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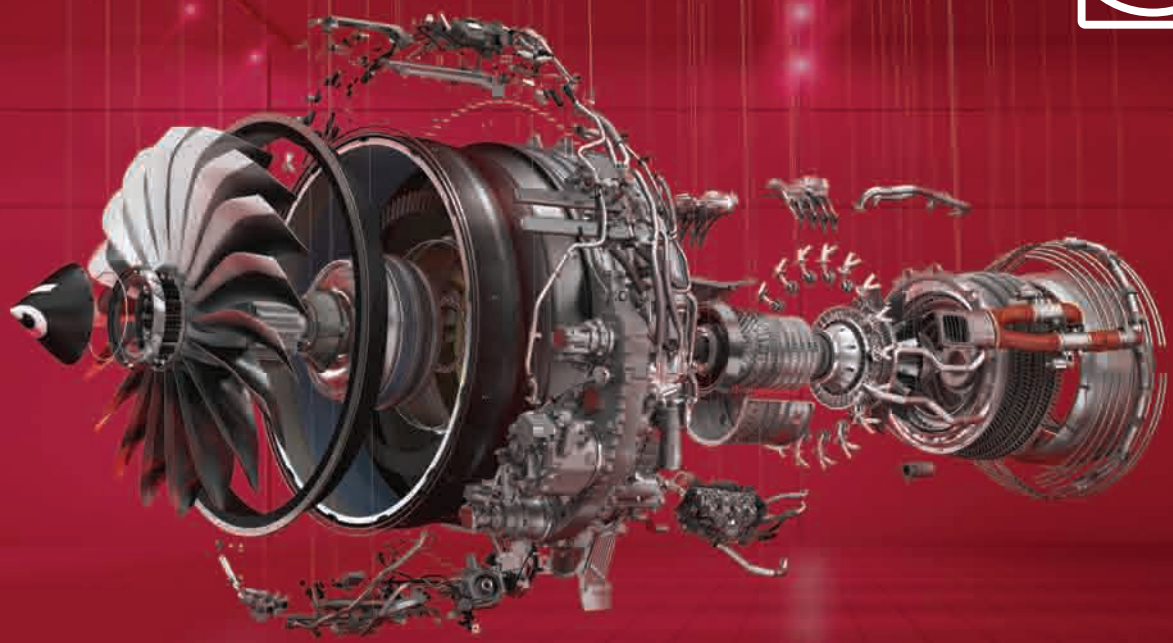

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Our next-generation LEAP engine is built on solid foundations. Drawing on the legendary architecture of the CFM56, we have expanded our technology and innovation even further. Delivering a new standard in fuel efficiency for CFM customers worldwide.

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CFM International is a 50/50 joint company between Snecma (Safran) and GE.

