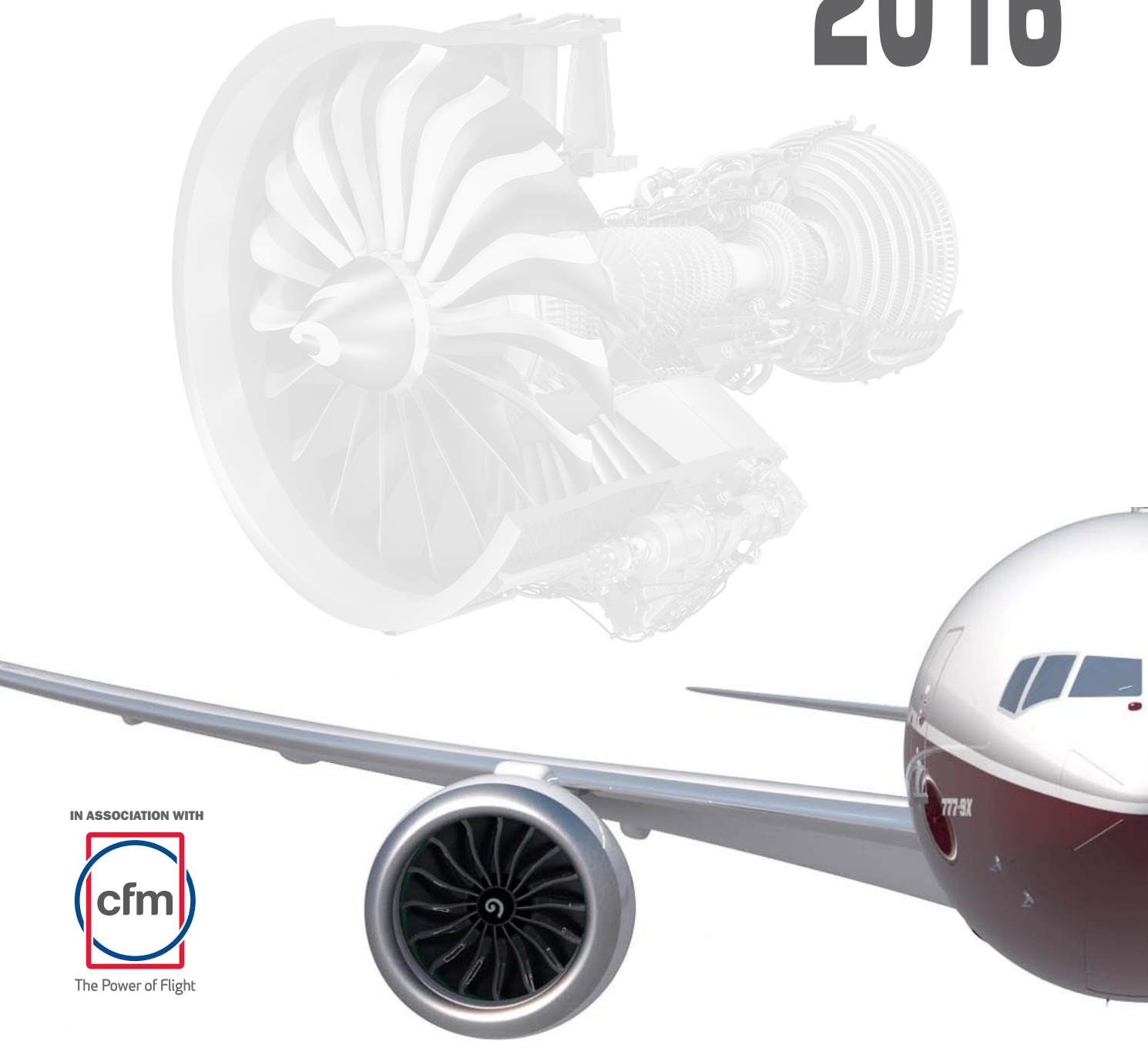
FlightGlobal

COMMERCIAL ENGINES

TURBOFAN FOCUS 2016



IN ASSOCIATION WITH

cfm

The Power of Flight


cfm
Demand.
And supplied.
More than 10,500 engines ordered and now delivering to customers worldwide, on schedule. **The architecture of reliability.**
cfmaeroengines.com
CFM International is a 50/50 joint company between GE and Safran Aircraft Engines
PERFORMANCE | EXECUTION | TECHNOLOGY
LEAP
MORE TO BELIEVE IN

CONTENTS

ENGINE EVENTS

MEMORABLE RECENT EVENTS

2015

NOVEMBER
- First flight test of the PW1200G-powered Mitsubishi MRJ
- EASA, FAA certificate Leap-1A for A320neo family
- Chengdu Airlines takes delivery of first CF34-10-powered ARJ21

DECEMBER
- Transport Canada certificates the PW1500G-powered CSeries CS100

2016

JANUARY
- First PW1100G-powered A320neo delivered to Lufthansa
- First flight test of the Leap-1B-powered 737 Max

FEBRUARY
- GE Aviation begins assembling first GE9X
- First flight test of the Leap-1A A321neo
- Rolls-Royce launches enhanced Trent XWB for the A350 with deliveries of the XWB-84 Enhanced Performance (EP) engine to SIA to begin in the fourth quarter of 2019

MARCH
- GE Aviation completes assembly of the first GE9X test engine
- First flight test of the PW1100G-powered A321neo
- Electric-driven PD-14 reverser tested for MC-21

MAY
- Leap-1B awarded joint FAA, EASA type certification
- FAA certificates the PW1400G for the MC-21
- Leap-1A-powered A320neo certified by EASA and FAA

WHAT TO WATCH FOR THE FUTURE: ENGINE ENTRY INTO SERVICE

2016 Q3/Q4

- PW1500G-powered CSeries with Swiss International Air Lines
- Leap-1A-powered A320neo

2017

- Trent 1000-TEN-powered 787-8/9
- Trent XWB-97-powered A350-1000
- Leap-1C-powered C919
- Leap-1B-powered 737 Max
- Trent 7000-powered A330neo

2018

- PW1200G-powered Mitsubishi MRJ
- PW1900G-powered E-Jet E190 E2
- PW1400G-powered MC-21
- PD-14-powered MC-21

2020

- GE9X-powered 777X
- PW1700G-powered E-Jet E175 E2

2026

- CJ1000A-powered C919

ENGINE ANALYSIS

How engine market share battles are playing out

As the engine manufacturers prepare for a crucial year during which two new powerplant protagonists in the single-aisle market are making their service debut, we examine the sector's key statistics for 2015.

This year has already seen Pratt & Whitney's new PW1000G geared turbofan entering service on the Airbus A320neo and deliveries of the rival Leap-1 from CFM International are due to start on the Airbus single-aisle in 2016. Data from Flight Fleets Analyzer reveals that last year the number of installed engines delivered to commercial operators on Airbus and Boeing airliners rose 3% to over 2,800 units. Again the CFM56 accounted just over half of these engines (52%) as it continues to be the sector's clear market leader in terms of shipments.

Obviously CFM's exclusive supply status on the 737 and continuing strong share on the A320 – both current and re-engined versions – drives this impressive performance.

Significantly, CFM's joint-venture partner GE moved into second place last year, ahead of International Aero Engines, delivering 504 installed engines, which represents almost a fifth of the total.

Based on installed engines, Fleets Analyzer shows that CFM continues to hold a 49% share of the 25,440 engines on firm backlog at the end of last year.

Although P&W delivered just 14 engines on mainline jets last year, it is making its presence felt in the backlog stakes where its 2,538 installed engines – almost entirely its PW1000G – equate to 10% of the entire backlog.

The two mainline programmes where there is still significant engine competition are the A320 family and the Boeing 787.

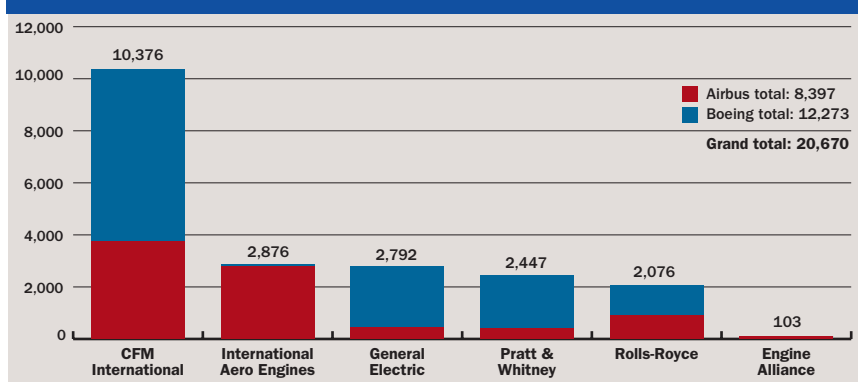
On the Airbus single-aisle programme, CFM reasserted itself last year in deliveries, taking a 54% share after rival IAE held the advantage in 2014 with a 51% share.

ENGINE MANUFACTURER RANKING FOR AIRBUS & BOEING

		2015 deliveries		Backlog*	
Rank	Manufacturer	Engines	Share	Engines	Share
1	CFM International	1,482	52%	12,428	49%
2	General Electric	504	18%	2,086	8%
3	International Aero Engines	448	16%	696	2%
4	Rolls-Royce	292	10%	2,770	11%
5	Engine Alliance	84	3%	136	1%
6	Pratt & Whitney	14	1%	2,538	10%
	Undecided	-	-	4,786	19%
TOTAL		**2,824**		**25,440**	

NOTES: *At 31 December 2015. Data for installed engines based on Airbus/Boeing types. Excludes corporate and military operators. SOURCE: Flight Fleets Analyzer

AIRBUS/BOEING FLEET BY ENGINE MANUFACTURER



NOTES: In-service and parked fleet at 31 December 2015. Boeing data includes former MDC types. Excludes corporate and military operators
SOURCE: Flightglobal Insight analysis using Flightglobal's Fleets Analyzer database

A330 ENGINE MANUFACTURER SHARE

	2015 deliveries		Backlog*	
Manufacturer	Aircraft	Share	Aircraft	Share
General Electric	20	20%	36	11%
Pratt & Whitney	7	7%	20	6%
Rolls-Royce	72	73%	222	65%
Undecided	-	-	61	18%
TOTAL	**99**		**339**	

767 ENGINE MANUFACTURER SHARE

	2015 deliveries		Backlog*	
Manufacturer	Aircraft	Share	Aircraft	Share
General Electric	16	100%	76	100%
Pratt & Whitney	0	-	0	-
TOTAL	**16**		**76**	

NOTES: *At 31 December 2015. Excludes corporate and military operators
SOURCE: Flight Fleets Analyzer

In backlog terms, CFM is still the leader (competing on both A320ceo and A320neo) with a third of the market but IAE partner P&W is growing its share. As the A320 market evolves towards the Neo where P&W offers its PW1000G, its share has increased from 20% in 2014 to 22% last year. However IAE – which only competes on the Ceo – has seen its share decline from 10% to 6%.

GE remains the lead supplier on the 787, powering 63% of the aircraft delivered last year. Rolls-Royce, which offers the only alternative, continues to power just under 40%.

In backlog terms, around a fifth of the aircraft on order are still to play for. Of the remainder where a powerplant choice has been made, just under half (48%) will have GE power.

Rolls is in a strong position on the two Airbus widebodies where there is a powerplant choice. It holds 65% of the backlog across the entire A330 programme (it is sole supplier on A330neo) and 54% on the A380. However GE's Engine Alliance partnership with P&W is the A380 leader in delivery terms, powering almost 80% of last year's shipments thanks to its long-standing deal from Emirates.

When the current Airbus and Boeing global airliner fleet is examined CFM is way out in front, powering around half of the 20,700 airliners in service. Around two-thirds of the global CFM-powered airliner fleet are Boeing 737s.

The four engine suppliers behind CFM are closely matched in the 2,000-3,000 aircraft range. IAE holds the next-largest share with almost 2,900 units (virtually all A320 family aircraft), closely followed by GE (2,792), P&W (2,447) and R-R (2,076).

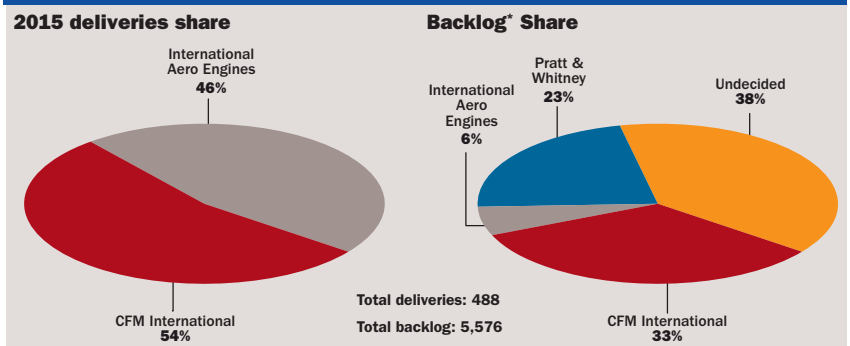
In the regional aircraft sector, GE was lead supplier last year, powering just over half of all deliveries. However it is Pratt that dominates the backlog with a 65% share. The company's PW1000G is being prepared for service on the Bombardier CSeries this summer while flight-testing is underway on the Mitsubishi MRJ and about to start on the Embraer E-Jet E2.

A380 ENGINE MANUFACTURER SHARE

	2015 deliveries		Backlog*	
Manufacturer	Aircraft	Share	Aircraft	Share
Engine Alliance	21	78%	34	24%
Rolls-Royce	6	22%	76	54%
Undecided	-	-	30	22%
TOTAL	**27**		**140**	

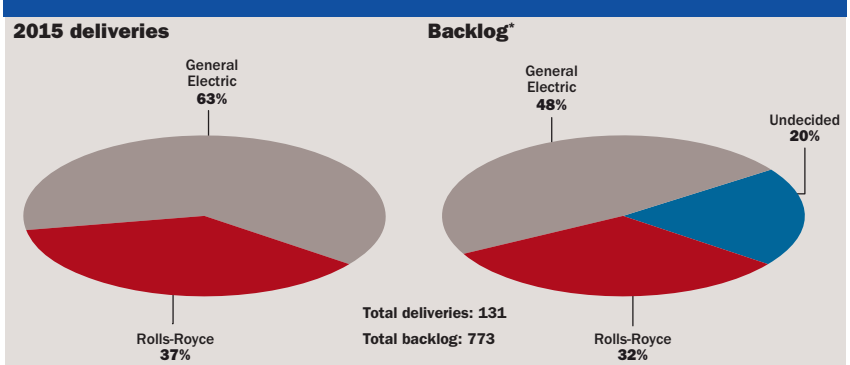
NOTES: *At 31 December 2015. Excludes corporate and military operators
SOURCE: Flight Fleets Analyzer

A320 FAMILY - ENGINE MANUFACTURER SHARE



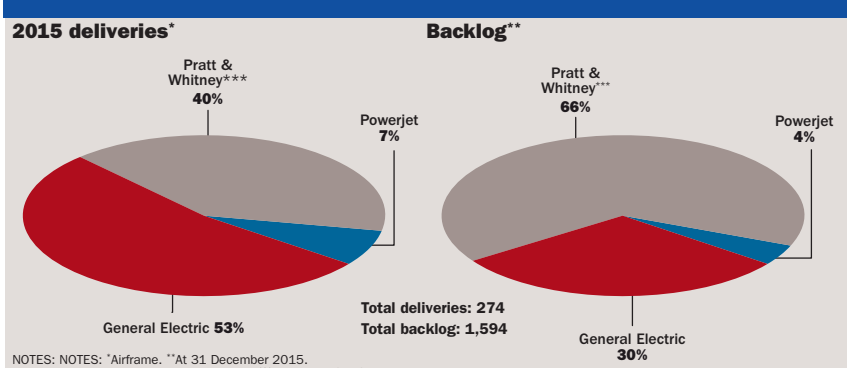
NOTES: *At 31 December 2015. Excludes corporate and military operators.
SOURCE: Flightglobal Insight analysis using Flightglobal's Fleets Analyzer database

787 - ENGINE MANUFACTURER SHARE



NOTES: *At 31 December 2015. Excludes corporate and military operators.
SOURCE: Flightglobal Insight analysis using Flightglobal's Fleets Analyzer database

REGIONAL AIRCRAFT ENGINE MANUFACTURER MARKET SHARE



NOTES: NOTES: *Airframe. **At 31 December 2015.
Excludes corporate and military operators. ***Including P&W Canada.
Data for firm orders for ATR, Bombardier (including CSeries), Comac, Embraer, Mitsubishi and Sukhoi.
SOURCE: Flightglobal Insight analysis using Flightglobal's Fleets Analyzer database

How GTF and Leap are shifting to operational mode

As a new generation of powerplants come online, all eyes will be on the CFM Leap when it debuts on the A320neo this year while rival Pratt & Whitney works to iron out problems suffered during the introduction of its geared turbofan

Sometimes the revolution begins with a whimper instead of a bang. After investing $10 billion over nearly 30 years in geared turbofan engine technology, the staging of the entry into service of the first pair of Pratt & Whitney PW1100Gs on a newly-delivered Lufthansa A320neo seemed more tentative than triumphant.

With zero fanfare and little notice, Lufthansa on 25 January quietly loaded passengers on an A320neo for a routine flight from Frankfurt to Munich, making for one of the most anticlimactic moments in aviation history.

The silence was made more awkward by coming two years late. Delays to the Mitsubishi Regional Jet and the Bombardier CSeries family pushed the arrival of the geared turbofan engine from late 2013 to early 2016 and allowed Airbus to claim the honour of introducing the first all-new centreline engine to enter the single-aisle market in nearly 30 years.

For some customers, however, the long-awaited PW1100G was still not quite ready for primetime. P&W's main engine rival – CFM International – will no doubt face similar scrutiny when the first Leap-1A-powered A320neo enters service this year. But the PW1100G's roughly eight-month lead on the Leap-series engine family meant it was the first to feel the pressure.

P&W plans to begin deliveries of PW1100G engines with upgraded software "soon", said Rick Deurloo, senior vice-president of sales, marketing and customer support, on 1 March at the ISTAT Americas conference in Phoenix.

Those upgrades should address about 80% of the teething issues that prompted Qatar Airways in December 2015 to withdraw as A320neo launch operator, Deurloo says. Further hardware upgrades are also coming to address the most prominent flaw in the PW1100G engine.

In all turbofan engines, superheated air can become trapped inside the casing after engine shutdown. Restarting the engine with that air inside can cause slight deformations in components, which can lead to more extensive damage. To prevent problems, a cycle of cooling air is run through the engine igniting the fuel. For most engines, this cooling cycle takes less than 1min for each engine. Indeed, CFM says the cooling cycle for the Leap is within a few moments of the 50s cooling cycle for the CFM56.

A damper is now installed on the third and fourth shaft bearings, starting with the geared turbofan engines destined for the 11th A320neo off the production line. The first 10 A320neos off the production line will be retrofitted with the new damper, which should help stiffen the shaft against thermal deformations.

How much the initial teething troubles will cost P&W in the long run is unclear. The competing Leap-1A engine for the A320neo will not enter service until this year, so no comparison is possible. But P&W officials point to other aspects of the PW1100G's performance, citing a comment by Airbus chief executive Fabrice Bregier that fuel burn is "perfect" and a claim by Lufthansa the fuel efficiency is slightly better than expected.

Although the Leap-1A has yet to enter service, the non-geared alternative to the P&W option remains on the same schedule set by CFM International at programme launch in July 2008. The Leap-1A received airworthiness certification in late November 2015, fulfilling CFM's pledge, more than seven years earlier, to complete that milestone by 2016.

"The Leap achieved either the exact date which has been set four years ago or we were able to be ahead of schedule," says Jean-Paul Ebanga, chief executive of CFM.

The certification campaign for the Leap-1B engine that powers the Boeing 737 Max is ongoing. Only one "minor" certification test remains unfinished as of early March, and final approval from the US Federal Aviation Administration is expected within weeks,

Lufthansa

The first Pratt & Whitney PW1100G-powered A320neo was delivered to Lufthansa in January 2016

said Ebanga at the ISTAT Americas conference on 29 February.

In addition to being on time, CFM officials also assert both engines for the A320neo and 737 Max are meeting promised fuel-burn performance.

P&W achieved a 20% reduction in specific fuel consumption, mostly by inserting a gearbox between the low-pressure turbine and the inlet fan, allowing designers to increase the length of the fan blades and thus raise the ratio of air bypassing the engine core from about 6:1, in the International Aero Engines V2500, to about 12:1 in the PW1100G.

CFM relies on a conventional architecture with the low-pressure turbine directly driving the front fan. That limited the expansion of the bypass ratio to grow from 6:1 to 10:1, but CFM compensated by increasing the efficiency of the engine core. CFM added a stage to the high-pressure compressor, raising the overall pressure ratio from the 30:1 class in the CFM56 to the 40:1 class in the Leap-1 series. As pressure loads rose, CFM added a second stage to the high-pressure turbine. The internal cooling was also reduced by inserting heat-resistant ceramic matrix composites in the shrouds of the first stage of the high-pressure turbine.

Despitethe upgrades, questions lingered about the Leap-1 engine's ability to meet fuel specifications. Airbus and Boeing officials have said repeatedly the engines should meet promised levels by the time the aircraft are ready to enter service.

Within months of the entry-into-service date of the Leap-powered A320neo, CFM officials insist the verity is already in on the fuel specification.

The first CFM Leap engine will enter service in 2016 on the A320neo

"In terms of engine performance, the Leap engines we are shipping right now, either in Toulouse or Seattle are on spec," Ebanga says.

In a subsequent interview at CFM headquarters in Cincinnati, CFM executive vice-president Allen Paxson added the same engines delivered to Airbus have demonstrated fuel-burn results on GE Aviation's flying testbed.

"I am confident that the engines we have delivered to Airbus are right on specification," he says.

Airbus has not named the launch operator for the Leap-powered A320neo, but CFM expects to deliver engines to six airlines within three months of entry into service, Paxson says.

The Leap-1B engines installed on the first 737 Max 8 had completed 22 test sorties within a month of the type's first flight, on 3 February, Paxson says.

"We are running the engines now on the ground and they are right on specification – and I'm talking ten-thousandths of a percent," he adds. "We are right there. We are very, very confident. Is it done? No, because we have not delivered it. But the engines are drinking the amount of fuel to meet our spec level so we are there. We are very confident that the -1A and the -1B will meet the committed level of performance."

A version of the Leap-1A is also developed for the Comac C919. CFM delivered the first Leap-1Cs to the Chinese narrowbody programme last year, as the C919 was originally scheduled to be the first to enter flight tests. First flight of the C919 is now scheduled in the third quarter.

By comparison, P&W's development work is still ramping up. The PW1500G is scheduled to enter service this year with Swiss on the Bombardier CS100. Russian manufacturer Irkut expects P&W to certificate the PW1400G engine for the MC-21 in the second quarter, although first flight has slipped to at least the end of this year.

