2
Mocambique EXpresso	6
National Airways	6
Solenta Aviation	8
Solenta Aviation Mozambique	2
Swaziland Airlink	6
Asia-Pacific	**Total 14**
JETGO Australia	10
Korea Express Air	4
Europe	**Total 104**
BMI Regional	36
Eastern Airways	6
HOP!	30
Komiaviatrans	8
Loganair	2
Maleth Aero	2
Nordica	2
Pan Europeenne Air Service	4
Windrose Airlines	14
Latin America	**Total 34**
Calafia Airlines	8
Satena	4
TAG	2
TAR Aerolineas	20
Middle East	**Total 10**
ATA Airlines	4
Ayit Aviation	2
Pouya Air	4
North America	**Total 676**
Aerodynamics	8
CommutAir	50
Envoy Air	192
ExpressJet Airlines	222
Piedmont Airlines	84
Trans States Airlines	108
Via Air	12
ROLLS-ROYCE BR700	**TOTAL 308**
Asia-Pacific	**Total 52**
QantasLink	40
Turkmenistan Airlines	12
Europe	**Total 34**

Volotea	34
North America	**Total 222**
Delta Air Lines	182
Hawaiian Airlines	40
ROLLS-ROYCE RB211	**TOTAL 1,038**
Africa	**Total 2**
TACV - Cabo Verde Airlines	2
Asia-Pacific	**Total 126**
Air Astana	10
Air China Cargo	8
Air Hong Kong	4
Blue Dart Aviation	12
China Air Cargo	2
China Postal Airlines	10
Nepal Airlines	2
Qantas	12
SCAT	4
SF Airlines	44
Sunday Airlines	4
Tasman Cargo Airlines	2
Turkmenistan Airlines	2
Xiamen Airlines	8
YTO Express Airlines	2
Europe	**Total 458**
Aer Lingus	2
ASL Airlines Belgium	4
Azerbaijan Airlines	4
Azur Air	2
British Airways	158
Cargolux	28
Cargolux Italia	12
Condor	26
Cygnus Air	4
DHL Air	46
European Air Transport	6
Icelandair	54
Ifly	2
Jet2	24
La Compagnie	4
OpenSkies	2
Primera Air Scandinavia	2
Privilege Style	4
Royal Flight	14
Silk Way West Airlines	4
Sky Gates Airlines	8
SW Italia	8
TCA	4
Thomas Cook Airlines	4
Titan Airways	2
TUI Airways	28
Yakutia Airlines	2
Middle East	**Total 8**
Arkia	2
DHL International Aviation EEMEA	2
Emirates Airline	4
North America	**Total 444**
American Airlines	68
ATI - Air Transport International	6
Cargojet Airways	12
Eastern Airlines	8
FedEx	132
Morningstar Air Express	14
United Airlines	124
UPS Airlines	80
ROLLS-ROYCE SPEY	**TOTAL 2**
Africa	**Total 2**
Fly-SAX	2
ROLLS-ROYCE TAY	**TOTAL 260**
Africa	**Total 4**
CemAir	2
Ocean Airlines	2
Asia-Pacific	**Total 164**
Air Niugini	26
Alliance Airlines	54
Bek Air	16
Network Aviation	34
Skippers Aviation	4
TransNusa Air Services	2
Virgin Australia Regional Airlines	28
Europe	**Total 38**
Adria Airways	2
Avantiair	4
Carpatair	2
Helvetic Airways	6
HOP!	2
KLM Cityhopper	2
Lufthansa	4
Montenegro Airlines	4
Trade Air	2
Tus Airways	10
Latin America	**Total 14**
Air Panama	10
Fly Allways	4
Middle East	**Total 40**
Iran Air	6
Iran Aseman Airlines	14
Karun Air	8
Kish Air	6
Qeshm Airlines	6
ROLLS-ROYCE TRENT	**TOTAL 3,342 (2,190)**
Africa	**Total 136 (100)**
Afriqiyah Airways	(20)
Air Austral	2
Air Leisure	6
Air Mauritius	4 (12)
Air Namibia	4
Air Peace	2
Air Senegal	(4)
Air Tanzania	(2)
Egyptair	20 (14)
Ethiopian Airlines	32 (36)
Libyan Airlines	(12)
RwandAir	4
South African Airways	58
Tunisair	4
Asia-Pacific	**Total 1,598 (864)**
Air Astana	(6)
Air Calin	(4)
Air China	146 (24)
Air New Zealand	34 (4)
Air Niugini	(2)
AirAsia X	44 (152)
ANA-All Nippon Airways	128 (50)
Asiana Airlines	34 (50)
Biman Bangladesh Airlines	4
Capital Airlines	16 (2)
Cathay Dragon	48
Cathay Pacific	146 (52)
Cebu Pacific Air	16
China Airlines	24 (4)
China Eastern Airlines	94 (52)
China Eastern Yunnan	4
China Southern Airlines	64 (44)
Fiji Airways	8
Garuda Indonesia	48 (28)
Hainan Airlines	52 (16)
Hong Kong Air Cargo	6
Hong Kong Airlines	40 (36)
Indonesia AirAsia Extra	4
Japan Airlines	(62)
Lion Air	6
Lucky Air	2 (2)
Malaysia Airlines	30 (2)
Nepal Airlines	(4)
NokScoot	8
Philippine Airlines	30 (12)
Qantas	48 (32)
Royal Brunei Airlines	8 (2)
Scoot	32 (8)
Shanghai Airlines	12
Shenzhen Airlines	6 (2)
Sichuan Airlines	24 (4)
Singapore Airlines	204 (192)
SriLankan Airlines	26 (8)
Thai AirAsia X	14
Thai Airways International	128
Thai Lion Air	6
Tianjin Airlines	8 (4)
Tibet Airlines	10
Vietnam Airlines	24 (4)
Virgin Australia	12
Europe	**Total 838 (402)**
Aer Lingus	(18)
Aeroflot Russian Airlines	44 (28)
Air Europa	32 (28)
Air France	(42)
Azerbaijan Airlines	8
British Airways	134 (68)
Brussels Airlines	4
Corsair	8
Edelweiss Air	4
Eurowings	2
Evelop Airlines	2
Finnair	22 (16)
Hi Fly	4 (2)
Iberia	64 (32)
Icelandair	(2)
Ifly	4
KLM Royal Dutch Airlines	(14)
LOT Polish Airlines	20 (8)
Lufthansa	180 (32)
MNG Airlines	2 (6)
NEOS	4 (4)
Nordwind Airlines	2
Norwegian	46 (16)
Norwegian Air UK	14
Onurair	6
Orbest	2
Rossiya Airlines	10
SAS	16 (18)
SWISS	28
TAP Air Portugal	8 (36)
Thomas Cook Airlines	16
Thomas Cook Airlines Scandinavia	6
TUI Airlines Nederland	2
Turkish Airlines	52
Virgin Atlantic Airways	76 (24)
Virgin Atlantic International	4
WOW air	6 (8)
XL Airways France	6
Latin America	**Total 144 (94)**
Air Caraibes	4 (6)
Avianca	42 (28)
Avianca Brazil	10
Avianca Cargo	10 (2)
Avianca Peru	2
Azul	14 (10)
French Bee	4
LATAM Airlines Brazil	12 (38)
LATAM Airlines Chile	40 (10)
LATAM Airlines Ecuador	4
TAME	2
Middle East	**Total 362 (558)**
Arkia	(4)
El Al	20 (12)
Emirates Airline	54 (156)
Etihad Airways	48 (124)
Gulf Air	14 (30)
Iran Air	4 (88)
Kuwait Airways	10 (20)
Mahan Air	24
Middle East Airlines	10
Oman Air	20
Qatar Airways	84 (104)
Saudia	74
Yemenia	(20)
North America	**Total 264 (172)**
Air Canada	16
Air Transat	36
American Airlines	124
Delta Air Lines	34 (82)
Hawaiian Airlines	48
Omni Air International	6
United Airlines	(90)