PERFORMANCE | EXECUTION | TECHNOLOGY

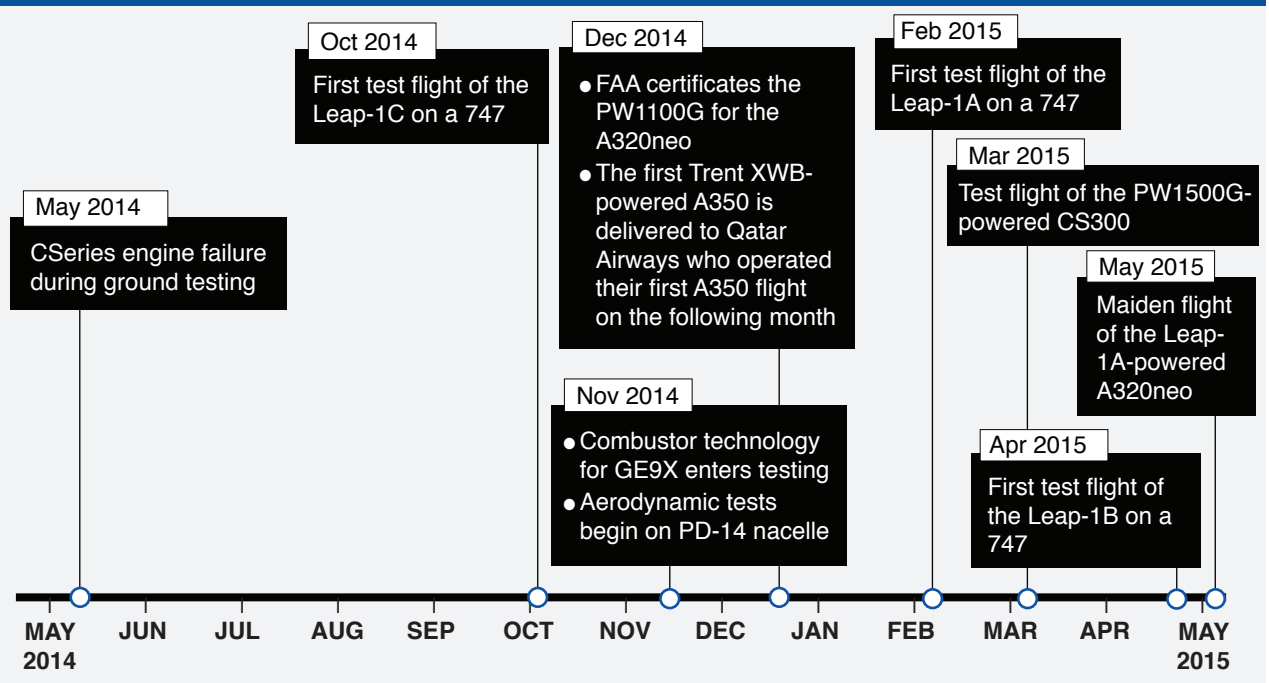
LEAP

MORE TO BELIEVE IN

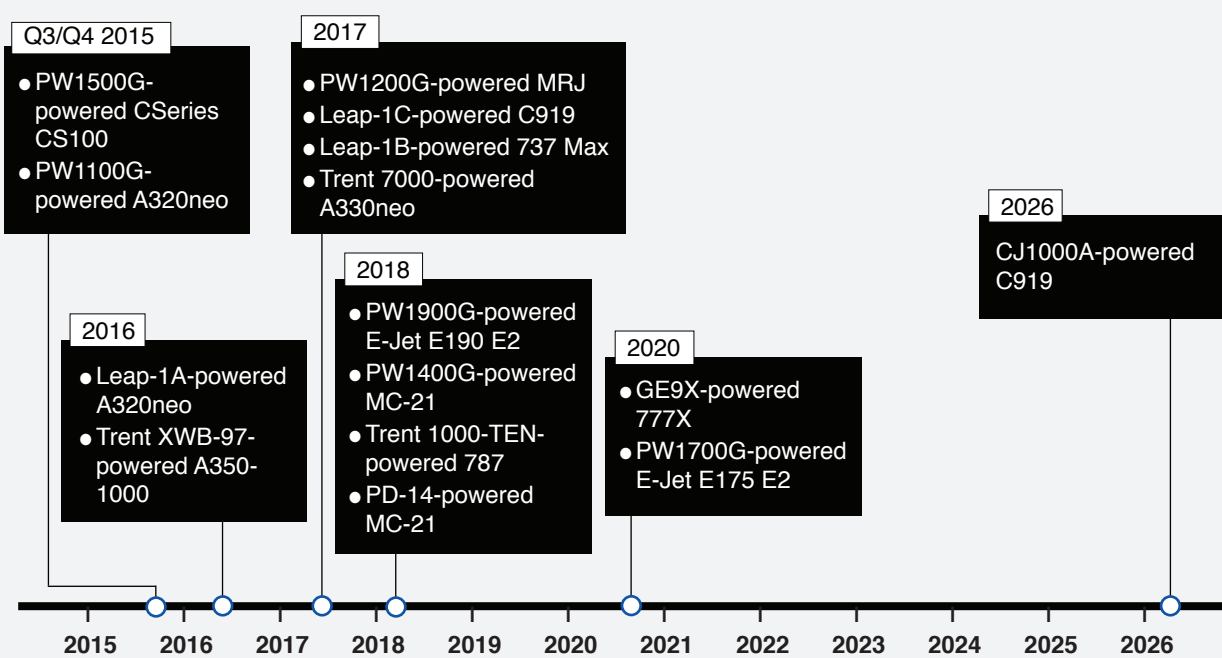
CONTENTS

ENGINE EVENTS

MEMORABLE EVENTS SINCE THE COMMERCIAL ENGINE 2014 REPORT WAS PUBLISHED



WHAT TO WATCH FOR THE FUTURE: ENGINE ENTRY INTO SERVICE



ENGINE ANALYSIS

2014 deliveries and year-end backlog overview

Two new powerplants make their debut in 2015, both on Airbus aircraft: the Rolls-Royce Trent XWB on the A350 XWB and the Pratt & Whitney PW1000G geared turbofan on the A320neo. P&W is vying for supremacy in the single-aisle market against powerful incumbent CFM International, which is the alternative choice on the A320neo and the exclusive supplier on Boeing's 737 Max family. In the regional arena, P&W's high exposure across the product offerings has resulted in an expanding market share.