Although the Mitsubishi Regional Jet (MRJ) completed first flight in November 2015, the PW1200G-powered airliner is scheduled to enter service at around the same time as the Embraer 190-E2, which is powered by the PW1900G engine. The PW1700G selected for the E175-E2 is scheduled to enter service two years later. P&W has delivered the first pair of PW1900Gs to the E190-E2, ahead of first flight in the second half of this year.

Engine selection trends on the A320neo

Chris Seymour, head of market analysis at Flight Ascend Consultancy, examines how Pratt & Whitney and CFM are faring in the battle to win A320neo customers

With the Airbus A320neo recently entering into service, how successful have the two engine manufacturers been in winning customers to power the re-engined twinjet?

Unlike the Boeing 737 Max where CFM International has exclusivity, there is a choice of two powerplants for the A320neo: incumbent supplier CFM (the GE/Snecma joint venture which has been on the A320 programme with its CFM56 since the start) offers the new-generation Leap-1A engine, against Pratt & Whitney with its PW1000G geared turbofan, which for the A320neo is designated PW1100G-JM.

Pratt & Whitney is a newcomer to the A320 programme in its own right but has been involved from the early days through the International Aero Engines consortium and became the majority shareholder in 2012 when it acquired Rolls-Royce's stake.

By March 2016, analysis of Flight Fleets Analyzer showed that the Neo family had amassed 4,502 firm orders from 60 airlines and lessors. Of these, engine choices have been announced for 2,856 aircraft, 63% of the total.

Where a choice has been made, the Leap-1A has won 1,544 orders, a 54% share, against 1,312 for PW1100G-JM. In terms of customers, the P&W engine has 30 versus 23 for Leap and also leads in direct airline orders, 22 versus 15. Nine lessors have ordered from CFM and eight from P&W.

Key wins for CFM, whose Leap-1A enters service in 2016, are AirAsia (304), recent customer Lion Air (183), EasyJet (130) and American Airlines (100), while lessor GECAS usually only orders aircraft with GE content and has 120 Neos on order. Leading customers for Pratt & Whitney are Indigo (180), Turkish (92), AerCap (90), GoAir (72) and JetBlue (70).

LESSORS

The operating lessors are an important component of the Neo customer base and to the success of a new type. With 984 orders to date, 11 lessors have a 22% share of the orderbook. Their engine choices to date are 34% Leap, 28% P&W and 38% to be decided. However, excluding GECAS who only orders CFM, the lessor share swings to 32% P&W. Most lessors will order a mix of engines to meet market demand and maximise liquidity of their portfolios.

To date, 31 customers, 52% of the total, have only chosen one engine type, for 1,969 orders (44%); 12 have chosen the Leap for 1,226 orders against 19 for 743 of the P&W engine. A further seven customers have also ordered 335 aircraft with one choice (87 CFM and 248 P&W), but also have another 561 orders where a choice has yet to be made. These include IndiGo and Avianca.

Eight customers have actually chosen both engines for 552 orders, 58% of which are for P&W. They also hold another 229 orders with no engine selected yet.

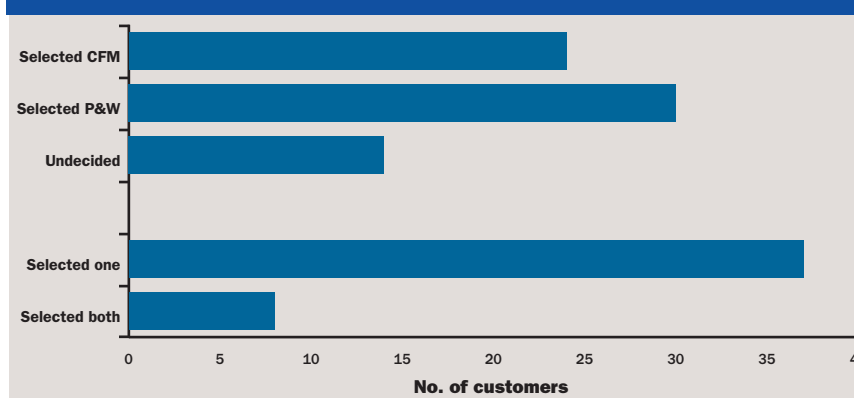
All are lessors except for one airline, Lufthansa, which is following the same practice it has on the A320ceo family where it uses both the CFM56 and V2500. While Lufthansa only has the V2500 on the A321ceo, for the next generation it has chosen a mix for both A320neos and A321neos. Lessors are flexible and have to use liquid assets, so they usually select both engines where a choice is available, to maximise attractiveness to lessees.

LOYALTY

The engine business is fiercely competitive and customer loyalty is a crucial factor. To date, 18 customers who have either the CFM56 or V2500 on the A320ceo family have remained with the same suppliers for almost 1,500 Neos.

Nine CFM A320ceo customers have ordered 995 Leap-powered A320neo aircraft with a further 100 ordered by Avianca yet to have a choice announced. Nine customers with V2500s powering

A320NEO FAMILY CUSTOMERS – ENGINE SELECTION



SOURCE: Flightglobal's Fleets Analyzer database

their A320ceos have remained with P&W on the Neo, accounting for almost 500 orders – 38% of their backlog. Again, one customer, IndiGo, has yet to reveal a choice for another 250 orders.

The number of customers who have changed their supplier compared to their current A320ceo fleet is relatively small to date – just eight airlines (five CFM and three PW) for 392 aircraft, a mere 9% of the backlog.

Six operators currently using both CFM56s and V2500s on their A320ceo fleet have decided on one supplier for 254 Neos – the largest being American, which chose the Leap despite operating almost 250 V2500 versus 150 CFM56 aircraft. LATAM Group, which has slightly more CFM56 types as a result of the LAN and TAM merger, has decided on the P&W engine for its orders.

Airbus and Boeing are fiercely competitive in the single-aisle market and the battle to win customers away from the competition can be intense. However, of the 60 current Neo customers, only five are new to the A320 programme, accounting for just 185 orders or 4% of the backlog. This is very indicative of aircraft-family loyalty when it comes to placing new orders.

Norwegian has 100 orders for Neos and has selected P&W for half of them; it has been an all-737 single-aisle operator to date but has chosen both Max and Neo for its future needs; albeit the airline's initial Neos will be leased to other operators through its Irish-based leasing entity.

Korean Air is a recent A321neo customer and has chosen P&W, as has Hawaiian which is adding 16 A321neos to its widebody fleet to serve US West Coast cities. Azul in Brazil is stepping up from Embraer 195s to 35 Leap-powered Neos. Israeli charter operator Arkia will replace 757s with A321neos but has yet to choose an engine for its four. Interestingly, none of these customers are switching from the 737 to the Neo, although Airbus has seen Air Canada and SilkAir switch in the opposite direction, from the A320ceo to 737 Max.

SITTING ON THE FENCE

There are still 13 airlines and lessors who have not yet made any choice for their combined 373 aircraft, including Wizz Air (110) and IAG (102 for subsidiaries British Airways, Iberia and Vueling). A further 479 aircraft have been ordered by unannounced customers, with choices yet to be revealed. Many of these orders are believed to be for Chinese customers.

Interestingly, the engine battle in the A320ceo sector is not done, with a fifth of the approximately 1,000 aircraft remaining on backlog still to play for. The CFM56 has been selected for around 45% of the A320ceos still on order, and the V2500 for around a third, while the remaining 21% of the backlog is yet to be allocated.

THE FUTURE

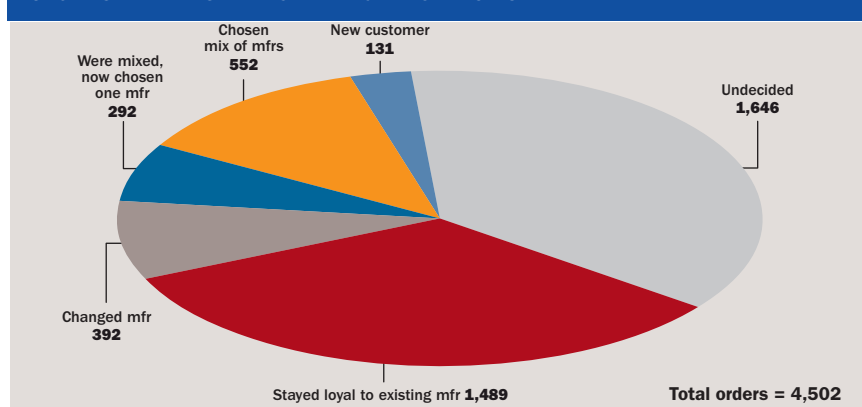
In terms of sales, neither the Leap nor the PW1100G currently has a clear advantage and there are still almost 1,650 orders for which a decision is yet to be made.

Looking into the longer term, the Flight Fleet Forecast is predicting demand for at least 9,800 Neos in the next 20 years, which equates to an open market for 5,300 more aircraft. There is an expectation that the better seat-mile costs of the A321neo will lead to a continued upsizing to this type. P&W has promised to deliver a performance improvement package in 2019 with a 2% reduction in specific fuel consumption and has launched a 35,000lb-thrust (160kN) version which has enabled Airbus to launch the long-range A321neo LR, with 30 orders already from Air Lease. CFM is expected to also develop upgrades in future on the Leap.

Currently the P&W engine has a 58% share of the A321neo order choice and if that share can be maintained then the overall engine market share over the longer term may just swing in favour of P&W. It could be a reverse of what is currently on the A320ceo, where CFM currently has a 56% share.

However, it is unlikely that either engine will gain a significant lead over the other, as the market for single-aisles is broad and diverse.

A320NEO FAMILY ORDERS BY ENGINE SELECTION



SOURCE: Flightglobal's Fleets Analyzer database

Can China and Russia threaten the single-aisle duopoly?

With Airbus and Boeing having dominated the commercial jet market for decades, will the ambitious upstarts in China and Russia be capable of threatening the world order?

This year is a significant one for the mainline jet sector: during 2016, not one but two all-new 150-seat airliners powered by next-generation engines will stake their claim for a slice of a market that for two decades has been the preserve of Airbus and Boeing.

China's Comac C919 was the first of these shiny new machines to break cover, rolling out in Shanghai in November 2015. As China's aerospace industry gets ready to fly the CFM International Leap-1C-powered twinjet, Russia's bid for single-aisle success is poised to make its debut. The Irkut MC-21, the prototype of which should emerge from the company's plant in Irkutsk in June, is powered by the Pratt & Whitney PW1400G – a derivative of the PW1000G geared turbofan.

While Western manufacturers are supplying the lead powerplants, both new types have engine options developed indigenously, albeit with the participation of international suppliers. The same is true for many of the primary systems, such as the avionics, flight controls and auxiliary power units.

The two twinjets are very similar in general configuration and size to the Airbus A320, incorporating single-aisle six-abreast cabins. And both feature fly-by-wire flight controls and have advanced cockpits equipped with sidesticks – active in the case of the MC-21. Both have metal fuselages, with the C919 adopting composites for the aft fuselage, fin and horizontal stabilisers. China has taken a less risky approach to Russia for the wing structure, plumping for aluminium whereas Irkut has gone with composites for its twinjet.

As things stand, the C919 is offered as a single variant, which seats 156 passengers in a two-class layout or 180 in a high-density configuration. Smaller and larger variants are proposed, but there's nothing firm yet.

Irkut offers two flavours of MC-21. The baseline -300 typically seats 163 passengers in a two-class layout or up to 211 in a high-density configuration, while the -200 accommodates 135 seats or up to 176 passengers in similar arrangements.

Both types have racked up orders from mainly local airlines and lessors. Flight Fleets Analyzer shows the Russian jet has 181 orders from eight customers (including 50 from flag carrier Aeroflot) and a further 79 options and commitments. Comac has secured orders for 282 C919s (from 13 customers including 10 in China) and a further 232 commitments. Significantly, two major lessors have each committed to take 20 C919s: BOC Aviation – the Singapore-based leasing arm of Bank of China – and GECAS, which is owned by CFM engine partner GE.

Irkut

The PW1400G-powered Irkut MC-21 should enter service in 2018

Assuming they complete their development and flight-test programmes on schedule, both twinjets are slated to enter service in around two years. And as they now crystallise from drawing board to reality, and flight-testing looms, the aviation world is starting to sit up and take more notice. But do they offer a genuine threat to Airbus and Boeing's re-engined single-aisles, with which they share powerplant and systems technology, or are they simply national vanity projects that are little more than sophisticated job-creation schemes?

150-SEAT AIRLINER COMPARISON

	C919	MC-21-300	A320neo	737 Max 8
MTOW (t)	78.9	76	75.5	82.2
Seating (2-class)	156	163	150	162
Range (nm)	3,000	2,700	3,700	3,500
Service entry	2018	2018	2016	2017
Engines	CFM Leap or ACAE CJ-1000	P&W PW1000G or Aviadvigatel PD-14	CFM Leap or P&W PW1000G	CFM Leap

SOURCE: Flightglobal/Ascend/Manufacturers

"On paper, both the MC-21 and C919 appear fully competitive in performance and economic terms with the A320neo and 737 Max. But this in itself is unlikely to be enough to convince significant numbers of prospective operators to acquire the aircraft on a global basis," says Rob Morris, who heads up Flight Ascend Consultancy.

"Because in addition to these, airlines will expect reliability to be as good as today's A320 and 737. This requires programme targets to be met – and neither manufacturer had managed to demonstrate any track record in this regard to date – then series production needs to be delivered, and most critically, product support on a global basis to ensure training, spares, airworthiness, 'AOG' and finance support, etc, are all managed to ensure that 99%-plus dispatch reliability. However, neither type, nor their manufacturer, offers any real degree of innovation over the Airbus and Boeing products and thus it is hard to see them becoming a major player with these projects."

For his part, Teal Group's vice-president of analysis Richard Aboulafia is clear that he views the motivation behind these new aircraft as political rather than a perceived market requirement. "There's nothing like the prospect of a government-managed, funded, and supported wannabe jetliner that inspires airlines to say 'thanks, but we'll take a pass on these'," he says.

"Back in the Cold War, we had 'Captive Nations Week', aimed at showing support for those luckless, grey, depressing countries behind the Iron Curtain. Perhaps now we should have 'Captive Airlines Week' aimed at supporting airlines forced by government fiat to buy jets designed and built by those very governments. Thankfully, the number of airlines in that unenviable position is quite small... Even in China, the airline industry is finding ways to assert itself. The agreement to build A320neos in Tianjin and the agreement to finish 737 Max aircraft in China gives Chinese airlines an excuse to continue buying what they want... Western jetliners."

Aboulafia is also not convinced that the Russian airlines will be forming a long queue for a locally designed and developed airliner, even if it has Western partners. "Well, we will see. Back in the 1990s, Russian airlines were told to keep buying Ilyushin Il-96s and Tupolev Tu-204s. They simply responded with a straightforward question: 'Does the government want a modest jetliner business or a healthy airline industry?'

WESTERN ALLURE

"The government relented, and Russian airlines got the Western jets they wanted. That killed the Tu-204 and Il-96."

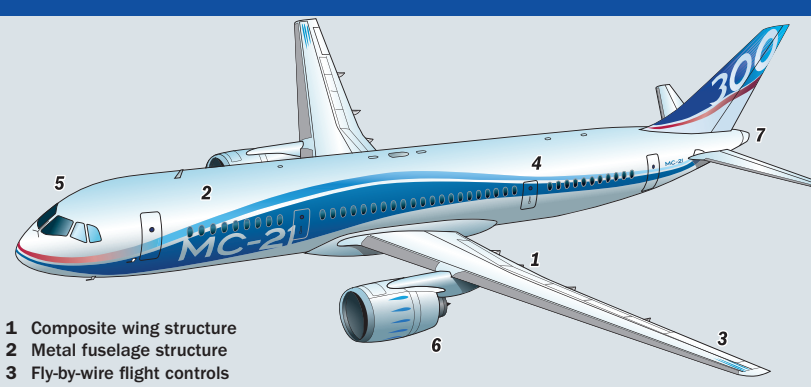
While these two new programmes are debuting almost simultaneously, one has a technical advantage over the other – at least on paper – says Ascend senior consultant Richard Evans. "The MC-21 is a much more advanced aircraft than the C919. It has a composite wing and an aspect ratio similar to the Bombardier CSeries, so it is arguably more advanced than even the A320neo.

"However, history suggests Russian types are generally higher in operating empty weight, and the new wing must represent an execution risk. If the MC-21 makes its cost and weight targets – which is not completely impossible – it might be a technical threat to the A320neo and 737 Max."

But even these technical innovations might not be enough for success in the world market, says Evans, as he believes airlines outside Russia would be very wary of support, reliability and maintenance cost, "so a market threat is unlikely".

The prospects for the C919 offering a genuine threat to Airbus and Boeing are even more limited as it offers no significant step over the original A320, says Evans.

IRKUT MC-21 KEY FEATURES



1 Composite wing structure
2 Metal fuselage structure
3 Fly-by-wire flight controls
4 Six-abreast cabin with 18in-wide seats
5 Two-crew flightdeck with active sidestick controllers and Rockwell Collins avionics (with Avionika-Russia and Irkut as integrator)
6 Pratt & Whitney PW1400G engines (28-31,000lb thrust) with Aviadvigatel PD-14 as option
7 Hamilton Sundstrand APS3200 or Aerosila TA18-200M APU

Two-variant family comprising baseline 163-seat (two-class) MC-21-300 followed by smaller 135-seat (two-class) MC-21-200

SOURCE: Ascend Flightglobal Consultancy

Morris thinks that the new twinjets could hamper Airbus and Boeing sales at Chinese and Russian airlines: "But even in those markets, operators need a fully competitive and reliable product and thus even that will be a tough challenge to overcome. But it is likely that there will be some market share taken from Airbus and Boeing in those markets, albeit small."

The latest Flight Fleet Forecast predicts that some 2,000 of the two new types will be delivered in the next 20 years (1,250 C919s and 750 MC-21s), representing 8% of the entire single-aisle market during that timeframe. Serial production of the C919 will be on a new assembly line which is scheduled to be completed at Shanghai Pudong airport in 2016 and be capable of outputting 150 aircraft a year by 2020.

However, Evans warns that one needs to look beyond the delivery numbers: "The record of Russian and Chinese manufacturers is that aircraft are delivered, but they do not necessarily stay in service. Many Tu-204/214s or Xian MA60s are parked, or in service at very low utilisation rates, leading to the conclusion that reliability and spares support is poor, and/or the aircraft are not competitive – such that the airline would rather fly Western-built types."

Another challenge for these airliners if they are to make a dent in the global market concerns their perception in current and future value terms among appraisers and the financial community.

"Clearly, asset-based financing – as we do – is relying on aircraft value and liquidity," says DVB Bank managing director of aviation research Bert van Leeuwen.

"Both types have not yet reached a stage where we can be comfortable about these key factors. Chinese lessors/airlines have taken positions in the C919, seemingly based on national interests, so that doesn't mean too much.

"So I wouldn't expect any 'Western' parties to take asset risk on these new designs in the near to medium term, unless based on very strong financial guarantees."

Ascend's full-life base value for a 2017 A320neo or 737 Max is around $51 million. "Neither the C919 nor MC-21 currently shows signs of the [A320/737's] level of market penetration, thus values are likely to be significantly lower and are hard to estimate," says Morris.

He sees the biggest challenge for both these projects as being able to deliver on promises. "In that regard, neither manufacturer has a proven track record of either innovation or delivery in the commercial sector. Thus, it's hard to see them breaking the market significantly with these products."

Comac

China's challenger: Comac's C919 rolled out in Shanghai in November 2015

AT A GLANCE

Commercial engines: manufacturer market share

NORTH AMERICA

MANUFACTURER	AIRCRAFT	ENGINES
CFM International	2,346	4,694
General Electric	2,121	4,474
Pratt & Whitney	925	2,000
Rolls-Royce	888	1,776
International Aero Engines	668	1,336
Honeywell	4	16
TOTAL	6,952	14,296

EUROPE

MANUFACTURER	AIRCRAFT	ENGINES
CFM International	2,988	6,124
General Electric	994	2,218
International Aero Engines	620	1,240
Rolls-Royce	592	1,430
Pratt & Whitney	180	386
Other	334	1,093
TOTAL	5,708	12,491

MIDDLE EAST

MANUFACTURER	AIRCRAFT	ENGINES
General Electric	449	932
CFM International	337	700
Rolls-Royce	166	368
International Aero Engines	132	264
Engine Alliance	91	364
Other	129	373
TOTAL	1,304	3,001

AFRICA

MANUFACTURER	AIRCRAFT	ENGINES
CFM International	377	790
General Electric	162	329
Rolls-Royce	93	206
Pratt & Whitney	78	184
International Aero Engines	50	100
Other	37	138
TOTAL	797	1,747

SOUTH AMERICA

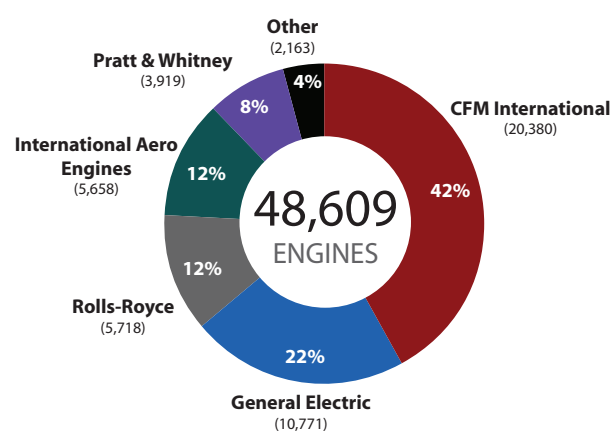
MANUFACTURER	AIRCRAFT	ENGINES
CFM International	694	1,400
General Electric	313	632
International Aero Engines	258	516
Pratt & Whitney	130	282
Rolls-Royce	93	186
Other	51	146
TOTAL	1,539	3,162

ASIA-PACIFIC

MANUFACTURER	AIRCRAFT	ENGINES
CFM International	3,316	6,672
International Aero Engines	1,131	2,262
General Electric	977	2,186
Rolls-Royce	782	1,692
Pratt & Whitney	349	836
Other	74	264
TOTAL	6,629	13,912

WORLD COMMERCIAL JET AIRCRAFT

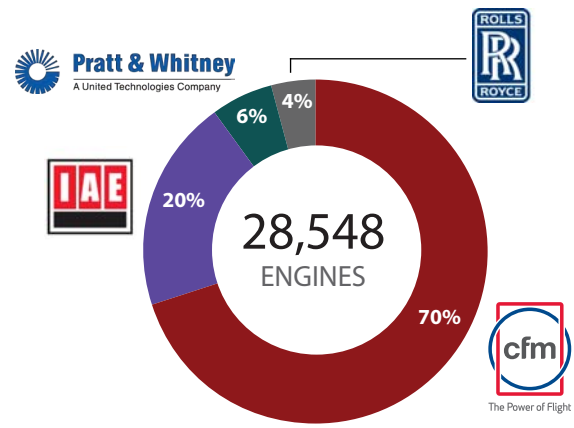
MANUFACTURER	AIRCRAFT	ENGINES
CFM International	10,058	20,380
General Electric	5,016	10,771
International Aero Engines	2,859	5,718
Rolls-Royce	2,614	5,658
Pratt & Whitney	1,752	3,919
Other	630	2,163
TOTAL	22,929	48,609