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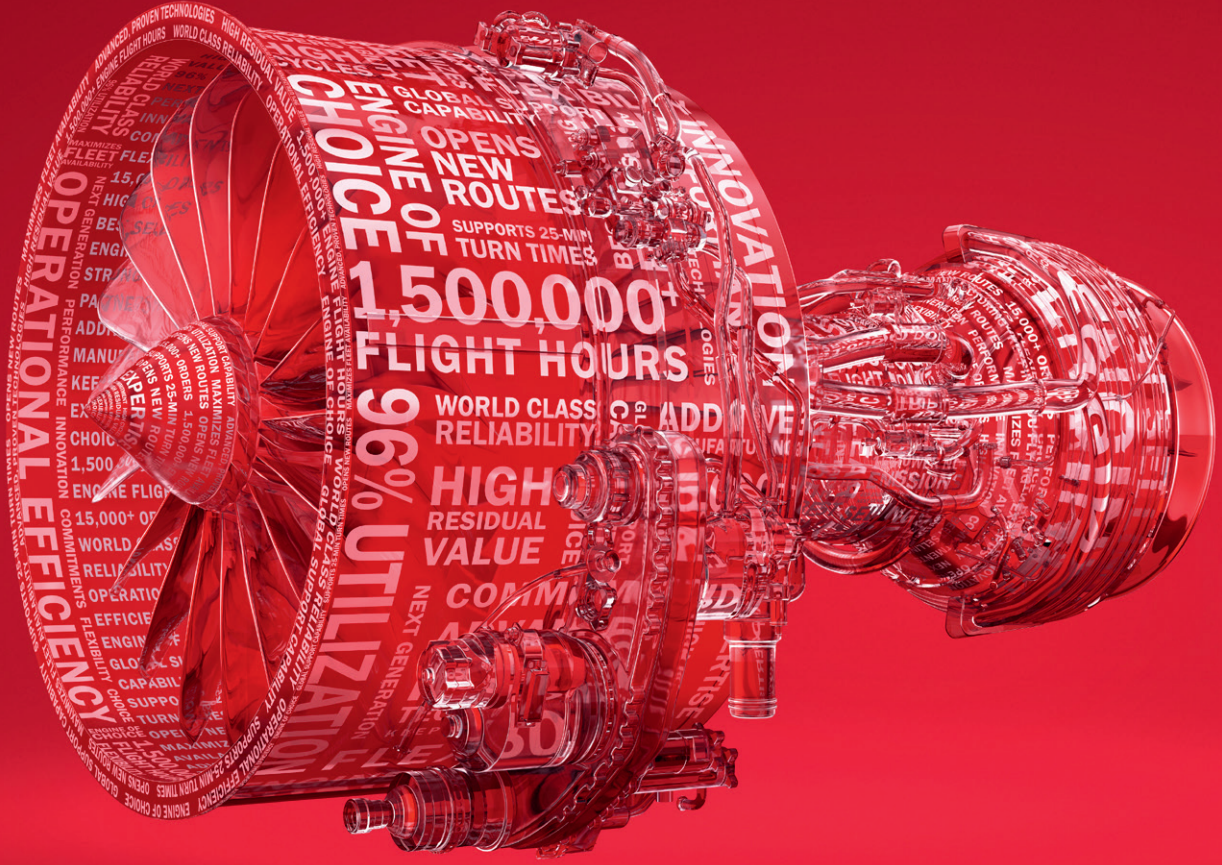

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