The widebody sector is now effectively a two-horse race, with a range of R-R-powered twinjets competing against an increasingly General Electric-centric Boeing product suite. Just the 787 and A380 remain as big jets in large-scale production where there is a choice of powerplant.

In 2014, Airbus and Boeing between them produced a record 1,324 commercial airliners, up 6% on the year before. This resulted in 2,746 installed engines being shipped by CFM, P&W, Rolls-Royce, International Aero Engines and Engine Alliance. The powerplant order backlog (based on installed units) at the end of last year stood at 24,650 engines.

The CFM56 engine was installed on over half of the commercial Airbus and Boeing aircraft delivered. CFM International has also taken a 49% share of the order backlog with 12,178 engines.

Airbus and Boeing's active commercial fleet at 31 December 2014 totalled 19,828 aircraft, with 7,903 for Airbus and 11,925 for Boeing. CFM International had a market share of 49% with 9,802 aircraft.

The Airbus A330 engine manufacturer share table (see right) shows that 78% of the deliveries in 2014 were completed with R-R Trent engines, with its aircraft backlog share standing at 75% (228 aircraft). A total of 105 A330s were delivered during the year while the backlog stood at 304 at the end of December, including 120 for the re-engined Neo variant.

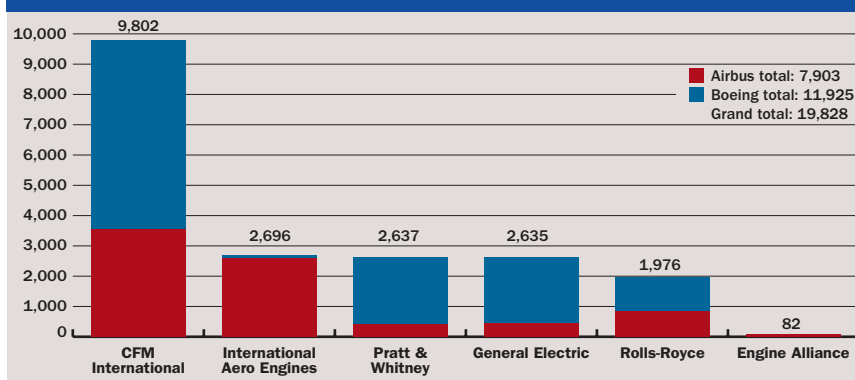
The Boeing 767 can be powered by either the GE CF6 or the P&W PW4000. The table (see right) shows that five GE-powered and a single P&W-powered aircraft were delivered in 2014. The backlog stood at 45 in total.

ENGINE MANUFACTURER RANKING FOR AIRBUS & BOEING

		2014 deliveries		Backlog*	
Rank	Manufacturer	Engines	Share	Engines	Share
1	CFM International	1,412	51%	12,178	49%
2	International Aero Engines	496	18%	1,060	4%
3	General Electric	452	16%	2,290	9%
4	Rolls-Royce	282	10%	2,704	11%
5	Engine Alliance	84	3%	224	1%
6	Pratt & Whitney	20	1%	2,108	9%
	Undecided	-	-	4,086	15%
TOTAL		2,746		24,650	

NOTES: *At 31 December 2014. Data for installed engines based on Airbus/Boeing types. Excludes corporate and military operators. SOURCE: Flightglobal Insight analysis using Ascend Online database

AIRBUS/BOEING FLEET BY ENGINE MANUFACTURER



NOTES: In-service & parked fleet at 31 December 2014. Boeing includes former MDC types. Excludes corporate and military operators. SOURCE: Flightglobal Insight analysis using Ascend Fleets database

A330 ENGINE MANUFACTURER SHARE

	2014 deliveries		Backlog*	
Manufacturer	Aircraft	Share	Aircraft	Share
General Electric	14	13%	45	15%
Pratt & Whitney	9	9%	27	9%
Rolls-Royce	82	78%	228	75%
Undecided	-	-	4	1%
TOTAL	105		304	

767 ENGINE MANUFACTURER SHARE

	2014 deliveries		Backlog*	
Manufacturer	Aircraft	Share	Aircraft	Share
General Electric	5	83%	43	100%
Pratt & Whitney	1	17%	0	-
TOTAL	6		45	

NOTES: *At 31 December 2014. Excludes corporate and military operators. SOURCE: Flightglobal Insight analysis using Ascend Online database

Engine Alliance is ahead of Rolls-Royce on the A380 – largely thanks to its success with the biggest customer Emirates. The GP7200 powered 70% of the A380s delivered last year and has been selected to power 34% of the backlog. Almost half the 165 A380s on backlog are still subject to an engine choice, but the bulk of these orders are for Emirates, where a selection awaits the outcome of the Airbus's decision whether to launch a re-engined version.