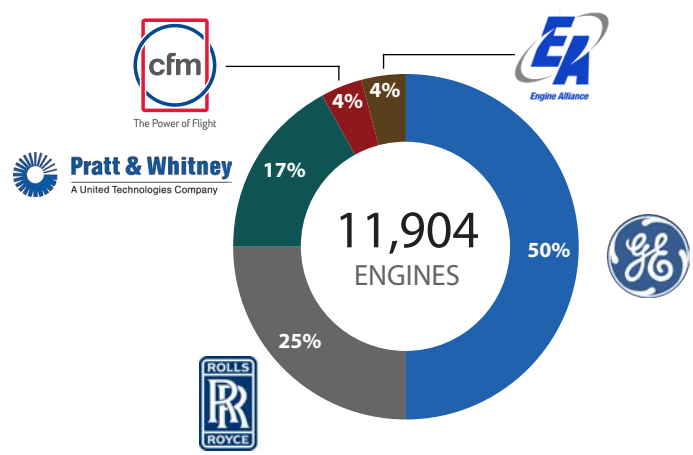
NOTE: Information for active commercial jets. Information includes narrowbody, widebody and regional jets in passenger, freighter, combi and quick change roles SOURCE: Flight Fleets Analyzer (May 2016)

Engine market share by market group

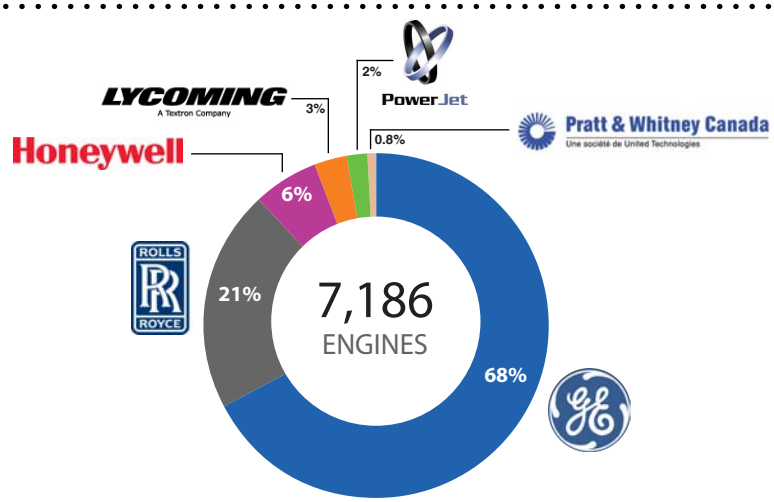
COMMERCIAL NARROWBODY AIRCRAFT		
MANUFACTURER	AIRCRAFT	ENGINES
CFM International	9,927	19,856
International Aero Engines	2,859	5,718
Pratt & Whitney	866	1,798
Rolls-Royce	588	1,176
TOTAL	14,240	28,548



COMMERCIAL WIDEBODY AIRCRAFT		
MANUFACTURER	AIRCRAFT	ENGINES
General Electric	2,589	5,917
Rolls-Royce	1,261	2,952
Pratt & Whitney	859	2,067
CFM International	131	524
Engine Alliance	111	444
TOTAL	4,951	11,904

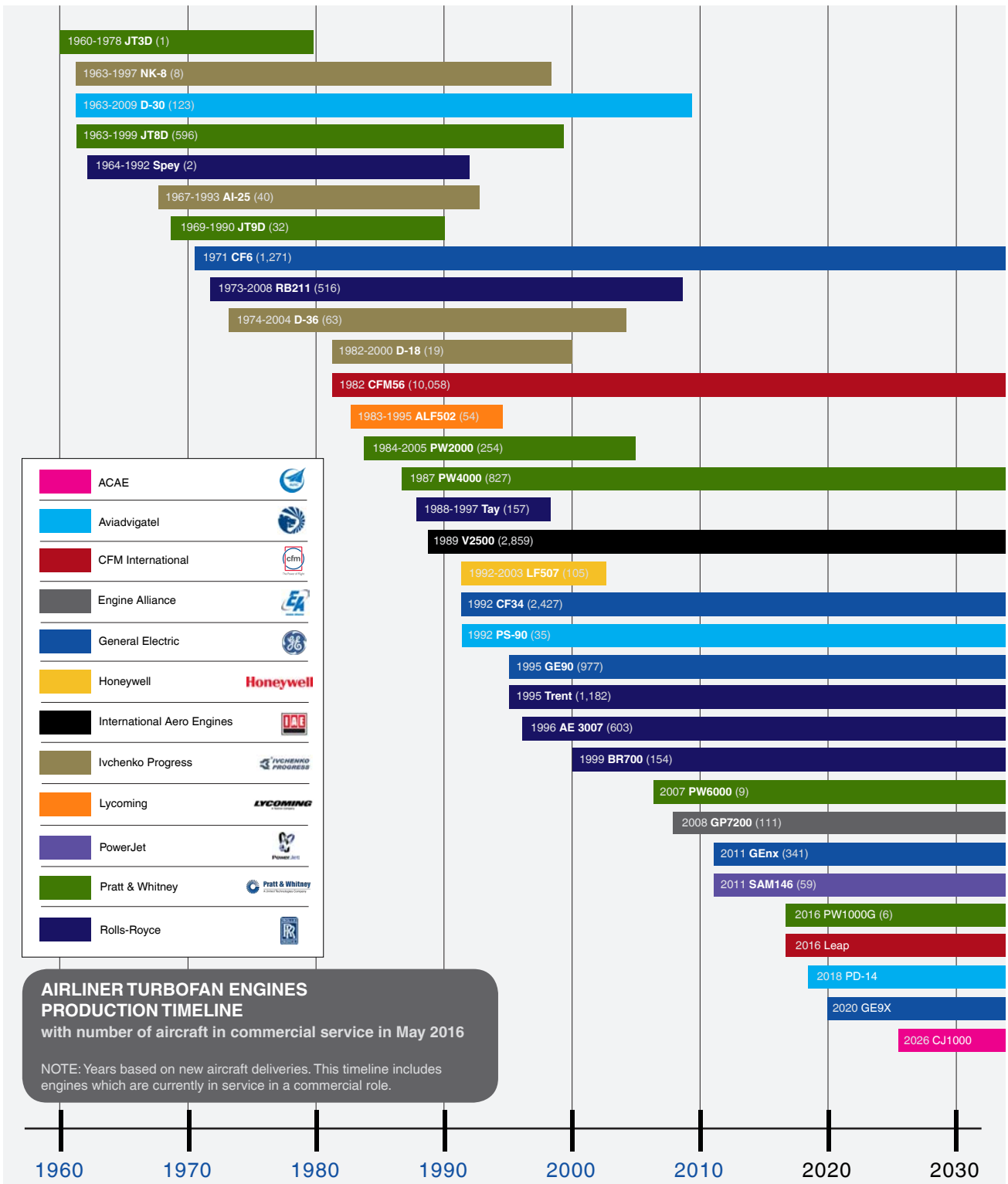


COMMERCIAL REGIONAL JET		
MANUFACTURER	AIRCRAFT	ENGINES
General Electric	2,427	4,854
Rolls-Royce	762	1,524
Honeywell	105	420
Powerjet	59	118
Lycoming	54	216
Pratt & Whitney	27	54
TOTAL	3,434	7,186



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 2016)

Airliner turbofan engines: production timeline



AIRLINER TURBOFAN ENGINES PRODUCTION TIMELINE

with number of aircraft in commercial service in May 2016

NOTE: Years based on new aircraft deliveries. This timeline includes engines which are currently in service in a commercial role.

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	CJ1000A	
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
	General Electric
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
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
	Lycoming
ALF502	BAe 146*
	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

COMMERCIAL ENGINES

Overview & specifications

AVIADVIGATEL

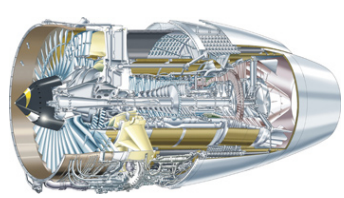
Aviadvigatel is a Russian design bureau founded in 1939 that specialises in developing civil and military aircraft engines. The company is the successor of the Soviet Soloviev Design Bureau which was responsible for the D-30 engine that is in service today on aircraft including the Il-62, Il-76, Tu-134 and Tu-154. The company is responsible for the PS-90 engine and is currently developing the new PD-14 for the new Russian Irkut MC-21 airliner. Aviadvigatel has now merged with the Perm Motors Group.

D-30 **(1963-2009)**

The D-30 entered service in 1963 while the last engine of that type was delivered in 2009. This engine was provided in the KP (1 and 2 series), KU (1 and 2 series) and the KU-154 variants. Aviadvigatel was the designer while the engines were produced by NPO Saturn in Rybinsk. The D-30 was developed and manufactured for aircraft ranging from fighters to tactical transport jets.

As of May 2016, there were just over 120 in-service aircraft powered by the D-30 in passenger and freight usage on the Il-62, Il-76, Tu-134 and Tu-154.

PS-90 **(1992-present)**



The PS-90 was developed to satisfy the demands of economy, performance and exhaust emission standards. It incorporates advanced technology including a high-bypass turbofan design, acoustically treated exhaust duct and full-authority digital engine control (FADEC).

The PS-90A – the initial variant – was certified in 1992, and eventually became the first Russian engine that accumulated over 9,000 hours without any removal, and was installed on Aeroflot's Il-96-300.

The PS-90 now powers Russian airliners including the Ilyushin Il-76 and Il-96 as well as the Tupolev Tu-204. As of May 2016, there were 35 aircraft powered by the PS-90 engine in a commercial role and only one on order.

PD-14 **(due in 2018)**

The PD-14 was announced in early 2010 and is Russia's answer to the latest turbofan engines for single-aisle aircraft from CFM International and Pratt & Whitney.

The engine is one of the two options for the powerplant on the Irkut MC-21 narrowbody. The PD-14's design has many similarities with the CFM International Leap engine. It is composed of 18 blades made from a titanium alloy.

Aerodynamic tests on the nacelle of the PD-14 began in November 2013 while an initial example of the engine has been fitted to a Ilyushin Il-76LL testbed in November 2015.

Aviadvigatel acknowledges that the PD-14 would also provide a new core that could be developed into an engine it calls the PD-18R, which would feature a fan-drive gear system similar to the PW1400G. In May 2016, there were 35 MC-21s on order due to be equipped with the PD-14.

Aviadvigatel - specifications

D-30	
Variants	KP, KU, KU-154
Characteristics	
Type	twin-spool, low bypass turbofan
Length (cm)	483
Fan diameter (cm)	146
Dry weight (kg)	2,305
Components (D-30KU)	
Architecture	axial
Low pressure spool	3-stage fan, 3-stage LPC, 4-stage LPT
High pressure spool	11-stage HPC, 2-stage HPT
Combustors	cannular
Performance	
Max thrust (lb)	23,150-26,400
Overall pressure ratio	17:1
Bypass ratio	2.3:1
Air mass flow (lb/sec)	
Thrust-to-weight ratio	3.8:1
Service entry	1963
Applications	Il-62, Il-76, Tu-134, Tu-154

PD-14	
Variants	
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	
Fan diameter (cm)	190
Dry weight (kg)	2,870
Components	
Architecture	axial
Low pressure spool	1-stage fan, 3-stage LPC, 6-stage LPT
High pressure spool	8-stage HPC, 2-stage HPT
Combustors	annular
Performance	
Max thrust (lb)	28,000-34,000
Overall pressure ratio	38-46:1
Bypass ratio	7.2-8.6:1
Air mass flow (lb/sec)	
Thrust-to-weight ratio	
Service entry	due in 2018
Applications	MC-21

PS-90	
Variants	A, A-76, A1, A2, A-42, A3
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	496
Fan diameter (cm)	190
Dry weight (kg)	2,950
Components	
Architecture	axial
Low pressure spool	1-stage fan, 2-stage LPC, 4-stage LPT
High pressure spool	13-stage HPC, 2-stage HPT
Combustors	annular
Performance	
Max thrust (lb)	38,400
Overall pressure ratio	30.85 :1 (PS-90A)
Bypass ratio	5:1 (PS-90A)
Air mass flow (lb/sec)	
Thrust-to-weight ratio	
Service entry	1992
Applications	Il,-76, Il-96, Tu-204

AVIC COMMERCIAL AIRCRAFT ENGINE COMPANY

The AVIC Commercial Aircraft Engine Company (ACAE) is a civil engine manufacturer founded in 2009 and is based in Shanghai, China. The company is a subsidiary of Aviation Industry Corporation of China (AVIC).

CJ-1000

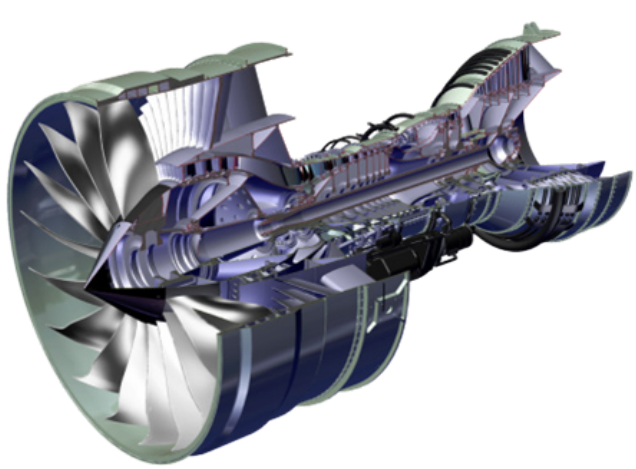
(due in 2026)

The CJ-1000 programme began in 2011 with the goal of developing a domestic alternative to the CFM International Leap-1C engine to power the Comac C919 narrowbody.

The CJ-1000 will produce thrust of up to 44,000lb and will be built in China. It will be the first Chinese-designed, high-bypass turbofan. The C919 will initially be equipped with CFM International Leap-1C engines and is scheduled to enter into service in 2017. A demonstrator engine for the CJ-1000 project is due to meet its performance requirements in 2018. ACAE aims to certify the CJ-1000 in 2022-25 with an entry into service in 2026.

In parallel, ACAE has begun preliminary work on the CJ-2000, an engine for the proposed C929 widebody airliner that Comac is supposed to develop with Russia's United Aircraft Corporation. The Chinese engine company also plans to develop a regional jet engine, the CJ-500.

ACAE hopes to market the CJ-1000 for use on jets on overseas markets. MTU has a 50/50 joint venture shop with China Southern Airlines for CFM International CFM56 and International Aero Engines V2500 powerplants in Zhuhai.



In February 2016, it was announced that GKN Aerospace will supply shafts for the CJ-1000, becoming the first confirmed Western supplier involved in the programme. The UK-based aerostructures will supply low pressure turbine shafts to ACAE from a facility in Norway.

The programme has attracted much interest in the past from Western suppliers, but GKN is the first to announce a confirmed supply contract. Germany's MTU Aero Engines, for example, worked with ACAE in 2012 to study the life cycle of the CJ-1000A, evaluating the feasibility of the design. But MTU has announced no further involvement in the project.

ACAE - specifications

CJ-1000	
Variants	
Characteristics	
Type	high bypass turbofan
Length (cm)	
Fan diameter (cm)	
Dry weight (kg)	
Components	
Architecture	axial
Low pressure spool	
High pressure spool	
Combustors	
Performance	
Max thrust (lb)	44,000
Overall pressure ratio	>40:1
Bypass ratio	
Air mass flow (lb/sec)	
Thrust-to-weight ratio	
Service entry	due in 2026
Applications	C919

CFM INTERNATIONAL

CFM International is a 50:50 joint venture between General Electric and Snecma (Safran) that was founded in 1974. The company is most famous for building CFM56 turbofans, an engine that now powers nearly 12,000 commercial and military aircraft including the Airbus A320 and Boeing 737 families. More than 28,000 CFM56s have been built since its introduction to the market in 1982.

The CFM56 core engine is derived from the General Electric F101 turbofan, developed by GE for military applications. The CFM56 first ran at the company's Evendale plant on 20 June 1974 and the first production models, installed in a re-engined McDonnell Douglas DC-8-70 airframe, entered service in April 1982.

The work split for the CFM56 engine takes advantage of the technological expertise and achievements of both Snecma and GE. GE builds the CFM56 core. The engine's core is the heart of any engine and is made up of three components: high-pressure compressor, combustor and high-pressure turbine. Snecma is responsible for the low-pressure turbine in the rear of the engine, which drives the CFM56 fan in the front, also engineered by Snecma.

CFM56 **(1982-present)**

The CFM56 was first contracted to re-engine DC-8 Super 70s, military 707s and Boeing KC-135s. It has a thrust range of 18,500-34,000lb-thrust (83-151kN) and first ran in 1974.

It is now one of the most common turbofan aircraft engines in the world with a market share of 52% of all commercial Airbus and Boeing aircraft currently in service. The CFM56 is also the powerplant on 13% of Airbus and Boeing narrowbodies on order as of May 2016.

In the early 1980s, Boeing selected the CFM56 to exclusively power its latest 737-300 variant, what is now called the 737 Classic. The CFM56 was first delivered on the 737 in 1984 and has powered all versions of the 737 ever since.

The CFM56 was first delivered on the A320 in 1988 and powers all models of the family, including the A318, A319, A320, A321, as well as A340-200 and A340-300 aircraft. The CFM56 is the most widely-used engine on commercial narrowbodies, with a current market share of 69%.

The CFM56 line has six engine models in its portfolio including the CFM56-2, CFM56-3, CFM56-5A, CFM56-5C, CFM56-5B and CFM56-7B.

The popularity of the CFM56 has created a global network of maintenance centres, run by Snecma, GE and third parties.

The CFM56 is currently fitted on 10,058 in-service aircraft in a commercial role. With 701 737s in its fleet in 2016, Southwest Airlines the carrier with the largest number of CFM56-powered aircraft in the world. American Airlines follows with a fleet that includes 423 A320 family and 737 aircraft powered by the CMF56.

Ryanair's fleet includes a total of 350 737s, while United Airlines' in-service fleet of more than 700 aircraft includes 312 737s. EasyJet is the operator with the largest number of CFM56-fitted Airbus aircraft, with a fleet of 226 A320s in service.

In May 2016, a firm order backlog of 1,658 airliners were due to be fitted with the CFM56, with Delta Air Lines leading the customer list with 140 aircraft, followed by Ryanair and Aeroflot with 121 and 85 aircraft respectively.

American Airlines

The CFM56 powers the majority of narrowboy aircraft in the world

LEAP

(due in 2016)

The Leap turbofan is the successor to the CFM56 line, which CFM has been working on since 1999. Leap (Leading Edge Aviation Propulsion) technology draws on developments made in previous years by GE and Snecma with engines such as the GE90 and GEnx.

Launched at the 2005 Paris air show as a possible CFM56 replacement, the Leap programme was at that time intended to supply the next generation of turbofans for all-new single-aisle aircraft by Airbus and Boeing. At that time, a few industry players expected a replacement for the A320 or 737 to appear before 2020.

Over the following years, the single-aisle market evolved rapidly. A competitor, P&W, introduced a fuel-saving fan-drive gear system in the narrowbody engine sector, the Chinese entered the market with a new single-aisle airframe, and Airbus and Boeing deferred plans for an all-new single-aisle. Instead, the US and European airframers settled for re-engining and updating their products within this decade.

The Leap is the only engine on all three narrowbodies in development with at least 160 seats (Airbus A320neo, Boeing 737 Max and Comac C919). The Leap fan will have a 198cm (78in) diameter for the A320neo and C919, and 175cm diameter for the 737 Max. All Leap fans will have 18 carbonfibre blades, significantly fewer than the CFM56-5B's 36 titanium blades and the CFM56-7B's 24 blades. Combined with a new lighter fan containment structure, the total weight savings will be 455kg per aircraft compared with a same-sized fan using metal blades and case.

The Leap engine will be the first commercial turbofan to incorporate ceramic matrix composites (CMCs), which are installed as the shroud encasing the first stage of the high-pressure turbine. CMCs are a lightweight material that can survive temperatures that would cause even actively-cooled metal blades to melt. Operators can expect 15% fuel burn improvements compared with the CFM56 engines currently in production. Noise levels will also be cut in half and NOx levels will meet CAEP/6 requirements with a 50% margin. CFM says that these improvements will not sacrifice the reliability and maintenance costs of the CFM56.

Airbus

The Leap-powered Airbus A320neo will enter service in 2016

Leap-1A

The Leap-1A is one of two engine options for the Airbus A320neo, due to enter service in 2016. The first Leap-1A was assembled in early 2013 and ground tests began the following month.

In November 2015, the FAA and EASA awarded separate type certificates for the Leap-1A, making it the only engine to receive type certifications from both the US Federal Aviation Administration and the European Aviation Safety Agency. The Leap-powered A320neo was then granted type certification by both authorities in May 2016.

Virgin America became the first airline to place firm orders for the A320neo in December 2010 with a deal for 30 aircraft. It subsequently selected the Leap-1A to power the aircraft.

Since its launch, the A320neo family has received more than 4,000 orders, making it the fastest-selling commercial aircraft in history. The backlog for the A320neo family stood at 4,501 by mid-May 2016, with over 1,500 to be equipped with the Leap-1A and more than 1,600 still unannounced.

Leap-1B

The Leap-1B engine is exclusive to the Boeing 737 Max. In December 2011, Southwest Airlines became the launch customer for the re-engined narrowbody, placing a firm order for 150 737 Max aircraft. At $19 billion based on list prices, this was the largest firm order in Boeing's history. The Dallas-based airline, which was also the launch customer for both the Boeing 737 Classic and Next Generation 737 series, showed a backlog of 200 737 Max aircraft in May 2016 and will take delivery of its first in 2017. In May 2016, the Leap-1B was awarded joint FAA, EASA type certification while the firm backlog for the 737 Max stood at more than 3,000 units.

Leap-1C

The Leap-1C has been chosen by China's Comac as the powerplant for its C919, a 168-190 passenger single-aisle twinjet. Accompanying the Leap-1C engine is an integrated propulsion system (IPS) built by Nexcelle, a joint venture between GE and Safran. The C919 will be the largest commercial airliner ever to be designed and built in China.

In October 2011, Chinese lessor ICBC Leasing announced an order for 45 C919s, as well as an agreement to be the launch customer for the aircraft.

The November 2015 approval of the Leap-1A by the EASA and FAA also cleared the Leap-1C engine. The C919's first flight is expected to take place towards the beginning of 2017, with initial deliveries scheduled to take place the same year. The C919 order backlog stood at 282 aircraft in May 2016.

Leading customers

Lion Air stood as the leading Leap customer as of May 2016, with an order backlog including 201 737 Max aircraft and 183 A320neo family aircraft. AirAsia had 304 Leap-fitted A320 family aircraft on order followed by Southwest Airlines with 200 737 Max and American Airlines who had an order backlog of A320neo and 737 Max aircraft with 100 units of each.