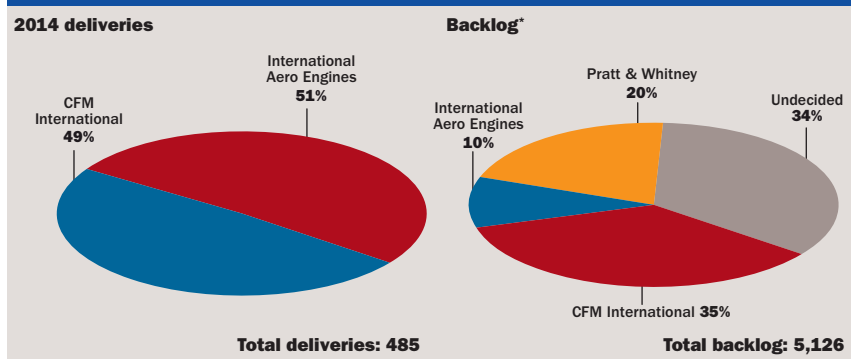
A380 ENGINE MANUFACTURER SHARE

	2014 deliveries		Backlog*	
Manufacturer	Aircraft	Share	Aircraft	Share
Engine Alliance	21	70%	56	34%
Rolls-Royce	9	30%	29	18%
Undecided	-	-	80	48%
TOTAL	30		165	

NOTES: *At 31 December 2014. Excludes corporate and military operators. SOURCE: Flightglobal Insight analysis using Ascend Online database

The A320 family engine manufacturer share for 2014 shows that out of the 485 A320s deliveries made during the year, 51% were fitted with IAE V2500 engines and 49% with the CFM56. The order backlog for the A320 family totalled 5,126 aircraft at the end of 2014. The share for CFM, P&W and IAE totalled 35%, 20% and 10% respectively. Powerplant selections for over a third of the A320 aircraft on order were still unannounced.

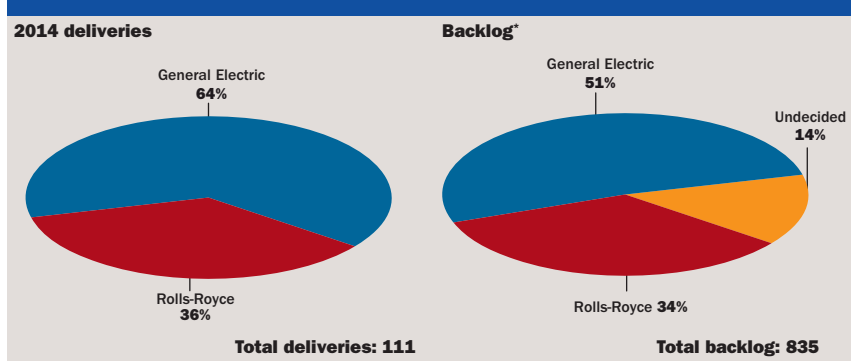
A320 FAMILY - ENGINE MANUFACTURER SHARE



NOTES: *At 31 December 2014. Excludes corporate and military operators.
SOURCE: Flightglobal Insight analysis using Ascend Fleets database

A total of 111 Boeing 787s were delivered in 2014, 46 more than in 2013. GE was primary vendor on the 787, powering 64% of the aircraft delivered while the R-R Trent accounted for the remaining 36%. The backlog for the 787 totalled 835 aircraft at the end of 2014. The split between GE and R-R was 51% and 34% respectively, with 14% still undecided.