Boeing

The Leap is the exclusive powerplant on the Boeing 737 Max which will enter service in 2017

CFM International - specifications

CFM56	
Variants	-2, -3, -5A, -5B, -5C, -7B
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	236-260
Fan diameter (cm)	152-183
Dry weight (kg)	1,940-3,990
Components	
Architecture	axial
Low pressure spool	1-stage fan, 3-stage LPC, 4-stage LPT
High pressure spool	9-stage HPC, 1-stage HPT
Combustors	annular
Performance	
Max thrust (lb)	19,500-34,000
Overall pressure ratio	27.5-38.3:1
Bypass ratio	5.1-6.5:1
Air mass flow (lb/sec)	677-1,065
Thrust-to-weight ratio	3.7:1
Service entry	1982
Applications	A320 family, A340, 737 family, DC-8

LEAP	
Variants	-1A, -1B, -1C
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	340
Fan diameter (cm)	175-198
Dry weight (kg)	
Components	
Architecture	axial
Low pressure spool	1-stage fan, 3-stage LPC, 7-stage LPT
High pressure spool	10-stage HPC, 2-stage HPT
Combustors	annular
Performance	
Max thrust (lb)	23,000-32,900
Overall pressure ratio	40:1
Bypass ratio	9:1-11:1
Air mass flow (lb/sec)	
Thrust-to-weight ratio	
Service entry	due in 2016 (on the A320neo)
Applications	A320neo family, 737 Max, C919

ENGINE ALLIANCE

Engine Alliance is a 50:50 joint venture between General Electric and P&W that was formed in 1996 to develop, manufacture, sell and support a family of engines for new high-capacity, long-range aircraft.

In mid-1996, Boeing announced it was beginning development of new growth derivatives of the 747, the 747-500/600. Neither GE Aircraft Engines nor P&W had engines in their own product lines in the necessary 70,000-85,000lb-thrust range. Each company had independently forecast worldwide demand for aircraft in this market segment, and had determined that it might not be large enough to justify the approximate $1 billion expense of developing a new centerline engine. A joint venture between these otherwise aggressive competitors seemed the logical solution and so, in August 1996, GE and P&W established the joint venture company GE-P&W Engine Alliance, to develop the GP7000 engine.

The idea was to use the core competencies of each parent company to design, develop, certify and manufacture a state-of-the-art high bypass turbofan engine for 450-seat and larger four-engined aircraft. Boeing later shelved its immediate plans for a growth 747 version while Airbus began to consider development of an aircraft called the A3XX, planned as the largest-ever commercial transport aircraft.

Airbus approached Engine Alliance about powering the new aircraft, and received preliminary development support in the form of various GP7000 engine designs for the A3XX between 1998 and 2000. Airbus made the commercial relationship official in December 2000 with the launch of the A380 programme, and in May 2001, the GP7000 programme was fully established when Air France selected the GP7270 to power the 10 A380-800 passenger aircraft it had on order.

GP7200

(2008-present)

The main application for Engine Alliance's first engine was originally the Boeing 747-500/600X projects, before these were cancelled as a result of a lack of demand from airlines. The engine has since been pushed for the Airbus A380 super-jumbo which carries the largest payload in aviation history.

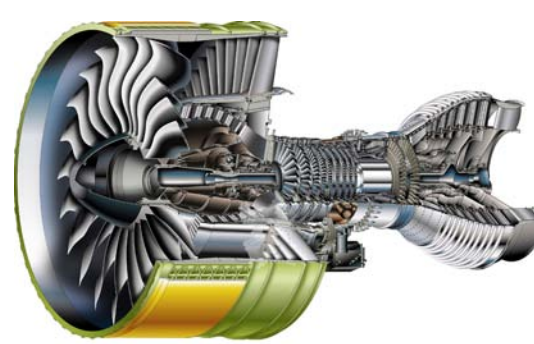
The GP7000 family is derived from the GE90 and PW4000 series. It is built on the GE90 core and the PW4000 low spool heritage. The engine is certificated at 76,500lb-thrust and 81,500lb-thrust.

The GP7200 engine was brought into service on the A380 in August 2008 by Emirates. The GP7200 is one of the two engine options for this aircraft and was designed specifically for it.

Emirates is Engine Alliance's primary customer, with a total of 77 A380s in its fleet and an additional 15 on order as of mid-May 2016.

Air France and Korean Air each operate ten A380s while Etihad Airways and Qatar Airways operate eight and six respectively. An order for three GP7200-powered A380s are also assigned to a company identified as Air Accord.

In May 2016, a total of 188 A380s were in service, of which 111 were powered by the GP7200, while the order backlog stood at 131 aircraft, with 24 assigned to the GP7200.



Engine Alliance - specifications

GP7200	
Variants	GP7270, GP7277
Characteristics	
Type	high bypass turbofan
Length (cm)	492
Fan diameter (cm)	314
Dry weight (kg)	6,725
Components	
Architecture	axial
Low pressure spool	1-stage fan, 5-stage LPC, 6-stage LPT
High pressure spool	9-stage HPC, 2-stage HPT
Combustors	annular
Performance	
Max thrust (lb)	73,470-80,290
Overall pressure ratio	36.1:1
Bypass ratio	8.8:1
Air mass flow (lb/sec)	2,000-2,600
Thrust-to-weight ratio	4.73:1
Service entry	2008
Applications	A380

Air France

Air France operates ten GP7200-powered A380s and has two on order

GENERAL ELECTRIC

General Electric's aerospace division, GE Aviation, operated under the name of General Electric Aircraft Engines (GEAE) until September 2005.

The General Electric Company built its first turbine engine in 1941 when it began development of Whittle-type turbojets under a technical exchange arrangement between the British and American governments. GE's first entry into the civil engine market was in the late 1950s, with a commercial version of the J79 designated CJ805. In 1967, GE announced the development of the CF6 high-bypass turbofan for future widebody airliners.

GE's presence in the engine market has expanded steadily since the early 1970s, and the manufacturer's engines now power the largest proportion of the world's active commercial widebody and regional aircraft. GE is in partnership with P&W through the Engine Alliance, which is responsible for the GP7200 engine designed for the A380. GE is also a partner with Snecma in CFM International.

CF6 (1971-present)

The CF6 engine entered the commercial widebody market in 1971 on the DC-10. It was GE's first major turbofan engine for commercial aviation.

The CF6 is currently in service on the 747, 767, A300, A310, A330, DC-10 and MD-11. The CF6-80C2 (military designation: F103) was selected to re-engine the C-5 RERP.

There are five models of the CF6: CF6-6, CF6-50, CF6-80A, CF6-80C2 and CF6-80E1. The first model, the CF6-6, was developed with 40,000lb-thrust, while the newest CF6-80E1 model, designed specifically for the Airbus A330, produces 72,000lb-thrust.

The engine family has completed over 325 million flight hours with more than 260 customers since it entered commercial revenue service. More than 1,200 CF6-powered airliners are still active around the world. The engine is still is still in production for the 767 and A330.

Boeing

FedEx is the only operator who has 767 aircraft on order

CF34 (1992-present)

The CF34 turbofan is a derivative of the GE TF34 which powers the US Air Force A-10 and US Navy S-3A.

The powerplant was first used on business jets in 1983 and on regional jets in 1992. The CF34 is now installed on regional jet family types including the Bombardier CRJ series, the Bombardier Challenger, the Embraer E-Jets and the Chinese Comac ARJ21.

There are now three models of the CF34 engine: CF34-3, CF34-8 and the latest CF34-10.

As of May 2016, there were more than 2,400 and 450 CF34-powered commercial aircraft worldwide on service and on order respectively across nearly 150 operators.

The CF-10A-powered ARJ21 came into service with Chengdu Airlines in November 2015 while the aircraft type showed an order backlog of 158 in May 2016.

SkyWest

SkyWest operates just over 300 CRJs

GE90 (1995-present)

The GE90 turbofan series is physically the largest engine in aviation history. It was developed from the Energy Efficient Engine, which was a programme funded by NASA in the 1970s to develop technologies suitable for energy efficient turbofans.

The GE90 was specifically designed for the Boeing 777 and was introduced into service in November 1995 with British Airways. Snecma of France and IHI of Japan are participants in the GE90 development programme, as was Avio of Italy, which is now a GE-owned subsidiary. The engine was originally certificated at 84,700lb-thrust with a fan diameter of 312cm. It comes in two models: the GE90-94B and GE90-115B.

The latest Boeing 777 variants – the -200LR/300ER and 777F – are exclusively powered by the GE90-115B. It has a fan diameter of 325cm and, with a nominal rating of 115,000lb-thrust, is the most powerful aircraft engine in the world.

On 10 November 2005, the GE90-110B1 powered a 777-200LR during the world's longest flight by a commercial airliner. The aircraft flew 21,601km in 22h 42min, flying from Hong Kong to London via the Pacific, then over the continental USA, and finally over the Atlantic to London. The GEnx engine, which entered service in 2011, is derived from a smaller core variant of the GE90.

A total of 75% of all the 777s in service in 2016 are powered by GE90 engines. In May 2016, a total of 977 GE90-powered 777s were in service, while the order backlog stood at 194.

Emirates is the carrier with the largest number of GE90-powered 777s with 139 in its fleet. The Middle Eastern carrier also has 36 GE90-powered 777s on order.

Air France operates 70 777s all fitted with the GE90 while 53 of the 70 777s that Cathay Pacific operates are powered by the GE90.

Boeing

Cathay Pacific recently took in its 70th 777, 53 of which GE90-powered

GEnx (2011-present)

The GEnx (General Electric Next-generation) is the successor to the CF6 and is based on the GE90's architecture. The engine is an option on the Boeing 787 and is exclusively used to power the 747-8.

The GEnx is intended to replace the CF6 in GE's production line delivering 15% better specific fuel consumption than the engines it replaces.

It is designed to stay on wing 30% longer while using 30% fewer parts, greatly reducing maintenance time and cost. The GEnx's emissions are expected to be as much as 95% below regulatory limits.

The GEnx features carbon-fiber composite fan blades and a reduced blade count (from 22 to 18 fan blades) and a composite fan case. The engine's LPT is lighter than its predecessor and also introduces Titanium Aluminide blades to stages 6 and 7.

There are two models of the GEnx: the GEnx-1B (used on the 787-8, 787-9 and 787-10) and the GEnx-2B (used on the 747-8 Intercontinental and Freighter).

In October 2011, Cargolux was the first customer to receive a GEnx-powered aircraft, fitted to its 747-8F.

Lufthansa is the main carrier for the 747-8 with 19 currently in its fleet. The third generation of the 747 is operated by 16 carriers in total. As of May 2016, there were 93 747-8s in service with a backlog of 23 units.

The GEnx was also fitted on 248 787s and the order backlog for that aircraft/engine pairing stood at 365. A total of 63% of the 787 in service are fitted with the General Electric powerplant option while almost half of the backlog is for the GE90, with an additional 15% of the engine option still unannounced.

Qatar

Qatar operates 28 GEnx-powered 787s and has two on order

GE9X

(due in 2020)

Boeing launched the 777X at the Dubai air show in 2013, backed by commitments for over 300 aircraft from four customers.

Boeing announced that it had selected the GE9X to exclusively power the 777X, extending the engine maker's propulsion monopoly to the next generation of the widebody type. The 777X is expected to compete with the Airbus A350-900 and A350-1000 over a wide span of the market, stretching from about 330 seats to more than 400, and offering ultra-long range.

The two-member 777X family in the 350- to 400-seat category sits at the top of Boeing's widebody twinjet line-up, above its three variants of the 787 and below the 747-8I. The 777X, which is due to enter service in 2020, is the successor to today's strong-selling 777-300ER, and ultra-long-range -200LR.

The 777-9X is the larger variant, featuring a slight stretch over the -300ER and raising seating by around 14 passengers in similar typical layouts. It will provide a range of more than 8,200nm (15,200km) and has a list price of US$377.2 million.

The 350-seat 777-8X is developed from the 777-200 airframe, with a 10-frame stretch. It will enter service in 2022 and will have a range of more than 9,300nm with a list price of US$349.8 million. Other major changes on the 777X include a larger, composite wing, which incorporates folding tips to allow it to use 777-sized parking bays and taxiways, the GE9X engines and a revised cabin.

The GE9X, which will have the largest fan produced by GE, will be the most fuel-efficient engine GE has ever produced on a per-pound-of-thrust basis, designed to achieve a 10% improved aircraft fuel burn versus the GE90-115B-powered 777-300ER and a 5% improved specific fuel consumption versus any twin-aisle engine at service entry.

In addition, the engine will deliver an approximate 10-to-1 bypass ratio, a 60-to-1 overall pressure ratio and margin to Stage 5 noise limits.

The GE9X will be the first to incorporate a hybrid composite fan blade, blending both carbon and glass fibres into the same part.

In February 2016, GE Aviation has confirmed that final assembly has started on the first full-scale GE9X engine. A second full-scale engine will follow in 2017 to be installed on a GE-owned Boeing 747 flying testbed. Boeing plans to start flying the engine on the first 777-9 test aircraft in 2018, followed by certification the following year and entry into service in 2020 with Emirates.

In May 2016, the 777X had 306 firm orders. Emirates alone has 150 units on order while Qatar Airways, Etihad Airways and Cathay Pacific show an order backlog of 60, 25 and 21 777X aircraft respectively. All Nippon Airways and Lufthansa each ordered 20 units of the widebody.

Emirates

Launch customer Emirates has 150 GE9x-powered 777X on order

GE - specifications

CF6	
Variants	-6, -50, -80
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	424-477
Fan diameter (cm)	266-289
Dry weight (kg)	4,067-4,104
Components (CF6-50 variant)	
Architecture	axial
Low pressure spool	1-stage fan, 3-stage LPC, 4-stage LPT
High pressure spool	14-stage HPC, 2-stage HPT
Combustors	annular
Performance (CF6-50 variant)	
Max thrust (lb)	52,500-61,500
Overall pressure ratio	29.2-31.1:1
Bypass ratio	4.24-4.4:1
Air mass flow (lb/sec)	1,900
Thrust-to-weight ratio	5.6-6:1
Service entry	1971
Applications	A300, A310, A330, 747, 767, DC-10, MD-11

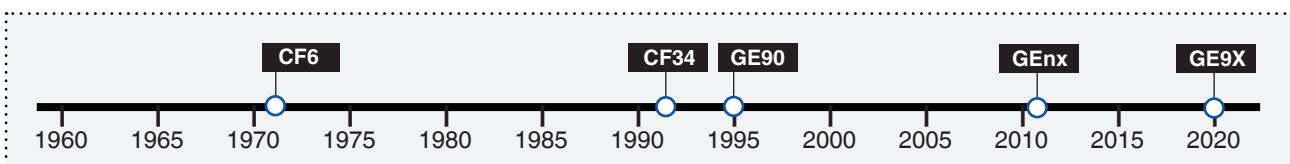
CF34	
Variants	-1, -3A, 3B, -8C, -8E, 10A, 10E
Characteristics (CF34-10A variant)	
Type	twin-spool, high bypass turbofan
Length (cm)	230-370
Fan diameter (cm)	140
Dry weight (kg)	1,700
Components (CF34-10A variant)	
Architecture	axial
Low pressure spool	1-stage fan, 3-stage LPC, 4-stage LPT
High pressure spool	9-stage HPC, 1-stage HPT
Combustors	annular
Performance (CF34-10A variant)	
Max thrust (lb)	17,640
Overall pressure ratio	29:1
Bypass ratio	5:1
Air mass flow (lb/sec)	440
Thrust-to-weight ratio	5.1:1
Service entry	1992
Applications	ARJ21, CRJ, E-Jet

GE90	
Variants	-76B, -77B, -85B, -90B, -92B, -94B, -110B1, -115B
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	729
Fan diameter (cm)	312-325
Dry weight (kg)	7,550-8,283
Components (GE90-115B variant)	
Architecture	axial
Low pressure spool	1-stage fan, 4-stage LPC, 6-stage LPT
High pressure spool	9-stage HPC, 2-stage HPT
Combustors	annular
Performance (GE90-115B variant)	
Max thrust (lb)	115,300
Overall pressure ratio	42:1
Bypass ratio	8.4:1
Air mass flow (lb/sec)	3,000
Thrust-to-weight ratio	6.3:1
Service entry	1995
Applications	777

GEnx	
Variants	-1B, -2B
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	469-495
Fan diameter (cm)	320-353
Dry weight (kg)	5,613-6,147
Components (-1B variant)	
Architecture	axial
Low pressure spool	1-stage fan, 4-stage LPC, 7-stage LPT
High pressure spool	10-stage HPC, 2-stage HPT
Combustors	annular
Performance (-1B variant)	
Max thrust (lb)	53,200-69,800
Overall pressure ratio	35.6-43.5:1
Bypass ratio	9.1:1
Air mass flow (lb/sec)	2,293-2,545
Thrust-to-weight ratio	5:1
Service entry	2011
Applications	747-8 (GEnx-2B), 787 (GEnx-1B)

GE9X	
Variants	
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	
Fan diameter (cm)	338
Dry weight (kg)	
Components	
Architecture	axial
Low pressure spool	1-stage fan
High pressure spool	11-stage HPC
Combustors	annular
Performance	
Max thrust (lb-thrust)	100,000-class
Overall pressure ratio	60:1
Bypass ratio	10:1
Air mass flow (lb/sec)	
Thrust-to-weight ratio	
Service entry	due in 2020
Applications	777-8X/9X

SERVICE ENTRY TIMELINE



Lufthansa

Lufthansa operates 19 747-8s all powered by the GEnx engine

INTERNATIONAL AERO ENGINES

International Aero Engines is a joint venture that was originally set up between P&W, Rolls-Royce, MTU Aero Engines and Japanese Aero Engine Corporation (JAEC). IAE was formed in 1983 to develop an engine for the 150-seat single-aisle market. In October 2011, R-R agreed to leave the consortium, making P&W the majority shareholder. The remaining members of IAE have agreed to extend their partnerships to 2045.

V2500

(1989-present)

The V2500 powerplant was introduced into service in May 1989 on Airbus A320s operated by Adria Airways. The engine also powers the A319 and A321 variants, the Boeing MD-90 and the military Embraer KC-390.

There are three commercial models of the V2500 engine – the V2500-A1, V2500-A5 and V2500-D5 – and each IAE partner contributes an individual module to the engine's construction. P&W provides the combustor and high-pressure turbine, R-R the high-pressure compressor, JAEC the fan and low-pressure compressor, and MTU the low-pressure turbine.

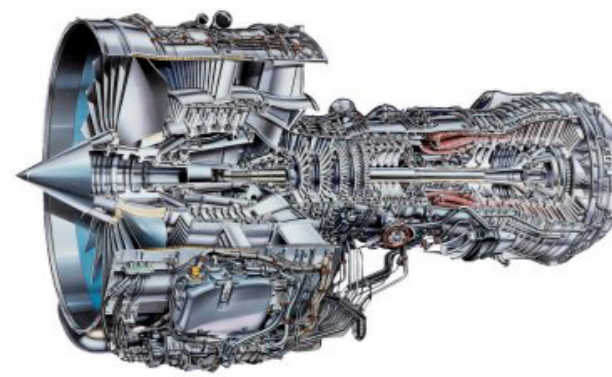
The V2500 features wide-chord, clapperless fan blade design which increases fuel efficiency and provides superior tolerance to foreign-object damage. The high-pressure compressor is a 10-stage design with advanced airfoil aerodynamics.

IAE unveiled the SelectOne performance improvement package for the V2500 in 2005 with launch customer IndiGo, with which it also signed an aftermarket agreement.

The next package of improvements is called SelectTwo and was launched in 2011. IAE is offering the SelectTwo package as a sales order option on V2500-A5 SelectOne engines, but has not announced a launch customer. The SelectTwo engine should trim fuel burn costs by 0.58% for an Airbus A320 on a 930km leg. This represents savings of roughly $4.3 million over a 10-year period for a 10-aircraft fleet of A320s completing 2,300 flights per year.

Although IAE promises smaller fuel burn savings than next-generation engines such as the Leap and PW1000G, SelectTwo shows that the joint venture is committed to providing support and continued investment in the engine.

The core and low-pressure spool of the two-shaft V2500 was left untouched by the upgrade. SelectTwo comprises software improvements for the electronic engine control and a new data entry plug.



In 2012, the 5,000th V2500 was delivered and the engine achieved 100 million flight hours. In 2013, IAE launched its Pure-V designation for the V2500 engines maintained with original IAE parts. The manufacturer's Pure-V programme was designed to help operators and lessors enhance residual values for their V2500 engines.

Rolls-Royce continues to service V2500s at its facilities, but this is done in a subcontractor role, with Pratt & Whitney managing the aftermarket support programme. While the existing V2500 fleet generates around 800 shop visits per annum, this is set to increase around 50% over the next five years.

There are currently more than 2,800 V2500-powered airliners in service around the world, and the engine has been chosen for approximately 300 A320 family aircraft on order.

American Airlines is the leading IAE user with 207 V2500-powered A320 family aircraft in its fleet followed by China Southern Airlines who has 180. JetBlue Airways and United Airlines operate 159 and 152 A320 family aircraft powered by the V2500 respectively.

Kingfisher Airlines and American Airlines are the V2500 leading customers for with 67 and 38 aircraft on order respectively.

IAE - specifications

V2500	
Variants	-A1, -A5, -D5, -E5
Characteristics (-A5)	
Type	twin-spool, high bypass turbofan
Length (cm)	320
Fan diameter (cm)	168
Dry weight (kg)	2,404
Components	
Architecture	axial
Low pressure spool	1-stage fan, 4-stage LPC, 5-stage LPT
High pressure spool	10-stage HPC, 2-stage HPT
Combustors	annular
Performance	
Max thrust (lb)	23,000-33,000
Overall pressure ratio	24.9-33.4:1
Bypass ratio	4.5-5.4:1
Air mass flow (lb/sec)	738-848
Thrust-to-weight ratio	
Service entry	1989
Applications	A319, A320, A321, MD-90

Airbus

Briitish Airways operates 128 V2500-powered A320 family aircraft

POWERJET

PowerJet is a 50:50 joint company which was formed by Snecma of France and NPO Saturn of Russia in July 2004. Snecma and NPO Saturn began to work together in 1997, when Snecma sub-contracted the production of CFM56 engine parts to NPO Saturn. PowerJet is responsible for the development and commercialisation of the SaM146, an engine purpose-designed for regional jets. PowerJet has one operational unit in France and a second in Russia.

SAM146

(2011-present)

The SaM146 engine powers the new Sukhoi Superjet 100 family of regional jets. The engine is a complete propulsion system comprising engine nacelle and equipment, featuring a single-stage high-pressure turbine and a high-pressure compressor with a reduced number of stages and parts.

PowerJet is responsible for all aspects of the SaM146 engine programme including the design, production, marketing, sales and services.

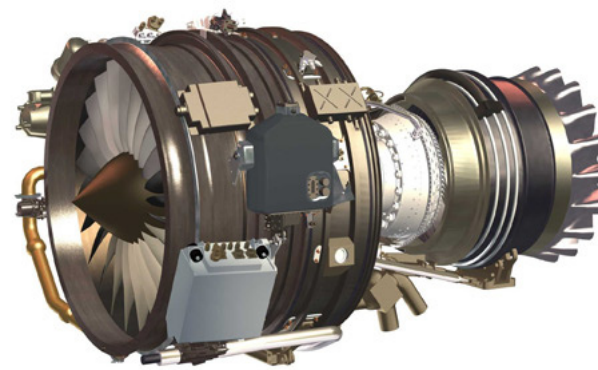
Snecma is responsible for the core engine, control systems, transmission (accessory gearbox, transfer gearbox), overall engine integration and flight testing. NPO Saturn is responsible for the components in the low-pressure section and engine installation on the Superjet 100.

With development starting in 2000, the Superjet 100 aircraft is a five-abreast seat configuration regional aircraft aimed at short-to-medium range routes in the 95-seat regional jet category. The aircraft is offered in basic (95B) and long range (95LR) variants, serving short to medium range routes between 1,645 to 2,470 nautical miles.

The engine underwent its first ground tests in July 2006 and its first engine flight tests began in December 2007. In May 2008, the first flight test of the SaM146 on the Sukhoi Superjet 100 was carried out and in May 2010, PowerJet completed all tests required for certification.

The type certificate for the SaM146 engine was issued by EASA in June 2010 and by the Russian certification body in August the same year. In April 2011, the first Sukhoi Superjet 100 was delivered to Armenian carrier Armavia, which ceased operations in April 2013.

The European Aviation Safety Agency certification (EASA) certified the Superjet 100 in February 2012. The fleet had accumulated more than 48,000 flight hours at mid-July 2014.



Depending on the model (1S15, 1S17 or 1S18), the SaM146 develops between 15,400lb-thrust and 17,800lb-thrust to meet thrust requirements for the 70- to 120-seat regional jet class. The SaM146 meets the most stringent environmental standards both in terms of emissions as well as noise.

SuperJet International forecasts a demand for about 5,900 jets in the 30-120 seat market in its 2012-31 market outlook. Jets in the 91-120 seat segment will account for about 63% of total deliveries with 3,700 deliveries within two decades.

North America is expected to represent 32% of the total demand in the 30-120 seat segment over the next 20 years, while Europe accounts for 30%. The company expects China to represent 12%, Asia-Pacific 11%, Latin American 10% of the total demand. The remaining 5% will be Africa and the Middle East.

As of May 2016, 59 Superjet 100s were in service, while the order backlog stood at 58. Aeroflot Russian Airlines operated 26 Superjets and had three on order. Mexican carrier Interjet operated 19 units and showed a backlog of nine.

Russia's Yamal Airlines, Ireland's CityJet and Mexico's Interjet showed backlogs of 24, 15 and nine units respectively for the Superjet during the same period.

Powerjet - specifications

SaM146	
Variants	-1S15, -1S17, -1S18
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	359
Fan diameter (cm)	122
Dry weight (kg)	1,708
Components	
Architecture	axial
Low pressure spool	1-stage fan, 3-stage LPC, 3-stage LPT
High pressure spool	6-stage HPC, 1-stage HPT
Combustors	annular
Performance	
Max thrust (lb)	15,400-17,800
Overall pressure ratio	28:1
Bypass ratio	4.43:1
Air mass flow (lb/sec)	
Thrust-to-weight ratio	5.3:1
Service entry	2011
Applications	Superjet 100

Sukhoi

Aeroflot Russian Airlines has 26 SaM146-powered Superjet 100s in its fleet

PRATT & WHITNEY

Pratt & Whitney was established in 1925 by Frederick Rentschler as part of United Aircraft and Transport Corporation (which later became known simply as the United Aircraft Corporation, and from 1975 as United Technologies). P&W manufactures products widely used in both civil and military aircraft. P&W began producing commercial jet engines in the late 1950s for the Boeing 707 and the Douglas DC-8, with models including the JT3 and the JT4A. The 727, 737 and DC-9 were later powered by the JT8D. P&W commercial engines have logged more than 1 billion hours of flight powering both the narrowbody and widebody aircraft that fly passengers and cargo around the world. In September 2013, P&W and R-R announced that they had abandoned plans for a joint venture to develop an engine to power future narrowbodies. P&W added that they would independently continue to invest in and develop applications of its geared turbofan engine to power the next generation of mid-sized aircraft.

JT8D

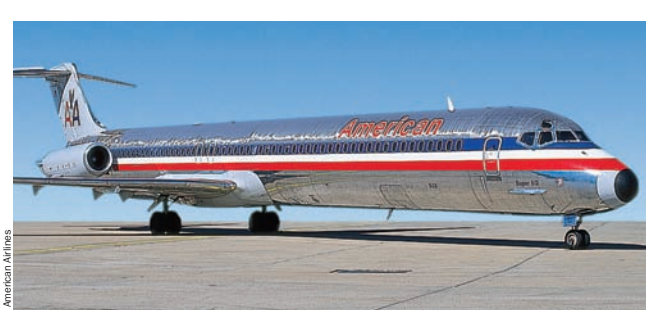
(1963-1999)

P&W introduced the JT8D to commercial aviation in 1964 on a Boeing 727-100.

There are eight models in the JT8D family, covering a thrust range of 14,000lb-thrust to 21,700lb-thrust and powering 727, 737-100/200, MD-80 and DC-9 aircraft. Since its introduction, more than 11,800 JT8D standard engines have been produced. The newer JT8D-200 series entered service in 1980, offering 18,500lb-thrust to 21,700lb-thrust. It is exclusively used in MD-80 series aircraft.

To ensure that the JT8D-200 stays current with environmental regulations, a low-emissions combustion system known as the E-Kit was developed. The E-Kit is FAR-25 certified and reduces JT8D-200 NOx emissions by 25%, unburned hydrocarbons by 99% and smoke by 52%. It exceeds all ICAO standards for newly-produced engines and it also qualifies for the Swiss Class 5 (cleanest) emissions category.

P&W and Aviation Fleet Solutions have jointly developed a noise reduction kit for JT8D-200-powered MD-80 aircraft, which was certified in 2006. As of May 2016, just under 600 JT8D powered aircraft were still in service.



American Airlines

American Airlines operates 91 JT8D-powered MD-80s

JT9D

(1969-1990)

The JT9D represented P&W's entry into the high-thrust, high-bypass ratio engine market. It was developed to power the Boeing 747, which entered service in 1970.

The JT9D family of engines comprises three distinct series. The JT9D-7 engine covers the 46,300lb-thrust to 50,000lb-thrust range, and the JT9D-7Q series has a 53,000lb-thrust rating. The later -7R4 series, introduced in 1982, covers the 48,000lb-thrust to 56,000lb-thrust range. These three engine types power 747, 767, A300, A310 and DC-10 aircraft.

P&W continues to invest in and support the JT9D family of engines. Upgrade programmes are in place to enable operators to improve durability, increase thrust and reduce noise. These update programmes are provided as JT9D Reduced Cost of Ownership Kits.

The JT9D has flown more than 169 million total hours to date. More than 600 aircraft take-offs are accomplished with JT9Ds every day.

JT9D production ended in 1990. A total of 32 JT9D powered aircraft were still active in May 2016.

Kalitta Air

Kalitta Air operates five JT9D-powered 747s

PW2000 (1984-2005)

The PW2000 was developed for the Boeing 757 in order to compete with R-R's RB211 and entered service in 1984 with Delta Air Lines, which was the civil aviation launch customer for the type.

The PW2000 covers a range of 37,000lb-thrust to 43,000lb-thrust. It was the first commercial engine with FADEC technology. An improved version of the PW2000, the Reduced Temperature Configuration (RTC), was introduced in 1994.

The PW2000 is certified to operate 180min extended twin-engined operations (ETOPS) and meets all current and proposed noise and emissions regulations around the world.

There are three models of the PW2000 engine: PW2037, PW2040 and PW2043. Introduced into service in 1991 as the F117-PW-100, the PW2040 is exclusively used on the four-engined Boeing C-17 Globemaster III military transport. The model also powers the US Air Force C-32A, the military version of the 757.

The current build standard, launched in 1994, is the PW2043 which provides 43,000lb-thrust. This model is the latest in the series to power the 757 and the 757-300. The improved model is known as the PW2000 RTC.

MTU Aero Engines holds a 21.2% stake in the engine, having developed the low-pressure turbine and turbine exit casing as well as critical parts of the turbine exhaust casing, high-pressure compressor and high-pressure turbine.

A total of 254 PW2000-powered 757s were in service in May 2016, with Delta Air Lines as the leading operator with 122 757s in its fleet.

The last PW2000 engine was delivered in 2005.

United Airlines

United Airlines operates 15 PW2000-powered 757s

PW4000 (1987-present)

The PW4000 was built as the successor to the JT9D in the high-thrust engine market and is certificated for a range of 52,000lb-thrust to 98,000lb-thrust. First delivered in 1987, the powerplant is now fitted on the 747, 767, 777, A300, A310, A330 and MD-11.

There are three PW4000 families, based on fan diameters: 94in, 100in and 112in. The PW4000 94in fan covers 52,000lb-thrust to 62,000lb-thrust. Approved for 180min ETOPS, equipped with FADEC and featuring single-crystal superalloy materials, it powers the 747-400, 767-200/300, MD-11, A300-600 and A310-300.

The PW4000 100in fan has a capability of 64,500lb-thrust to 70,000lb-thrust and was specifically developed for the A330. It entered service in 1994 with 90min ETOPS approval and was approved for 180min ETOPS in 1995.

The latest version – the PW4170 Advantage 70 – received US Federal Aviation Administration certification on 22 December 2008 and entered service in 2009 with the A330-200 Freighter. It is offered both as a new engine and as an upgrade to existing engines.

The PW4000 112in fan entered service in 1995 as the launch engine for the 777. It is the largest P&W commercial engine offering 74,000lb-thrust to 98,000lb-thrust. The PW4098, with 84,000lb-thrust, was the first engine to enter service already approved for 180min ETOPS, and was subsequently approved for 207min, the maximum allowable, along with all other PW4000 112in models.

A higher-thrust version of the engine, the 90,000lb-thrust PW4090, powers an increased gross-weight 777. The 98,000lb-thrust PW4098 powers the 777 up to 660,000lb take-off weight. More than 800 PW4000-powered aircraft were in service in May 2016 across seven aircraft types including more than 200 for the A330

UPS Airlines

UPS Airlines operates 52 PW4000-powered A300s

PW6000 (1987-present)

The high-bypass PW6000 turbofan was designed for the Airbus A318 and was first delivered in 2007 after development delays. It has a design range of 18,000lb-thrust to 24,000lb-thrust. The PW6000 powers a total of nine A318s, all of which operated by Avianca Brazil.

Overall, the engine has a small market share and there have been no orders for it since its last deliveries in 2008. MTU has been responsible for assembling the PW6000 under licence in Hannover, although there are no engines currently on order.

PW1000G (2016)

PW1000G is the designation for P&W's new high-bypass geared turbofan, previously known as the Advanced Technology Fan Integrator (ATFI). The engine has been in development for many years and the manufacturer has invested more than $1 billion in the technology.

P&W claims that the PW1000G delivers a 12-15% reduction in fuel burn, with up to 15% reduction in CO2 emissions and up to 50% in NOx emissions and engine noise. The powerplant uses an advanced gear system which allows the engine's fan to operate at a different speed from the low-pressure turbine.

MTU is responsible for supplying the PW1000G's high speed, three-stage low-pressure turbine and half of the powerplant's eight-stage high-pressure compressor. The engine was tested on the P&W-owned 747SP, and the second phase of flight testing was conducted on an A340-600. The testbed aircraft, with the engine in the number two pylon position, flew for the first time from Toulouse in October 2008.

PW1100G

The PW1000G was chosen by Airbus to power the re-engined A320neo after P&W failed to reach an agreement with R-R to offer the engine jointly through the IAE venture, which also includes JAEC and MTU Aero Engines. The FAA certificated the PW1100G for the A320neo in December 2014 while the aircraft entered service with launch customer Lufthansa in January 2016.

Back in March 2011, Indian low-cost carrier IndiGo selected the PW1000G to power up to 150 updated A320s. In March 2016, they became the second operator to take delivery of the re-engined Airbus.

PW1200G, PW1400G, PW1500G

The PW1000G has also been selected for the Mitsubishi MRJ regional jet (PW1200G), Bombardier CSeries airliner (PW1500G) and is offered as an option on the United Aircraft (UAC) Irkut MC-21 with the PW1400G engine variant which received US type certification in May 2016.

P&W completed the first flight of the PW1217G for the MRJ on P&W's 747SP on 30 April 2012, beginning the year-long flight testing phase for engine certification. The first flight test of the MRJ was completed in November 2015. Mitsubishi is using five flight test aircraft for the flight campaign, which is expected to cover 2,500 hours of testing. The first delivery of the 78-92 passenger MRJ aircraft has now been delayed until the second quarter of 2017.

The Bombardier CSeries made its maiden flight in September 2013 while the narrowbody is due to enter service in July 2016 with Swiss.

PW1700G and PW1900G

The PW100G has also been selected as the exclusive engine for Embraer's new second generation E-Jet aircraft family. Scheduled to enter service in 2018, the Embraer E-Jet E2 family of aircraft will be equipped with the PW1700G and PW1900G engines.

As of May 2016, the overall PW1000G order backlog stood at 2,219 combined for the A320neo family (1,301), CSeries (320), E-Jet E2 (267), MRJ (223) and MC-21 (108). SkyWest Airlines stood out as the main PW1000G customer with an order backlog of MRJ and E-Jet E2 aircraft with 100 of each.

There were also 1,657 A320neo family aircraft on order for which an engine selection had yet to be announced.

Bombardier

The first Bombardier CSeries will be delivered to Swiss in 2016

P&W - specifications

JT8D	
Variants	-1, -7, -9, -11, -15, -17, -209, -217, -219
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	304-391
Fan diameter (cm)	101-125
Dry weight (kg)	
Components	
Architecture	axial
Low pressure spool	2-stage fan, 6-stage LPC, 2-stage LPT
High pressure spool	7-stage HPC, 1-stage HPT
Combustors	cannular
Performance	
Max thrust (lb)	14,000-21,700
Overall pressure ratio	18.2-19.4:1
Bypass ratio	0.96-1.74:1
Air mass flow (lb/sec)	
Thrust-to-weight ratio	
Service entry	1964
Applications	727, 737-100/200, DC-9, MD-80

JT9D	
Variants	-3, -7
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	325-355
Fan diameter (cm)	235
Dry weight (kg)	
Components	
Architecture	axial
Low pressure spool	1-stage fan, 3-stage LPC, 4-stage LPT
High pressure spool	11-stage HPC, 2-stage HPT
Combustors	annular
Performance	
Max thrust (lb)	46,300-56,000
Overall pressure ratio	23.4:1
Bypass ratio	5.0:1
Air mass flow (lb/sec)	
Thrust-to-weight ratio	5.4-5.8:1
Service entry	1970
Applications	A300, A310, 747, 767, DC-10

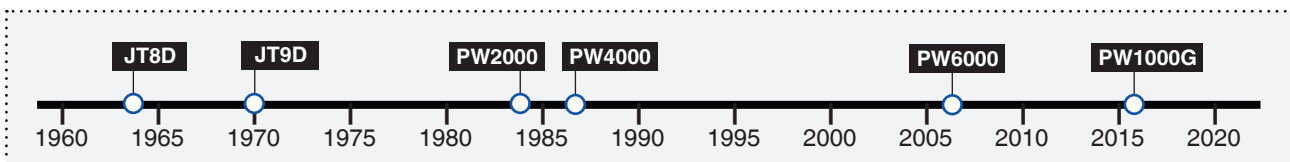
PW2000	
Variants	PW2037, PW2040, PW2043
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	360
Fan diameter (cm)	200
Dry weight (kg)	3,221
Components (PW2037)	
Architecture	axial
Low pressure spool	1-stage fan, 4-stage LPC, 2-stage LPT
High pressure spool	12-stage HPC, 3-stage HPT
Combustors	annular
Performance	
Max thrust (lb)	37,250-43,000
Overall pressure ratio	27.6-31.2:1
Bypass ratio	6.0:1
Air mass flow (lb/sec)	
Thrust-to-weight ratio	
Service entry	1984
Applications	757, II-96M

PW4000	
Variants	-94, -100, -112
Characteristics (-94 series)	
Type	twin-spool, high bypass turbofan
Length (cm)	390
Fan diameter (cm)	248
Dry weight (kg)	4,272
Components (-94 series)	
Architecture	axial
Low pressure spool	1-stage fan, 4-stage LPC, 4-stage LPT
High pressure spool	11-stage HPC, 2-stage HPT
Combustors	annular
Performance (-94 series)	
Max thrust (lb)	50,000-62,000
Overall pressure ratio	32.0-35.4:1
Bypass ratio	5.0:1
Air mass flow (lb/sec)	
Thrust-to-weight ratio	6-7:1
Service entry	1987
Applications	A300, A310, A330, 747, 767, 777, MD-11

PW6000	
Variants	
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	274.9
Fan diameter (cm)	158.4
Dry weight (kg)	2,449
Components	
Architecture	axial
Low pressure spool	1-stage fan, 4-stage LPC, 3-stage LPT
High pressure spool	6-stage HPC, 1-stage HPT
Combustors	annular
Performance	
Max thrust (lb)	18,000-24,000
Overall pressure ratio	26.1-28.2:1
Bypass ratio	4.8-5.0:1
Air mass flow (lb/sec)	
Thrust-to-weight ratio	4.7:1
Service entry	2007
Applications	A318

PW1000G	
Variants	
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	340
Fan diameter (cm)	140-210
Dry weight (kg)	2,857
Components (PW1100G)	
Architecture	axial
Low pressure spool	1-stage, 3-stage LPC, 3-stage LPT
High pressure spool	8-stage HPC, 2-stage HPT
Combustors	annular
Performance	
Max thrust (lb)	15,000-32,000
Overall pressure ratio	
Bypass ratio	9-12.5:1
Air mass flow (lb/sec)	
Thrust-to-weight ratio	3.85-5.26:1
Service entry	2016
Applications	A320neo, CSeries, MRJ, MC-21, E-Jet E2

SERVICE ENTRY TIMELINE



Airbus

In March 2016, Indian carrier IndiGo received its PW1100G-powered A320neo, becoming the second operator to take delivery of the re-engined Airbus

ROLLS-ROYCE

Rolls-Royce was founded in 1906 by Henry Royce and Charles Rolls, and produced its first aircraft engine in 1914. The company has produced commercial jet engines since the 1950s, beginning with the Avon for the de Havilland Comet and the Sud Aviation Caravelle. The Conway engine came to prominence in the early 1960s and was fitted on the 707, DC-8 and the Vickers VC10. The Spey engine, also produced in the 1960s, was designed for the BAC One-Eleven and the three-engined Hawker Siddeley Trident.

The development of a high-bypass turbofan engine forced R-R into bankruptcy and it was nationalised by the British government in 1971. However, the company survived and, thanks to the RB211 – the first true three-spool engine – it became a global player in the airline industry. R-R engines are now in service around the world on more than 20 types of commercial aircraft including various narrowbody, widebody and regional jets and powers more than 2,000 aircraft.

In September 2013, R-R and P&W announced that they had abandoned plans for a joint venture to develop an engine to power future narrowbodies. The two engine makers had in October 2011 declared their intention to pursue the collaboration, to be focused on high-bypass ratio geared turbofan technology to power aircraft in the 120- to 230-seat segment.

In February 2014, R-R announced the development of two new Trent-based engines – ready for service in 2020 and 2025 – which it says will deliver fuel efficiencies of up to 10% over the Trent XWB.

Spey (1964-1992)

The R-R Spey was designed in the late 1950s and came into service in 1964 on a Hawker Siddeley Trident aircraft operated by British European Airways.

The engine has powered both military and civil aircraft types, with more than 1,000 aircraft fitted in its history and was produced by Rolls-Royce until 1992.

In passenger operations, the powerplant was fitted on the Fokker F28 airliner which stopped being produced in the late 1980s. The Spey is now mainly used in the business aviation sector on the Gulfstream II and III.

As of May 2016, only two F28s were still in service.

LUCKY LUKE/FlightReport.com

Fly-SAX is one of the two carriers in the world flying a F28 aircraft

RB211 (1973-2008)

The RB211 family of high-bypass turbofan engines are capable of generating 37,400lb-thrust to 60,600lb-thrust and are divided into three series: RB211-22, RB211-524 and RB211-535.

The RB211-22 came into service in 1972 on the Lockheed L-1011 TriStar aircraft, a year later than originally planned. It was officially superseded by the Trent series in the 1990s.

The RB211-524 entered service in 1977 with British Airways on the 747-200. The RB211-524G, rated at 58,000lb-thrust, and the RB211-524H, certificated at 60,600lb-thrust, were developed in response to the larger 747-400. They were the first versions to feature FADEC. The -524H model entered

American Airlines

American Airlines currently operates 61 RB211-powered 757s

service with British Airways in 1990 and achieved 180min ETOPS approval on the 767 three years later.

In 1997, the RB211-524G/H engines were upgraded with high pressure (HP) turbine systems – technology developed on the Trent 700 engine family. These variants (designated as RB211-524G/H-T) are 200lb lighter, offer 40% lower NOx emissions and 2% lower fuel burn. The RB211-524 is the first engine to achieve more than 27,500h on wing. The -524 fleet has now logged nearly 66 million flying hours, and almost 12.5 million flight cycles.

The RB211-535 entered service in 1983 as a launch engine on the new 757. In 1988, American Airlines ordered 50 757s powered by the RB211-524E4. It is more reliable and quieter than its direct competitor, the PW2037, but is not as efficient. The engine was also selected to power the Tupolev Tu-204-120. It entered service in 1992 and was the first Western engine to power a Russian airliner. In 1990, it achieved 180min ETOPS approval on the 757.

The RB211-535 is still in service with more than 60 operators and powers 516 aircraft including more than 430 Boeing 757s around the world. It has accumulated over 60 million flying hours and around 24 million cycles.

Tay (1988-1997)

Derived from the Spey, the R-R Tay was first run in 1984. The Tay family powers the Fokker 70 and 100 regional jets as well as business jets including the Gulfstream IV family. It was also used to re-engine the 727 but is no longer used on this aircraft.

In May 2016, there were 157 active Tay engines in commercial application in the world, all powering Fokker 70 and 100 aircraft.

KLM

KLM cityhopper has 15 Fokker 70s in its fleet

BR700 (1999-present)

The BR700 engine family was developed by BMW and R-R through the joint venture company BMW R-R to power regional and corporate jets.

R-R took full control of the company in 2000. The first BR700 entered service on the Gulfstream V in 1997 and entered service on the Boeing 717 in 1999.

Production of the 717 ceased in 2006 and there were more than 150 BR700-powered 717s in service in May 2016.

Hawaiian Airlines

Hawaiian Airlines operates 18 BR700-powered 717s

Trent (1995-present)

The Trent is a development of the RB211 and, like its predecessor, it uses a three-spool design. It was first delivered in 1995 on the A330, and on the 777 the following year. The Trent is now exclusively fitted to the A340-500/600, with its first deliveries on that aircraft taking place during 2002.

There are now seven variants, including the Trent 500, 700, 800, 900, 1000, the XWB and the most recent 7000. The Trent is one of two engine options for the A380 and the 787. The Trent XWB is currently the only engine available on the A350 XWB.

Trent 700 was the first engine in the family. Optimised for the A330 family to deliver power requirements for all weights of that aircraft, it entered service in 1995 with Cathay Pacific. It is rated at 72,000lb-thrust and received 180min ETOPS approval in 1996.

Designed for the 777 family, the Trent 800 entered service in 1996. It provides between 75,000lb-thrust to 95,000lb-thrust and is the lightest engine in its class.

The Trent 500 came into service in August 2002 with Virgin Atlantic. The variant is optimised for the A340 aircraft to deliver requirements of 53,000lb-thrust and 56,000lb-thrust for the A340-500 and A340-600 respectively.

The Trent 900 is an engine option on the A380 family and is certified at 70,000lb-thrust, 72,000lb-thrust, 76,000lb-thrust and 80,000lb-thrust. It came into service in 2007 on the first A380 by launch customer Singapore Airlines.

The Trent 1000 was selected in April 2004 by Boeing as one of the two engine options to power the 787 Dreamliner. On 26 October 2011, the first Trent-powered 787 entered into service with ANA on a flight from Tokyo to Hong Kong.

The Trent XWB was designed specifically for the A350 XWB family. It is to be the sixth member of the Trent family and have the largest fan designed for a R-R engine. The Trent XWB is the powerplant for the A350-800 and -900, providing a single engine type across the aircraft family.

Certification of the Trent XWB was awarded by EASA in February 2013 while the A350 maiden flight occurred in June of that year. Launch customer Qatar Airways took delivery of its A350-900, one of 80 A350s it has on order, on 22 December 2014 and operated its first flight on 15 January 2015. In May 2016, the Middle-Eastern carrier had eight A350s in its fleet.

The Trent 7000 is the seventh generation of the Trent family and is the exclusive powerplant on the Airbus' re-engined A330neo, set to enter service in 2017. Airbus launched the A330neo at the Farnborough air show in 2014. The programme has given Airbus a competitor to the Boeing 787-8, and a replacement for the successful A330 for customers unwilling to trade up to the larger A350.

The Trent 7000 is based on the latest iteration of the Trent 1000 for the Boeing 787, the Trent 1000-TEN, and includes features such as weight-saving blisks in the compressor and a system that integrates engine dressings into composite raft-like structures.

As of May 2016, there were 1,182 Trent-powered aircraft in service in the world, with 1,342 on order. The number of firm orders for the A330neo stood at 186, including 66 for Malaysia's AirAsia X.

The backlog for the A350 stood at 782 while the firm orders for the 787, A380 and A330ceo were 263, 75 and 36 units respectively.

Airbus

The Rolls-Royce Trent 7000 is the exclusive powerplant on the re-engined A330neo. Air Asia X is the A330neo's main customer with 66 units on order

AE 3007 (1996-present)

The R-R AE 3007 entered into service in 1996 and is used on regional, corporate and military aircraft. The Embraer ERJ family is the regional aircraft powered by this engine with more than 600 ERJs in commercial operation.

The ERJ fleet has more than 23 million flight hours accumulated on the AE 3007A series of powerplants, contributing to a total 32 million flight hours on the engine.

The last ERJs delivered for passenger usage were taken in 2011 by Hainan Airlines. Regional carrier ExpressJet Airlines is the main operator of passenger ERJs with 183 units in its fleet. The AE 3007 is still in production but destined only for aircraft in the business and military sectors.

Embraer

ExpressJet Airlines currently operates 183 ERJ-145s

Rolls-Royce - specifications

Spey	
Variants	RB.163, RB.168, RB.183
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	245-297
Fan diameter (cm)	82.6
Dry weight (kg)	1,856
Components (RB.183)	
Architecture	axial
Low pressure spool	1-stage fan, 4-stage LPC, 2-stage LPT
High pressure spool	12-stage HPC, 2-stage HPT
Combustors	cannular
Performance	
Max thrust (lb)	11,030-11,995
Overall pressure ratio	16.9:1
Bypass ratio	0:64:1 (RB.163)
Air mass flow (lb/sec)	204
Thrust-to-weight ratio	5:1
Service entry	1964
Applications	F28

RB211	
Variants	-524, -535
Characteristics	
Type	tripple-spool, high bypass turbofan
Length (cm)	300-320
Fan diameter (cm)	188-220
Dry weight (kg)	3,300-4,4490
Components (524 series)	
Architecture	axial
Low pressure spool	1-stage fan, 3-stage LPT
Intermediate pressure spool	7-stage IPC, 1-stage IPT
High pressure spool	6-stage HPC, 1-stage HPT
Combustors	annular
Performance	
Max thrust (lb)	7,264-9,874
Overall pressure ratio	29.5:1 (-524)
Bypass ratio	4.3-4.1
Air mass flow (lb/sec)	
Thrust-to-weight ratio	
Service entry	1972
Applications	747, 757, 767, L-1011, Tu-204

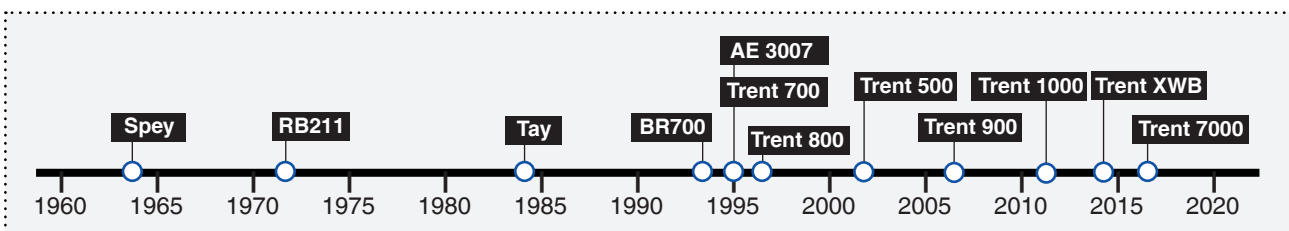
RB.183 Tay	
Variants	611, 620, 650
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	238
Fan diameter (cm)	114
Dry weight (kg)	1,501
Components (620-15 variant)	
Architecture	axial
Low pressure spool	1-stage fan, 3-stage LPC, 3-stage LPT
High pressure spool	12-stage HPC, 2-stage HPT
Combustors	cannular
Performance	
Max thrust (lb)	13,850-15,100
Overall pressure ratio	
Bypass ratio	3.04-3.1:1
Air mass flow (lb/sec)	
Thrust-to-weight ratio	4.2:1
Service entry	1984
Applications	Fokker 70/100

BR700	
Variants	-710, -715, -725
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	329-466
Fan diameter (cm)	178-182
Dry weight (kg)	1,635-1,891
Components	
Architecture	axial
Low pressure spool	1-stage fan, 1-stage LPC, 2-stage LPT
High pressure spool	10-stage HPC, 2-stage HPT
Combustors	annular
Performance	
Max thrust (lb)	14,750-22,000
Overall pressure ratio	24:1
Bypass ratio	4.2:1
Air mass flow (lb/sec)	
Thrust-to-weight ratio	
Service entry	1994
Applications	717

Trent	
Variants	-500, -700, -800, -900, -1000, -XWB, -7000
Characteristics (XWB)	
Type	three-spool, high bypass turbofan
Length (cm)	581.2
Fan diameter (cm)	300
Dry weight (kg)	7,277
Components (XWB)	
Architecture	axial
Low pressure spool	1-stage fan, 6-stage LPT
Intermediate pressure spool	8-stage IPC, 2-stage IPT
High pressure spool	6-stage HPC, 1-stage HPT
Combustors	annular
Performance	
Max thrust (lb)	53,000-115,000
Overall pressure ratio	50:1 (XWB)
Bypass ratio	9.3:1 (XWB)
Air mass flow (lb/sec)	2,840 (-1000)
Thrust-to-weight ratio	6.189:1 (-1000)
Service entry	1995 (Trent 700)
Applications	A330, A330neo, A340, A350, A380, 777, 787

AE3007	
Variants	-C, -H, -A
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	270
Fan diameter (cm)	98
Dry weight (kg)	720
Components	
Architecture	axial
Low pressure spool	1-stage fan, 1-stage LPC, 3-stage LPT
High pressure spool	14-stage HPC, 2-stage HPT
Combustors	annular
Performance	
Max thrust (lb)	6,495-8,917
Overall pressure ratio	18-20:1
Bypass ratio	4.8:1
Air mass flow (lb/sec)	240-280
Thrust-to-weight ratio	4.1-5.6:1
Service entry	1995
Applications	ERJ-145 family

SERVICE ENTRY TIMELINE



Airbus

Singapore Airlines currently operates two Trent XWB-powered A350s in its fleet and has 65 on order

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 18 May 2016 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 452
Africa	**Total 44**
Almajara Aviation	4
BADR Airlines	8
CEIBA Intercontinental	4
El Dinder Aviation	4
Global Air	4
Green Flag Aviation	4
Kush Aviation	4
Lina Congo	4
Victoria Air	4
Lina Congo	4
Victoria Air	4
Asia, Australasia & Middle East	**Total 123**
Air Almaty	8
Air Koryo	24
Air Kyrgyzstan	3
Al-Rafedain Falcon	4
CATIC	4
Jordan International Air Cargo	4
Kaz Air Trans	5
Khatlon Air	8
Pouya Air	8
Sayakhat	3
State Air Company Berkut	4
Syrianair	16
TAPC Aviatrans	8
Turkmenistan Airlines	12
Uzbekistan Airways	12
Europe	**Total 285**
223rd State Airline Flight Unit	8
Air Stork	8
AK Eleron	4
Alpha Air	4
ALROSA Air Company	17
Aviacon Zitotrans	24
Azal Avia Cargo	4
Belavia	9
Beriev	2
Europa Air	16
Gazpromavia	9
Kosmos Airlines	2
Maximus Airlines	4
Oscar Jet	12
Rada Airlines	4
Royal Flight	32
Ruby Star	16
Shar ink	12
Silk Way Airlines	20
Sirius Aero	4
Sky Prim Air	4
TransAVIAexport Airlines	24
Turuhan Aviacompany	10
Yuzhmashavia	8
ZetAvia	28
AVIADVIGATEL PD-14	**TOTAL (70)**
Europe	**Total (70)**
Aviakapital-Servis	(70)
AVIADVIGATEL PS-90	**TOTAL 102 (4)**
Asia, Australasia & Middle East	**Total 12**
Air Koryo	4
Jordan International Air Cargo	8
Europe	**Total 66 (4)**
Aviastar-TU	6
Ilyushin Design Bureau	4
Red Wings Airlines	14
Rossiya Special Flight Detachment	14 (4)
Silk Way Airlines	8
Volga-Dnepr Airlines	20
North/South America	**Total 24**
Cubana	24
CFM INTERNATIONAL CFM56	**TOTAL 20,380 (3,316)**
Africa	**Total 790 (64)**
Aero Contractors	24
Afriqiyah Airways	12
Air Algerie	54 (14)
Air Arabia Egypt	2
Air Arabia Maroc	10
Air Austral	6
Air Cairo	12
Air Cote d Ivoire	8
Air Ghana	2
Air Leisure	12
Air Madagascar	6
Air Mauritius	28
Air Namibia	8
Air Peace	12
Air Zimbabwe	2
AirInter1	4
Allied Air Cargo	6
Almasria Universal Airlines	2
AMC Airlines	2
Arik Air	26 (16)
ASKY	6
Azman Air	4
BADR Airlines	12
Buraq Air	6
CAA - Compagnie Africaine d'Aviation	4
Camair Co	4
CEIBA Intercontinental	6
Comair (South Africa)	28 (2)
Congo Airways	4
Daallo Airlines	2
ECAir	4
Egyptair	40 (16)
Eritrean Airlines	2
Ethiopian Airlines	36
Fastjet Tanzania	4
First Nation Airways	4
flyEgypt	4
Ghadames Air Transport	2
Gomair	2
Jambo Jet	4
Jubba Airways	6

Karinou Airlines	2
Kenya Airways	24
Kulula	20
Libyan Airlines	6
Libyan Wings	4
Linhas Aereas de Mocambique	4 (6)
Malawian Airlines	2
Mango	22
Mauritania Airlines International	6
Med-View Airline	6
Midwest Airlines (Egypt)	(2)
Nile Air	2
Nouvelair Tunisie	8
Nova Airways	2
Royal Air Maroc	76
RwandAir	8
Safair	18
SonAir	2
South African Airways	48
Star Air	8
Sudan Airways	4
TAAG Angola Airlines	10
TACV - Cabo Verde Airlines	2
Tarco Air	10
Tassili Airlines	8
Trans Air Congo	8
Tunisair	56 (8)
United Nigeria	2
Asia, Australasia & Middle East	**Total 7,372 (1,082)**
9 Air	14 (28)
Air Arabia	70 (12)
Air Arabia Jordan	4
Air Busan	2
Air China	444 (28)
Air China Inner Mongolia	6
Air Do	18
Air Incheon	4
Air India	102
Air India Express	40
Air Kyrgyzstan	4
Air Manas	4
Air Niugini	6
Air Tahiti Nui	20
Air Vanuatu	2
AirAsia	162 (4)
AirAsia India	12
AirAsia Japan	2
Airblue	16
Airwork (NZ)	12
AlNaser Airlines	2
ANA - All Nippon Airways	106
ANA Wings	40
Ariana Afghan Airlines	4
AsiaCargo Express	4
ATA Air	4
Avia Traffic Company	6
Bassaka Air	4
Batik Air	74 (22)
Bhutan Airlines	4
Biman Bangladesh Airlines	8
BOC Aviation	(66)
Capital Airlines	44
Cardig Air	4
Caspian Airlines	8
Cathay Pacific	20
CDB Leasing Company	(58)
Cebu Pacific Air	86 (4)
Cham Wings	4
Chang An Airlines	6
Chengdu Airlines	42
China Aircraft Leasing	(4)
China Airlines	52
China Aviation Supplies	(2)
China Eastern Airlines	340 (94)
China Eastern Airlines Jiangsu	54
China Eastern Yunnan	132
China Postal Airlines	44
China Southern Airlines	430 (38)
China United Airlines	64
China Xinhua Airlines	10
Chongqing Airlines	4
Citilink	68 (16)
Dalian Airlines	16
Donghai Airlines	32 (12)
Dragon Aviation Leasing Company	(6)
Druk Air	6
Eastar Jet	30
El Al	38
Emirates Airline	16
Etihad Airways	2
EVA Air	40
Express Air	8
Express Freighters Australia	8
Far Eastern Air Transport	(2)
Fiji Airways	10
Fly Baghdad	2
Fly Jordan	4
Flydamas	2
flydubai	98 (22)
Flynas	52 (40)
Fuzhou Airlines	16
Garuda Indonesia	156
Global Jet Airlines	4
GoAir	38
Grand China Air	6
Gulf Air	32
Hainan Airlines	238 (14)
Hebei Airlines	18 (14)
Himalaya Airlines	2
Hong Kong Airlines	22 (4)
Hong Kong Express Airways	10
ICBC Leasing Co	(52)
IndiGo	2
Indonesia AirAsia	36
Indonesia AirAsia X	10
Iran Air	6
Iran Aseman Airlines	8
Iraqi Airways	34 (36)
Japan Airlines	100
Japan TransOcean Air	24 (12)
Jazeera Airways	14
Jeju Air	48 (4)
Jet Airways	150
JetConnect	16
Jiangxi Airlines	6
Jin Air	34
Jordan Aviation	10
Juneyao Airlines	96 (2)
Kalstar Aviation	4
Kam Air	4
Kish Air	4
K-Mile Air	4
Korean Air	78 (2)
Kunming Airlines	32 (4)
Kuwait Airways	36
Lao Airlines	8
Lion Air	216 (120)
Loong Air	36 (4)
Lucky Air	58 (4)
Mahan Air	16
Malaysia Airlines	112 (20)
Maldivian	4
Malindo Air	32 (2)
Mandarin Airlines	2
MIAT - Mongolian Airlines	4 (4)
Middle East Airlines	8
Mihin Lanka	(4)
My Indo Airlines	4
Myanmar Airways International	8
Myanmar National Airlines	6 (6)
Nam Air	10
Nauru Airlines	10
Neptune Air	2
NewGen Airways	12
Nok Air	42 (8)
Okay Airways	38 (18)
Oman Air	50 (6)
Orient Thai Airlines	18
Pakistan International Airlines	22
PAL Express	18
Palau Pacific Airways	2
Peach	34 (6)
Philippine Airlines	44
Philippines AirAsia	16
Qantas	134
Qatar Airways	16
Qeshm Airlines	4
Qingdao Airlines	18 (2)
Quikjet	2
R Airlines	2
Regent Airways	6
Rotana Jet	2
Royal Falcon Airlines	4
Royal Wings	2
Ruili Airlines	18 (12)
Safi Airways	6
Saudi ARAMCO Aviation	8

Saudia	106 (60)
SCAT	12
SF Airlines	24
Shandong Airlines	182 (26)
Shanghai Airlines	138 (2)
Shenzhen Airlines	264 (16)
Siam Air	8
Sichuan Airlines	30 (10)
SilkAir	30 (4)
Sky Angkor Airlines	4
Skymark Airlines	52
Solaseed Air	24
Solomon Airlines	2
Somon Air	12
SpiceJet	50
Spring Airlines	110
Spring Airlines Japan	6
SriLankan Airlines	10
Sriwijaya Air	78
Star Flyer	18 (2)
Sunkar Air	2
Taban Air	2
Tajik Air	4
Texel Air	4
Thai AirAsia	94
Thai Airways International	4
Thai Express Cargo	2
Thai Lion Air	40
Thai VietJet Air	2
Tianjin Airlines	16
Tibet Airlines	30
Tigerair Australia	8
Tigerair Taiwan	(4)
Toll Priority	6
Travira Air	2
Tri MG Airlines	6
Trigana Air	10
Turkmenistan Airlines	16 (6)
T'way Air	28
UNI Air	4
Union Express Charter Airline	2
Up	8
Urumqi Airlines	12
Uzbekistan Airways	18
Vanilla Air	18 (4)
VietJet Air	64 (44)
Virgin Australia	116 (10)
Virgin Australia International	32
Vision Air International	2
West Air (China)	16
Wings of Lebanon	4
Xiamen Airlines	250 (76)
Yangtze River Express	44
YTO Express Airlines	6
Zagros Airlines	12
Europe	**Total 6,124 (962)**
Adria Airways	2
Aer Lingus	72
Aeroflot Russian Airlines	212 (170)
Aigle Azur	18
Air Bridge Cargo Express	6
Air Bucharest	2
Air Corsica	10
Air Europa	40 (16)
Air France	288 (6)
Air Horizont	4
Air Malta	16
Air Moldova	6
airBaltic	24
airberlin	158 (14)
AirExplore	2
Airzena - Georgian Airways	6
Alba Star	8
Alitalia	152
ALROSA Air Company	6
Anadolu Jet	60
ASL Airlines France	28
ASL Airlines Hungary	8
ASL Airlines Ireland	2
Atlantic Airways (Faroe Islands)	6 (2)
Atlasglobal	16
Atlasjet Ukraine	2
Aurora	22
Austrian	58
Aviolet	6
Azerbaijan Airlines	20
Azur Air Ukraine	6
B&H Airlines	(4)
Belair	16
Belavia	32 (6)
Blue Air	34
Blue Panorama Airlines	2
Bluebird Cargo	12
Blu-Express	6
Bravo Air	2
British Airways	8
Brussels Airlines	52
Bul Air	2
Bulgaria Air	10
Cargo Air	14
Condor	30
Corendon Airlines	20
Corendon Dutch Airlines	6
Croatia Airlines	12
Czech Airlines	16
Dart Airlines	8
easyJet	452 (88)
easyJet Switzerland	46
Edelweiss Air	12
Ellinair	2
Enter Air	34 (4)
European Air Transport	2
Eurowings	24 (32)
Evelop Airlines	4
Finnair	74
Freebird Airlines	10
Gazpromavia	4
Germania	44
Germanwings	70
Globus	38
Go2sky	6
Goiania Comercio E Servicos Internacionais Lda	(6)
Grand Cru Airlines	2
Hamburg International	-4
Helvetic Airways	2
Hermes Airlines	2
Hi Fly	8
Hi Fly Malta	4
HolidayJet	6
Iberia	110
Iberia Express	40
Izair	16
Jet Time	24
Jet Time Finland	2
Jet2	96 (60)
Jetairfly	42
KLM Royal Dutch Airlines	96
Limitless Airways	2
LOT Polish Airlines	6
Lufthansa	232 (18)
Lufthansa CityLine	28
Luxair	12
Maleth Aero	2
Meridiana	20
Mistral Air	6
Monarch Airlines	16
NEOS	12
Niki	38
Nordavia - Regional Airlines	18
Nordwind Airlines	8
Norwegian	116 (48)
Norwegian Air International	76 (10)
Norwegian Air UK	2
Olympus Airways	2
Pegas Fly	6
Pegasus	118 (14)
Plus Ultra	8
Pobeda	24
Primera Air Nordic	12
Primera Air Scandinavia	2
Rossiya - Russian Airlines	96
Royal Flight	2
Ryanair	700 (242)
S7 Airlines	88 (46)
SAS	196
SATA International	6
Small Planet Airlines (Germany)	2
Small Planet Airlines (Lithuania)	12
Smartlynx	4
Smartwings	16
SunExpress	42 (32)
SunExpress Germany	28
Swiftair	16
Swiss	128
Tailwind Airlines	14
Taimyr Air - NordStar	20
TAP Portugal	102

TAROM	24
Thomas Cook Airlines	48
Thomas Cook Airlines Belgium	10
Thomas Cook Airlines Scandinavia	16
Thomson Airways	68
Titan Airways	4
TNT Airways	34
Transavia Airlines	80 (2)
Transavia France	52 (26)
Travel Service Airlines	26
Travel Service Hungary	2
Travel Service Poland	2
Travel Service Slovakia	2
TUI Airlines Nederland	14
TUIfly	56
TUIFly Nordic AB	12
Turkish Airlines (THY)	202 (20)
Ukraine International Airlines	52 (2)
Ural Airlines	68 (14)
UTair	94 (76)
VIM Airlines	8
Volotea	6
Vueling Airlines	122
VVB Aviation Malta	2
West Atlantic	20
White	2
Wind Rose Aviation Company	2
WOW air	10
XL Airways France	2
Yakutia Airlines	8
Yamal Airlines	12
YanAir	6
North/South America	**Total 6,094 (754)**
Aer Caribe Peru	2
Aerolineas Argentinas	98 (42)
Aerolineas Estelar	2
Aeromexico	100
Air Canada	144
Air Canada Jetz	6
Air Canada Rouge	48 (2)
Air North	10
Air Panama	2
Air Transat	16
Alas Uruguay	6
Alaska Airlines	306 (46)
Albatros Airlines	2
Allegiant Air	58
Aloha Air Cargo	6
American Airlines	846 (64)
ATX Air Services LLC	2
Avianca	118 (4)
Avianca Brazil	60 (4)
Avianca Costa Rica	2
Avianca Ecuador	18
Avianca El Salvador	8
Aviation Capital Group	(10)
Avior Airlines	12
Bahamasair	6
Boliviana de Aviacion	38
Canadian North	20
Caribbean Airlines	24
Cayman Airways	8
Clube Nauitico Agua Limpa	2
Colt Cargo	4
ConocoPhillips Alaska Inc	2
ConocoPhillips Alaska Inc & BP Exploration(Alaska)	4
Conviasa	2
Copa Airlines	146 (20)
Copa Airlines Colombia	8
Cubana	8
Delta Air Lines	542 (280)
Eastern Air Lines	10
EasySky	2
EG&G Special Projects	12
Enerjet	4
Estafeta Carga Aerea	8
First Air	8
Flair Airlines	10
Frontier Airlines	116 (30)
GECAS	(34)
GOL	266 (4)
Interjet	84
KaiserAir	2
Kalitta Charters II	2
LAC - Linea Aerea Cuencana	2
LAN Airlines	74 (4)
LAN Colombia	20
LAN Peru	12
Latin American Wings	2
LC Peru	8
Magnicharters	18
Miami Air International	12
National Nuclear Security Adminstration	4
Northern Air Cargo	4
One Airlines	2
Peruvian Airlines	14
Rio Linhas Aereas	2
Rutaca	2
Samaritans Purse	4
Sideral Air Cargo	12
Sierra Pacific Airlines	2
Sky Airline	26
Songbird Airways	4
Southern Air	10
Southwest Airlines	1402 (92)
Sun Country Airlines	38
Sunwing Airlines	34 (2)
Surinam Airways	10
Swift Air	20
TAM Linhas Aereas	120 (20)
TAME	4
United Airlines	624 (82)
Vensecar Internacional	4
Virgin America	122 (4)
VivaAerobus	14
VivaColombia	18
WestJet	226 (10)
Xtra Airways	14

CFM INTERNATIONAL LEAP	**TOTAL (8,520)**
Africa	**Total (56)**
Comair (South Africa)	(16)
Ethiopian Airlines	(40)
Asia, Australasia & Middle East	**Total (3,392)**
ABC Financial Leasing	(90)
Air China	(26)
Air India	(28)
Air Niugini	(8)
AirAsia	(608)
ALAFCO Aviation Lease and Finance Company	(82)
BOC Aviation	(168)
BoCom Leasing	(60)
CCB Financial Leasing Corporation	(100)
CDB Leasing Company	(20)
China Aircraft Leasing	(40)
China Eastern Airlines	(24)
China Southern Airlines	(24)
Citilink	(20)
City Airways	(20)
Etihad Airways	(52)
flydubai	(150)
Garuda Indonesia	(100)
Hainan Airlines	(46)
ICBC Leasing Co	(88)
Jet Airways	(150)
Jetstar	(198)
Korean Air	(60)
Lion Air	(768)
Myanmar National Airlines	(8)
Nok Air	(16)
Okay Airways	(16)
Oman Air	(54)
Ruili Airlines	(72)
Sichuan Airlines	(40)
SilkAir	(74)
SpiceJet	(84)
SriLankan Airlines	(4)
Virgin Australia	(80)
Vistara	(14)
Europe	**Total (1,960)**
AerCap	(254)
Avolon Aerospace Leasing	(80)
easyJet	(260)
Enter Air	(4)
Icelandair	(32)
Lufthansa	(82)
Monarch Airlines	(60)
Norwegian	(200)
Pegasus	(150)
Ryanair	(200)
SAS	(60)
SMBC Aviation Capital	(240)
SunExpress	(30)
Thomson Airways	(94)
Travel Service Airlines	(38)
TUI Travel PLC	(26)
Turkish Airlines (THY)	(150)
North/South America	**Total (3,112)**

Aeromexico	(120)
Air Canada	(122)
Air Lease Corporation	(238)
Alaska Airlines	(74)
American Airlines	(400)
Avianca	(66)
Aviation Capital Group	(156)
Azul	(126)
CIT Aerospace	(90)
Copa Airlines	(122)
Eastern Air Lines	(20)
Frontier Airlines	(160)
GECAS	(370)
GOL	(138)
Interjet	(80)
Jetlines	(10)
OKAir Airlines	(4)
Southwest Airlines	(400)
Sunwing Airlines	(8)
United Airlines	(198)
Virgin America	(80)
WestJet	(130)
ENGINE ALLIANCE GP7200	**TOTAL 444 (96)**
Asia, Australasia & Middle East	**Total 404 (76)**
Emirates Airline	308 (52)
Etihad Airways	32 (8)
Korean Air	40
Qatar Airways	24 (16)
Europe	**Total 40 (8)**
Air France	40 (8)
North/South America	**Total (12)**
Air Accord	(12)
GENERAL ELECTRIC CF34	**TOTAL 4,854 (908)**
Africa	**Total 160**
Air Burkina	4
Arik Air	10
CemAir	12
DAC Aviation East Africa	2
Egyptair Express	24
Fly540	8
Fly-SAX	4
Freedom Airlines Express	2
Interstate Airways	2
Kenya Airways	30
Libyan Airlines	2
Linhas Aereas de Mocambique	4
Maluti Sky	4
Nova Airways	2
Petro Air	4
Petroleum Air Services	4
Proflight Zambia	2
Royal Air Maroc	8
RwandAir	4
SA Express	24
Sudan Airways	2
Tunisair Express	2
Asia, Australasia & Middle East	**Total 522 (420)**
7th Sky	4
Afghan Jet International Airlines	2
Air Astana	18
Air Costa	6
Air India Regional	4
Airnorth	8
Arkia	6 (2)
CDB Leasing Company	(40)
Chengdu Airlines	2 (58)
China Express Airlines	46 (30)
China Southern Airlines	40
City Airways	(20)
Colorful Guizhou Airlines	6 (8)
Felix Airways	2 (12)
Fly Baghdad	2
FMI Air Charter	2
Fuji Dream Airlines	20 (2)
Garuda Indonesia	36
GX Airlines	18
Hebei Airlines	12 (2)
Henan Airlines	(100)
Ibex Airlines	18 (2)
ICBC Leasing Co	(54)
Iraq Gate	4
Iraqi Airways	12
J-Air	54 (24)
Kalstar Aviation	4
Mandarin Airlines	12
Med Airways	2
Myanmar Airways International	(4)
Myanmar National Airlines	4
National Jet Express	2
Oman Air	8
Qingdao Airlines	2
Royal Jordanian	10
Saudia	20
Saurya Airlines	2
SCAT	10
Shandong Airlines	2 (20)
Shanghai Airlines	(10)
Tianjin Airlines	90 (32)
uSKY AIR	2
Virgin Australia	30
Europe	**Total 876 (134)**
Adria Airways	24
Air Dolomiti	20
Air Europa	22
Air Moldova	4
Air Nostrum	60 (44)
Airzena - Georgian Airways	4
Aldus Aviation	(32)
Alitalia Cityliner	40
Anadolu Jet	12
Aurigny Air Services	2
Austrian	12
Azerbaijan Airlines	10 (4)
BA CityFlyer	36
Backbone Aviation A/S	4
Belavia	16
Binter Canarias	4
BoraJet	14
Bulgaria Air	8
CityJet	(10)
Eurowings	28
Flybe	40 (8)
HOP!	106
IrAero	12
Jetairfly	6
KLM cityhopper	62 (32)
LOT Polish Airlines	48
Lufthansa CityLine	90
Montenegro Airlines	8
Nextjet	2
Nordic Aviation Capital	(4)
Nordic Regional Airlines	24
Nordica	2
People's Vienna Line	2
Rusline	36
Saratov Airlines	4
SAS	40
Severstal Aircompany	12
Swiss	14
Ukraine International Airlines	10
UVT-Aero	14
West Atlantic Sweden	4
Yamal Airlines	20
North/South America	**Total 3,296 (354)**
Aerolineas SOSA	2
Aeromexico Connect	94
Air Canada	50
Air Georgian	30
Air Wisconsin	138
Amaszonas	14
Amaszonas del Paraguay	2
Amaszonas Uruguay	2
American Airlines	40
Austral Lineas Aereas	46
Avianca El Salvador	24
Azul	166
Boliviana de Aviacion	4
Compass Airlines	124
Conviasa	26
Copa Airlines	24
Copa Airlines Colombia	22
Costa Airlines	2
Elite Airways	18
Endeavor Air	236
Envoy	96 (54)
Estafeta Carga Aerea	4
ExpressJet Airlines	266
Flair Airlines	2
GECAS	(10)
GoJet Airlines	108
Horizon Air	(60)
Jazz	64 (10)
JetBlue Airways	118 (48)
MCS Aero Carga	6
Mesa Airlines	248 (18)
PSA Airlines	216 (14)
R1 Airlines	4

Republic Airlines	226
Satena	2
Shuttle America	112 (48)
Sky Regional Airlines	32
SkyWest Airlines	708 (92)
TAME	6
Voyageur Airways	14
GENERAL ELECTRIC CF6	**TOTAL 3,095 (204)**
Africa	**Total 61**
Aeronexus	4
Air Algerie	22
Air Mauritius	4
Allied Air Cargo	3
ECAir	2
Egyptair	2
Ethiopian Airlines	2
Kabo Air	4
Libyan Airlines	6
Royal Air Maroc	12
Asia, Australasia & Middle East	**Total 946 (18)**
AHS Air International	4
Air Calin	4
Air Do	8
Air Hong Kong	16
Air Japan	24
Air New Zealand	10
Air Niugini	2
ANA - All Nippon Airways	76
Ariana Afghan Airlines	4
Asiana Airlines	72
Cargo Air Lines	4
China Airlines	136
China Cargo Airlines	8
DHL International Aviation EEMEA	4
Emirates Airline	8
Etihad Airways	4
EVA Air	62 (8)
Express Freighters Australia	2
Flynas	4
Garuda Indonesia	8
Global Charter Services	8
Iran Air	24
Iraqi Airways	10
Japan Airlines	82
Jet Airways	16 (10)
Jordan Aviation	4
Mahan Air	46
Mega Maldives Airlines	8
MIAT - Mongolian Airlines	2
Nippon Cargo Airlines	20
Pakistan International Airlines	2
Qantas	92
Qatar Airways	56
Qeshm Airlines	6
Raya Airways	2
Royal Jordanian	2
Saudia	28
SF Airlines	2
Shaheen Air International	12
Sunday Airlines	2
Taban Air	2
Thai Airways International	40
Unique Air	4
Uni-top Airlines	4
Yangtze River Express	12
Europe	**Total 704 (24)**
Aer Lingus	16 (4)
Air Atlanta Icelandic	4
Air Cargo Global	4
Air Europa	12
Air France	30
AirBridgeCargo	32
Airbus Transport International	10
Alitalia	28
Azerbaijan Airlines	4
Azur Air	4
Blue Panorama Airlines	6
Brussels Airlines	6
CargoLogicAir	4
Cargolux	8
Condor	10
DHL Air	8
EuroAtlantic airways	8
Finnair	16
Hi Fly	2
Iberia	24 (18)
Icelandair	4
Jetairfly	2
KLM Royal Dutch Airlines	108
Lufthansa	52
Lufthansa Cargo	36
Martinair	12
Meridiana	8
MNG Airlines	8
NEOS	6
Nordwind Airlines	2
Pegas Fly	2
Privilege Style	2
Rossiya - Russian Airlines	4
Royal Flight	4
S7 Airlines	4
SATA International	4
Solinair	2
South Airlines (Armenia)	8
Star Air	22
SunExpress Germany	8
TAP Portugal	14
TCA	4
Thomas Cook Airlines	6
Thomson Airways	6
Titan Airways	2
TNT Airways	10
TransAVIAexport Airlines	8
TUI Airlines Nederland	2
TUIFly Nordic AB	4
Turkish Airlines (THY)	64 (2)
UTair	6
Virgin Atlantic Airways	32
Wamos Air	4
West Atlantic Sweden	4
White	2
XL Airways France	2
North/South America	**Total 1,384 (162)**
21 Air	4
ABX Air	44
Aerolineas Argentinas	4 (4)
AeroUnion	8
Air Canada	30
Air Canada Rouge	12
Air Transat	18
Amazon.com	10
American Airlines	78
Amerijet International	12
ATI - Air Transport International	2
Atlas Air	84
Boliviana de Aviacion	6
Cargojet Airways	18
Centurion Air Cargo	18
Conviasa	4
Delta Air Lines	128 (8)
Dynamic International Airways	2
FedEx	418 (150)
Fly Jamaica	2
Fortress Investment Group	3
Hawaiian Airlines	2
Kalitta Air	40
KF Aerospace	6
LAN Airlines	36
LAN Argentina	6
LAN Cargo	4
LAN Cargo Colombia	2
LAN Colombia	6
Mas Air	2
National Airlines	8
Omni Air International	16
Polar Air Cargo	36
SBA Airlines	4
Solar Cargo	3
TAB Airlines	9
TAM Cargo	8
TAM Linhas Aereas	28
Transcarga International Airways	2
United Airlines	32
UPS Airlines	203
Western Global Airlines	16
WestJet	10
GENERAL ELECTRIC GE90	**TOTAL 1,954 (388)**
Africa	**Total 66 (6)**
Air Austral	6 (4)
CEIBA Intercontinental	2
Egyptair	12
Ethiopian Airlines	32
TAAG Angola Airlines	14 (2)
Asia, Australasia & Middle East	**Total 1,212 (186)**
Air China	40 (12)
Air China Cargo	16
Air India	30 (6)

Air New Zealand	14
ANA - All Nippon Airways	44 (12)
Biman Bangladesh Airlines	8
Cathay Pacific	106
China Airlines	20
China Cargo Airlines	12
China Eastern Airlines	24 (16)
China Southern Airlines	50 (2)
Emirates Airline	278 (72)
Etihad Airways	70 (2)
EVA Air	46 (28)
Garuda Indonesia	20
Hong Kong Airlines	(12)
Iraqi Airways	2
Japan Airlines	48
Jet Airways	8
Korean Air	46 (26)
Kuwait Airways	4 (20)
Pakistan International Airlines	22 (10)
Philippine Airlines	12 (4)
Qatar Airways	102 (16)
Saudia	92
Singapore Airlines	54
Thai Airways International	28
Turkmenistan Airlines	4
Vietnam Airlines	2
Virgin Australia International	10
Europe	**Total 426 (40)**
Aeroflot Russian Airlines	28 (12)
AeroLogic	16
Air France	140 (2)
Alitalia	20
Austrian	10
British Airways	78
KLM Royal Dutch Airlines	52 (2)
Lufthansa Cargo	10
Nordwind Airlines	6
Swiss Global Air Lines	6 (12)
TNT Airways	6
Turkish Airlines (THY)	54 (12)
North/South America	**Total 250 (52)**
Aeromexico	8
Air Canada	48 (2)
American Airlines	40
Delta Air Lines	20
FedEx	54 (18)
Intrepid Aviation Group	(8)
LAN Cargo	6
Southern Air	10
TAM Cargo	(4)
TAM Linhas Aereas	20
United Airlines	44 (20)
GENERAL ELECTRIC GE9X	**TOTAL (592)**
Asia, Australasia & Middle East	**Total (552)**
ANA - All Nippon Airways	(40)
Cathay Pacific	(42)
Emirates Airline	(300)
Etihad Airways	(50)
Qatar Airways	(120)
Europe	**Total (40)**
Lufthansa	(40)
GENERAL ELECTRIC GENX	**TOTAL 868 (742)**
Africa	**Total 42 (28)**
Arik Air	(22)
Ethiopian Airlines	24
Kenya Airways	14
Royal Air Maroc	4 (6)
Asia, Australasia & Middle East	**Total 438 (378)**
Air China	24
Air India	42 (12)
ALAFCO Aviation Lease and Finance Company	(16)
Cathay Pacific	52 (4)
China Southern Airlines	20
Etihad Airways	16 (130)
EVA Air	(40)
Hainan Airlines	20 (6)
Japan Airlines	52 (38)
Jetstar	22
Korean Air	44 (44)
Nippon Cargo Airlines	32 (8)
Oman Air	6 (12)
Qantas	(16)
Qatar Airways	56 (4)
Royal Jordanian	10 (12)
Saudia	16 (8)
Uzbekistan Airways	(4)
Vietnam Airlines	14 (24)
Xiamen Airlines	12
Europe	**Total 212 (106)**
AerCap	(4)
Air France	(12)
AirBridgeCargo	32
Azerbaijan Airlines	4
CargoLogicAir	(4)
Cargolux	52 (4)
Jetairfly	2
KLM Royal Dutch Airlines	10 (52)
Lufthansa	76
Silk Way West Airlines	12 (8)
Thomson Airways	18 (6)
Transaero Airlines	(16)
TUI Airlines Nederland	6
North/South America	**Total 176 (150)**
Aeromexico	18 (14)
Air Canada	36 (38)
Air Lease Corporation	(56)
American Airlines	30 (54)
Atlas Air	16
CIT Aerospace	(6)
GECAS	(20)
Polar Air Cargo	20
United Airlines	56 (42)
HONEYWELL LF507	**TOTAL 420**
Africa	**Total 56**
Air Annobon	4
Air Libya	4
Airlink	48
Asia, Australasia & Middle East	**Total 84**
Mahan Air	32
National Jet Express	32
Qeshm Airlines	16
Taban Air	4
Europe	**Total 240**
BRA-Braathens Regional Airlines	48
Brussels Airlines	48
CityJet	68
Ellinair	8
Jota Aviation	4
Swiss Global Air Lines	64
North/South America	**Total 40**
Aerovias DAP	8
Eco Jet	16
North Cariboo Air	8
Summit Air Charters	8
INTERNATIONAL AERO ENGINES V2500	**TOTAL 5,718 (626)**
Africa	**Total 100**
Air Seychelles	6
Almasria Universal Airlines	6
Egyptair	28
Fastjet Tanzania	4
FastJet Zimbabwe	2
Global Aviation Operations	2
Libyan Airlines	2
Nesma Airlines	6
Nile Air	6
South African Airways	38
Asia, Australasia & Middle East	**Total 2,526 (260)**
Air Astana	26
Air Busan	26
Air Calin	4
Air China	82
Air India	30
Air Macau	34
Air New Zealand	58 (2)
Airblue	6
Asiana Airlines	64
ATA Air	6
Atrak Air	4
Bangkok Airways	40
BOC Aviation	(20)
Cambodia Angkor Air	6
Capital Airlines	76
Cebgo	2
China Aircraft Leasing	(16)
China Eastern Airlines	182 (2)
China Eastern Airlines Jiangsu	28
China Southern Airlines	360 (4)
Chongqing Airlines	24
Citilink	12
Dragonair	46
Etihad Airways	66
Fly Baghdad	4
Golden Myanmar Airlines	2
Gulf Air	12
Hong Kong Express Airways	16 (4)
ICBC Leasing Co	(22)
IndiGo	206

Iran Air	4
Iran Aseman Airlines	6
Iraqi Airways	4
Israir	6 (2)
Jetstar	118
Jetstar Asia	36
Jetstar Japan	40
Jetstar Pacific	24 (8)
Juneyao Airlines	4 (2)
Kingfisher Airlines	(134)
Middle East Airlines	22
Mihin Lanka	8
Nepal Airlines	4
PAL Express	2
Philippine Airlines	38 (8)
Philippines AirAsia	12
Qatar Airways	82
Royal Brunei Airlines	16
Royal Jordanian	24
SaudiGulf Airlines	4
Shaheen Air International	16
Shenzhen Airlines	60
Sichuan Airlines	168
SilkAir	30
Sky Angkor Airlines	2
SpiceJet	4
SriLankan Airlines	6
Syrianair	12
Thai Airways International	8
Thai Smile	32
Tianjin Airlines	30
Tigerair	46
Tigerair Australia	28
Tigerair Taiwan	16 (2)
TransAsia Airways	16 (4)
UNI Air	4
V Air	8 (12)
Vietnam Airlines	106
Virgin Australia Regional Airlines	4
Vistara	20 (6)
West Air (China)	26 (4)
Yemenia	4 (8)
Zagros Airlines	4
Europe	**Total 1,240 (152)**
Adria Airways	4
Aegean Airlines	94
Air Moldova	2
Air Serbia	20
Air VIA	2
Alphastream AG	(30)
Astra Airlines	2
Atlas Atlantique Airlines	2
Atlasglobal	24
Atlasjet Ukraine	2
BH Air	2
British Airways	256
Bulgarian Air Charter	2
Cobalt Air	2
DAT - Danish Air Transport	8
Ellinair	4
Finnair	10 (8)
FlyOne	2
Freebird Airlines	4
Germanwings	52
Hi Fly	2
Lufthansa	128
Monarch Airlines	52
Nordwind Airlines	4
Novair	2
Onurair	34
SAS	50
Small Planet Airlines (Lithuania)	6
Small Planet Airlines (Poland)	12
Smartlynx Estonia	2
SMBC Aviation Capital	(10)
Thomas Cook Airlines	8
Titan Airways	4
Turkish Airlines (THY)	200 (16)
Ural Airlines	4
Vueling Airlines	88 (20)
Wizz Air	134 (68)
WOW air	4
Yamal Airlines	12
North/South America	**Total 1,852 (198)**
American Airlines	414 (76)
Aruba Airlines	6
Avianca	4
Avianca Costa Rica	20
Avianca El Salvador	44 (2)
Avianca Peru	6
CIT Aerospace	(4)
Cubana	2
Delta Air Lines	130
Dominican Wings	2
JetBlue Airways	318 (32)
LAN Airlines	32
LAN Argentina	26
LAN Ecuador	12
LAN Peru	38
Mexicana	(8)
Sky Airline	4
Spirit Airlines	170 (62)
TAM Linhas Aereas	148
TAME	14
United Airlines	304
VECA	4
VivaAerobus	34 (10)
Volaris	120 (12)
IVCHENKO-PROGRESS AI-25	**TOTAL 111**
Asia, Australasia & Middle East	**Total 33**
Bek Air	6
East Kazakhstan Region Air Enterprise	6
Syrianair	12
Zhetysu Aviakompania	6
Zhezair	3
Europe	**Total 78**
Aerobratsk	3
Albatross Aero Club	3
Amur Airlines	9
Avialift-DV	3
Barkol Aviakompania	3
Belogorie	3
Gazpromavia	12
Petropavlovsk-Kamchatsky Air Enterprise	9
Rossiya Special Flight Detachment	3
Rsk MIG	3
Severstal Aircompany	3
SIBNIA	6
Sukhoi Multipurpose Aircompany	6
Tulpar Air	3
Vologda Air Enterprise	9
IVCHENKO-PROGRESS D-18	**TOTAL 78**
Europe	**Total 78**
Antonov Airlines	34
Maximus Airlines	4
Volga-Dnepr Airlines	40
IVCHENKO-PROGRESS D-36	**TOTAL 161**
Africa	**Total 10**
Green Flag Aviation	4
Tarco Air	6
Asia, Australasia & Middle East	**Total 17**
Irtysh Air	3
Kaz Air Jet	8
Pouya Air	6
Europe	**Total 134**
Aerom	2
Antonov Airlines	2
Ayk Avia	4
Black Sea Airlines	6
Cavok Air	2
Grozny-Avia	24
Izhavia Udmurtia	21
KrasAvia	24
Motor Sich Airlines	2
Saratov Airlines	21
Shar ink	4
Skiva Air	4
South Airlines (Armenia)	6
Uktus Avia Company	2
UTair Cargo	10
IVCHENKO-PROGRESS D-436-148	**TOTAL 26 (68)**
Asia, Australasia & Middle East	**Total 4**
Air Koryo	4
Europe	**Total 10 (62)**
Angara Airlines	10
Ilyushin Finance Company	(40)
Rossiya Special Flight Detachment	(2)
Silk Way West Airlines	(20)
North/South America	**Total 12 (6)**
Cubana	12 (6)
KUZNETSOV DESIGN NK-8	**TOTAL 24**
Asia, Australasia & Middle East	**Total 6**
Air Koryo	6
Europe	**Total 18**
223rd State Airline Flight Unit	18
LYCOMING ALF502	**TOTAL 216**
Africa	**Total 20**

Air Libya	4
Cronos Airlines	8
Daallo Airlines	4
Starbow	4
Asia, Australasia & Middle East	**Total 84**
Avia Traffic Company	4
Aviastar Mandiri	8
Mahan Air	32
National Jet Express	24
Skyforce Aviation	4
Skyjet Airlines	8
Tez Jet Airlines	4
Europe	**Total 64**
Astra Airlines	4
BAE Systems (Corporate Air Travel)	8
Bulgaria Air	4
Flybe	4
Pan Air	36
WDL	8
North/South America	**Total 48**
Aerovias DAP	8
Star Peru	32
TAM - Transporte Aereo	8
POWERJET SAM146	**TOTAL 118 (116)**
Asia, Australasia & Middle East	**Total (4)**
Sky Angkor Airlines	(4)
Europe	**Total 64 (48)**
Aeroflot Russian Airlines	52 (6)
CityJet	(30)
Gazpromavia	16
Ilyushin Finance Company	(8)
Red Wings Airlines	6
Yakutia Airlines	4 (2)
Yamal Airlines	2 (48)
North/South America	**Total 38 (18)**
Interjet	38 (18)
PRATT & WHITNEY JT3D	**TOTAL 4**
Africa	**Total 4**
Trans Air Cargo Services	4
PRATT & WHITNEY JT8D	**TOTAL 1,254**
Africa	**Total 93**
Africa Charter Airline	8
African Express Airways	6
Air Kasai	2
Air Zimbabwe	2
Allegiance Airways - Gabon	2
Astral Aviation	2
Canadian Airways Congo	6
DANA Air	10
Emirate Touch Aviation Services	3
Exclusive Alliance	2
Global Aviation Operations	4
Gomair	5
Interair	2
ITAB - International Trans Air Business	2
JedAir	2
Jubba Airways	2
Karinou Airlines	2
Lyca Cargo	3
Niger Airlines	2
Safe Air Company	3
Serve Air	15
Trans Air Congo	8
Asia, Australasia & Middle East	**Total 181**
Air Almaty	3
AIRFAST Indonesia	10
Airstream Aviation	2
Astro Air International	2
ATA Air	12
Caspian Airlines	14
Express Air	2
Far Eastern Air Transport	16
FitsAir	2
Gryphon Airlines	2
Iran Air	8
Iran Airtours	12
Iran Aseman Airlines	12
Iraqi Airways	2
Jayawijaya Dirgantara	4
Kam Air	10
Kish Air	14
Majestic Air Cargo	3
Neptune Air	3
Raya Airways	9
Seair International	2
SKA Air & Logistics (SkyLink Arabia)	3
Sky Capital Airlines	2
Taban Air	10
Trigana Air	4
Vision Air International	2
Zagros Airlines	16
Europe	**Total 44**
ALK Airlines	2
Bravo Air	4
Bulgarian Air Charter	20
DAT - Danish Air Transport	2
Meridiana	16
North/South America	**Total 936**
Aerolineas Estelar	8
Aeronaves TSM	18
Aeropostal	12
Aerosucre Colombia	8
Aerovias DAP	4
Air Class Lineas Aereas	6
Air Inuit	4
Air North	2
Allegiant Air	98
American Airlines	182
Amerijet International	9
Ameristar Charters	16
Andes Lineas Aereas	10
Aserca Airlines	16
Asia Pacific Airlines	6
Avior Airlines	8
C & M Airways	2
Canadian North	10
Cargojet Airways	15
Delta Air Lines	232
EasySky	4
Everts Air Alaska	8
First Air	4
Glencore Canada Corp	4
Global Air	4
Gulf & Caribbean Cargo	9
InselAir	10
InselAir Aruba	4
Interjet West	3
Kalitta Charters II	24
LASER	20
Lineas Aereas Suramericanas	21
Magnicharters	2
National Nuclear Security Adminstration	2
Nolinor Aviation	10
Northern Air Cargo	6
Olympia Aviation	2
Orange Air	4
PanAir Cargo	3
PAWA Dominicana	12
Perla Airlines	4
Peruvian Airlines	6
Red River Aircraft Leasing LLC	3
Rio Linhas Aereas	12
Rutaca	8
SELVA Colombia	3
Sierra Pacific Airlines	4
SkyWay Enterprises	2
TAM - Transporte Aereo Militar	6
Total Linhas Aereas	15
TransAir	8
Uniworld Air Cargo (1)	2
USA Jet Airlines	17
Venezolana	12
World Atlantic Airlines	12
PRATT & WHITNEY JT9D	**TOTAL 98**
Africa	**Total 28**
Eritrean Airlines	2
Interair	2
Kabo Air	12
MaxAir	12
Asia, Australasia & Middle East	**Total 32**
Caspian Airlines	4
Iran Air	4
Kam Air	2
Orient Thai Airlines	10
Uni-top Airlines	12
Europe	**Total 4**
TCA	4
North/South America	**Total 34**
Atlas Air	8
Dynamic International Airways	4
Kalitta Air	20
Vision Airlines	2
PRATT & WHITNEY PW1000G	**TOTAL 12 (4,438)**
Asia, Australasia & Middle East	**Total 8 (1,688)**
Air Astana	(22)
Air Costa	(100)
Air Mandalay	(12)

Air New Zealand	(36)
ALAFCO Aviation Lease and Finance Company	(100)
ANA - All Nippon Airways	(96)
BOC Aviation	(30)
Cebu Pacific Air	(60)
China Aircraft Leasing	(36)
China Southern Airlines	(48)
Falcon Aviation Services	(4)
GoAir	(144)
Gulf Air	(20)
Hong Kong Express Airways	(24)
ICBC Leasing Co	(20)
IndiGo	8 (352)
Iraqi Airways	(10)
J-Air	(64)
Korean Air	(80)
Mihin Lanka	(4)
Philippine Airlines	(60)
Qatar Airways	(100)
Royal Brunei Airlines	(14)
SaudiGulf Airlines	(32)
Tianjin Airlines	(4)
Tigerair	(78)
TransAsia Airways	(12)
VietJet Air	(126)
Europe	**Total 4 (1,166)**
AerCap	(182)
Aeroflot Russian Airlines	(100)
airBaltic	(40)
Azur Air Ukraine	(10)
BRA-Braathens Regional Airlines	(20)
Czech Airlines	(2)
Ilyushin Finance Company	(80)
Lease Corporation International	(40)
Lufthansa	4 (116)
Macquarie AirFinance	(80)
Norwegian	(76)
Novair	(6)
Odyssey Airlines	(20)
Red Wings Airlines	(20)
SMBC Aviation Capital	(60)
Swiss	(60)
Turkish Airlines (THY)	(184)
UTair	(20)
VEB-Leasing JSC	(40)
VIM Airlines	(10)
North/South America	**Total (1,584)**
Air Lease Corporation	(34)
Aircastle Advisor LLC	(50)
Aviation Capital Group	(24)
Azul	(60)
CIT Aerospace	(60)
Delta Air Lines	(150)
Eastern Air Lines	(40)
Hawaiian Airlines	(32)
JetBlue Airways	(140)
LAN Airlines	(90)
Republic Airways Holdings Inc	(80)
SkyWest Airlines	(400)
Spirit Airlines	(110)
TAM Linhas Aereas	42)
Trans States Holdings	(100)
VivaAerobus	(80)
Volaris	(92)
PRATT & WHITNEY PW2000	**TOTAL 508**
Africa	**Total 8**
Ethiopian Airlines	6
TACV - Cabo Verde Airlines	2
Asia, Australasia & Middle East	**Total 18**
Raya Airways	2
Tajik Air	6
Uzbekistan Airways	10
Europe	**Total 42**
Aer Lingus	6
Azur Air	12
European Air Transport	8
OpenSkies	4
VIM Airlines	12
North/South America	**Total 472**
ATI - Air Transport International	12
Delta Air Lines	244
DHL Aero Expreso	6
FedEx	76
L-3 Communications Advanced Aviation LLC	2
United Airlines	30
UPS Airlines	70
PRATT & WHITNEY PW300	**TOTAL 54**
Africa	**Total 6**
Avex Air	2
SkyBird Air	4
Asia, Australasia & Middle East	**Total 2**
Royal Star Aviation Inc	2
Europe	**Total 24**
Private Wings Flugcharter	2
Sun-Air of Scandinavia	22
North/South America	**Total 22**
Calm Air	2
FlyMex	2
Key Lime Air	4
Ultimate Jetcharters	14
PRATT & WHITNEY PW4000	**TOTAL 1,969 (38)**
Africa	**Total 43**
Air Zimbabwe	4
Arik Air	4
Camair Co	2
Egyptair	6
Ethiopian Airlines	12
Global Africa Aviation	9
Kabo Air	4
Med-View Airline	2
Asia, Australasia & Middle East	**Total 826 (36)**
Air Astana	6
Air China	26
Air China Cargo	12
Air Hong Kong	4
Air India	16
Air Niugini	2
Airblue	2
ANA - All Nippon Airways	70
Asia Atlantic Airlines (Thailand)	4
Asiana Airlines	52
Biman Bangladesh Airlines	8
Cargo Air Lines	8
Cathay Pacific	32
China Airlines	16
China Cargo Airlines	4
China Southern Airlines	54 (6)
El Al	42
Hainan Airlines	6
Hong Kong Airlines	12
Iraqi Airways	4
Japan Airlines	32
Jin Air	6
Kingfisher Airlines	(30)
Korean Air	196
Lion Air	8
Mahan Air	2
Malaysia Airlines	38
Orient Thai Airlines	4
Pakistan International Airlines	6
Qatar Airways	8
Royal Jordanian	4
Saudia	44
Shanghai Airlines	12
Silk Road Cargo Business	2
Singapore Airlines Cargo	36
Thai Airways International	2
Uzbekistan Airways	16
Vietnam Airlines	26
Yemenia	4
Europe	**Total 268**
Aerotranscargo	8
Air Cargo Global	4
Air Greenland	2
airberlin	28
AirBridgeCargo	4
ASL Airlines Ireland	8
Austrian	12
Azur Air	6
BH Air	2
Brussels Airlines	10
Condor	18
Corsair	12
Czech Airlines	2
Edelweiss Air	2
EuroAtlantic airways	6
European Air Transport	42
Hi Fly	6
Ifly	2
Martinair	10
MNG Airlines	4
Onurair	2
Orbest	2
Pegas Fly	8
Privilege Style	2
Rossiya - Russian Airlines	4
SATA International	4

TAP Portugal	14
TAROM	2
Turkish Airlines (THY)	22
Ukraine International Airlines	8
Wamos Air	12
North/South America	**Total 832 (2)**
ABX Air	6
Aerolineas Argentinas	8
Air Canada Rouge	20
Air Caraibes	10
American Airlines	18
Atlas Air	16
Centurion Air Cargo	4
Delta Air Lines	168
FedEx	107
French Blue	(2)
Hawaiian Airlines	14
Omni Air International	2
Sky Lease Cargo	12
United Airlines	262
UPS Airlines	185
PRATT & WHITNEY PW6000	**TOTAL 18**
North/South America	**Total 18**
Avianca Brazil	18
ROLLS-ROYCE AE 3007	**TOTAL 1,206**
Africa	**Total 106**
AeroJet-Transporte Aero Limitada	2
Africa World Airlines	6
Air 26	6
Air Katanga	2
Air Namibia	8
Air Taraba	2
Airlink	30
ALS	4
Bristow Helicopters (Nigeria)	4
Cronos Airlines	4
Diexim Expresso	2
Equaflight	4
Fly Blue Crane	4
Groupe Transair	2
Mauritania Airlines International	2
Mocambique EXpresso	6
Solenta Aviation	8
Swaziland Airlink	6
Westair Aviation	4
Asia, Australasia & Middle East	**Total 74**
Air Mandalay	4
China Eastern Airlines	6
JetGo Australia	6
Korea Express Air	2
NovoAir	6
Reliance Industries	2
Rotana Jet	6
Tianjin Airlines	42
Europe	**Total 138**
Air Europa	2
BAE Systems (Corporate Air Travel)	2
BMI Regional	28
Dniproavia	14
Eastern Airways	8
HOP!	34
Komiaviatrans	10
Luxair	6
Nordica	8
Pan Europeenne Air Service	4
PGA - Portugalia Airlines	10
Regional	2
SiAvia	10
North/South America	**Total 888**
ADI Charter Services	6
Aereo Calafia	6
Aeromexico Connect	36
BizCharters Inc	2
Champion Air LLC	2
CommutAir	4
Delux Public Charter LLC	4
Envoy	222
ExpressJet Airlines	366
Hendrick Motorsports LLC	4
IBC Airways	4
Petroecuador - Unidad de Aviacion	2
Piedmont Airlines	10
Satena	4
Shuttle America	66
TAR Aerolineas	14
Trans States Airlines	118
Ultimate Jetcharters	2
Via Air	12
Victory Air LLC	4
ROLLS-ROYCE BR700	**TOTAL 308**
Asia, Australasia & Middle East	**Total 52**
QantasLink	40
Turkmenistan Airlines	12
Europe	**Total 38**
Volotea	38
North/South America	**Total 218**
Delta Air Lines	182
Hawaiian Airlines	36
ROLLS-ROYCE RB211	**TOTAL 1,160**
Africa	**Total 10**
Cairo Aviation	4
ECAir	2
MaxAir	4
Asia, Australasia & Middle East	**Total 168**
Air Astana	10
Air China Cargo	8
Air Hong Kong	12
Arkia	4
Blue Dart Aviation	12
Cathay Pacific	20
China Southern Airlines	22
DHL International Aviation EEMEA	6
Mega Maldives Airlines	2
MIAT - Mongolian Airlines	2
Nepal Airlines	4
Orient Thai Airlines	2
Qantas	16
SCAT	4
SF Airlines	28
Sunday Airlines	4
Tasman Cargo Airlines	2
Turkmenistan Airlines	2
Xiamen Airlines	8
Europe	**Total 468**
Azerbaijan Airlines	8
Azur Air	6
British Airways	178
Cargolux	24
Cargolux Italia	12
Condor	26
Cygnus Air	4
DHL Air	42
European Air Transport	16
Icelandair	52
Ifly	2
Jet2	22
La Compagnie	4
OpenSkies	2
Privilege Style	4
Royal Flight	10
Sea Air	2
Silk Way Italia	4
Silk Way West Airlines	8
Thomas Cook Airlines	4
Thomson Airways	28
Titan Airways	4
TNT Airways	4
Yakutia Airlines	2
North/South America	**Total 514**
Allegiant Air	8
American Airlines	122
ATI - Air Transport International	6
Cargojet Airways	10
Colt Cargo	2
Dynamic International Airways	4
FedEx	136
Fly Jamaica	2
Morningstar Air Express	12
National Airlines	4
SBA Airlines	4
United Airlines	124
UPS Airlines	80
ROLLS-ROYCE SPEY	**TOTAL 4**
Africa	**Total 4**
Fly-SAX	2
Toumai Air Tchad	2
ROLLS-ROYCE TAY	**TOTAL 314**
Africa	**Total 4**
Golden Wings Aviation	2
Kush Air	2
Asia, Australasia & Middle East	**Total 186**
Air Niugini	24
Alliance Airlines	46
Bek Air	14
Iran Air	8
Iran Aseman Airlines	8
Iranian Naft Airlines	8

Kish Air	6
Network Aviation	28
Qeshm Airlines	8
Skippers Aviation	4
TransNusa Air Services	2
Transwisata Air	2
Virgin Australia Regional Airlines	28
Europe	**Total 106**
Austrian	34
Avantiair	4
Carpatair	2
Croatia Airlines	2
Denim Air	2
Helvetic Airways	10
KLM cityhopper	30
Montenegro Airlines	4
Nextjet	2
Nordica	2
PGA - Portugalia Airlines	12
Trade Air	2
North/South America	**Total 18**
Air Panama	10
Fly Allways	2
InselAir Aruba	6
ROLLS-ROYCE TRENT	**TOTAL 2,666 (2,802)**
Africa	**Total 82 (92)**
Afriqiyah Airways	(20)
Air Austral	(4)
Air Mauritius	(12)
Air Namibia	4
Air Seychelles	4
Egyptair	22 (2)
Ethiopian Airlines	(36)
Libyan Airlines	(12)
RwandAir	(4)
South African Airways	48
Tunisair	4 (2)
Asia, Australasia & Middle East	**Total 1,580 (1,590)**
Air Astana	(6)
Air China	106 (50)
Air New Zealand	28 (12)
Air Niugini	(2)
AirAsia X	42 (152)
ALAFCO Aviation Lease and Finance Company	(12)
ANA - All Nippon Airways	94 (84)
Asiana Airlines	16 (68)
Capital Airlines	4
Cathay Pacific	118 (96)
Cebu Pacific Air	12
China Airlines	(28)
China Eastern Airlines	84 (40)
China Eastern Yunnan	6
China Southern Airlines	48
Dragonair	38
El Al	12 (10)
Emirates Airline	58 (200)
Etihad Airways	88 (126)
Fiji Airways	8
Flynas	2
Garuda Indonesia	48 (32)
Gulf Air	12
Hainan Airlines	44
Hong Kong Airlines	26 (30)
Indonesia AirAsia X	4
Japan Airlines	(62)
Kuwait Airways	10 (20)
Lion Air	6
Mahan Air	24
Malaysia Airlines	24 (8)
Middle East Airlines	8 (2)
NokScoot	6
Oman Air	20
Philippine Airlines	30 (12)
Qantas	48 (32)
Qatar Airways	48 (144)
Royal Brunei Airlines	8 (2)
Saudia	32 (40)
Scoot	22 (18)
Shanghai Airlines	12
Sichuan Airlines	16
Singapore Airlines	194 (210)
SriLankan Airlines	26 (14)
Thai AirAsia X	12
Thai Airways International	106 (28)
Tianjin Airlines	2
Tibet Airlines	(2)
TransAsia Airways	8 (8)
Vietnam Airlines	8 (20)
Virgin Australia	12
Yemenia	(20)
Europe	**Total 680 (556)**
Aer Lingus	(18)
AerCap	(10)
Aeroflot Russian Airlines	44 (44)
Air Europa	22 (42)
Air France	(50)
Avolon Aerospace Leasing	(30)
AWAS	(4)
Azerbaijan Airlines	8
British Airways	114 (92)
Brussels Airlines	2
Corsair	8
Edelweiss Air	4
EuroAtlantic airways	2
Evelop Airlines	4
Finnair	10 (28)
Hi Fly	6
Iberia	68 (32)
Icelandair	(2)
LOT Polish Airlines	12 (4)
Lufthansa	166 (50)
MNG Airlines	2 (6)
NEOS	(6)
Norwegian	20 (54)
Onurair	4
SAS	16 (16)
Swiss	28
TAP Portugal	(28)
Thomas Cook Airlines	14
Thomas Cook Airlines Scandinavia	6
Turkish Airlines (THY)	34 (4)
VIM Airlines	2
Virgin Atlantic Airways	78 (36)
XL Airways France	6
North/South America	**Total 294 (426)**
Air Canada	16
Air Caraibes	(14)
Air Lease Corporation	(94)
Air Transat	26
American Airlines	124 (44)
Avianca	28 (36)
Avianca Brazil	2
Avianca Cargo	10 (2)
Avianca Peru	2
Aviation Capital Group	(10)
Azul	8 (10)
CIT Aerospace	(62)
Delta Air Lines	16 (136)
Hawaiian Airlines	44 (14)
LAN Airlines	42 (22)
TAM Linhas Aereas	4 (50)
TAME	2
United Airlines	(70)

FlightFleets Analyzer

Introducing Fleets Analyzer...

The most trusted and timely fleet data, intelligence and insight

- Identify opportunities and understand the global fleet
- Streamline your workflow and collaborate easily
- Gain a competitive edge with the most up-to-date data
- Quickly access data and improve efficiency

Find out more and request your demo at

www.flightglobal.com/fleetsanalyzer

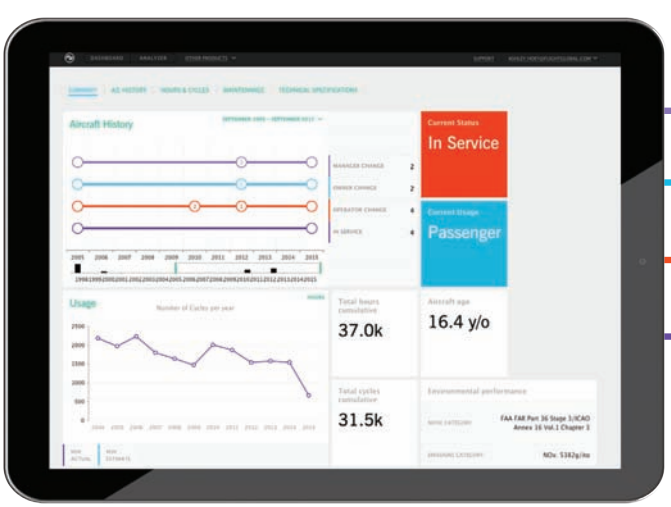


Illustration shows conceptual data only


cfm
Delivering
...on fuel burn and all of our promises.
We promised that our new LEAP engine would deliver an improvement in fuel burn compared to the best CFM engines, enable aircraft to comply with future chapter 14 regulations and achieve margins in NOx emissions versus CAEP/6 standards. On all counts LEAP is delivering, on time and on spec. **LEAP. The architecture of reliability.**
cfmaeroengines.com
CFM International is a 50/50 joint company between GE and Safran Aircraft Engines
PERFORMANCE | EXECUTION | TECHNOLOGY
LEAP
MORE TO BELIEVE IN