787 - ENGINE MANUFACTURER SHARE



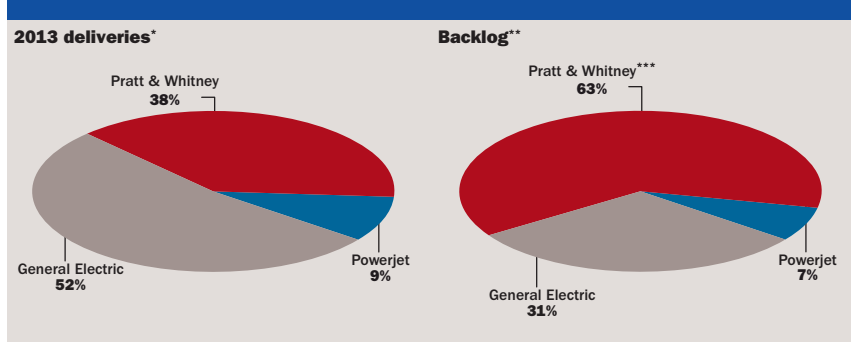
REGIONAL AIRCRAFT

In the regional market, the delivery data includes the ATR 42/72, Embraer E-Jet, Bombardier CRJ, Dash 8 and the Sukhoi Superjet 100. GE is the lead supplier thanks to its prime position on the Bombardier CRJ and E-Jet. The US Manufacturer powered 52% of the 276 regional airliner deliveries last year. P&W (including P&W Canada) and Powerjet follow with 38% and 9% respectively.

The total backlog for manufacturers ATR, Bombardier (including the CSeries), Comac (ARJ21), Embraer, Mitsubishi and Sukhoi stood at 1,534 at the end of December 2014.

P&W had the largest market share at 63%, while GE and Powerjet achieved a market share of 31% and 7% respectively. The PW1000G powered types account for 63% of the 1,534 regional aircraft on backlog.

REGIONAL AIRCRAFT ENGINE MANUFACTURER MARKET SHARE



NOTES: *Airframe. **At 31 December 2014. 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 Ascend Fleets database

Geared turbofans usher P&W into Big Data era

By 2030, tens of thousands of Pratt & Whitney geared turbofans will be generating a staggering amount of data, as well as thrust. The combined fleet will stream 12 petabytes – equivalent to 12 million gigabytes – to servers on the ground every year, with each engine capturing 50 times the amount of data collected by P&W's previous commercial powerplants.

As geared-fan architecture enables a step change in propulsive efficiency, P&W is counting on the power of all that incoming data to drive a substantial improvement in engine reliability. The ultimate result should be a reduction in maintenance costs as the manpower needed to support the fleet declines to one-tenth of staffing levels today.

"On average, it takes 10 people to manage a single engine," says Matthew Bromberg, president of P&W's aftermarket business. "Through analysing data on the engine and providing all the feedback to the customer that's necessary they can go down to a single person."

Capturing the data is the easy part. Each geared turbofan that powers an aircraft built by one of five major manufacturers – Airbus, Bombardier, Embraer, Irkut and Mitsubishi – comes equipped with sensors that capture 5,000 parameters, or 10 gigabytes of data every second. The types of parameters that will be measured include temperatures, air and liquid pressures, rotational speeds and vibrations.

The real challenge is developing a ground-based infrastructure capable of storing, processing and analysing 12 petabytes of information every year. A petabyte is so big a number it is difficult to conceptualise. As Bromberg grasps for intelligible examples, he sounds like an astronomy professor attempting to analogise the number of stars in a galaxy.

A petabyte is "six times the amount of data stored in all US research institutions today", he says.

Like any aerospace company, P&W uses data-driven systems to inform design and engineering. Simulation models are used today to predict all aspects of engine performance, including aerodynamics, thermodynamics and structural integrity. The PW4000 also monitors about 100 parameters every second; this data is used to identify performance and reliability trends. The PW1000G family, however, requires a new level of support, and P&W decided it needed to look outside for help.

Last July, P&W announced forming a partnership with IBM to begin building the information-processing infrastructure that will be necessary to cope with the geared turbofan fleet's data requirements. IBM has invested $24 billion recently in data and analytics technology, says Larry Volz, a P&W vice-president and the chief information officer.

"We believe [the IBM partnership] will be an accelerator," Volz says. "They won't the be only folks we use in this journey, and we're already starting to partner with universities and colleges and other companies as well."

Two geared turbofan engines – the PW1100G for the Airbus A320neo and the PW1500G – are scheduled to enter service with customers later this year. The PW1200G for the Mitsubishi Regional Jet and the PW1400G for the Irkut MC-21 are scheduled to complete first flights later this year. The PW1900G and the PW1700G for the Embraer E-190/195 E2 and the E-175 E2, respectively, have now started assembly. As the aircraft programmes ramp up production, each engine will be feeding a continuous stream of performance data that must be stored and analysed.

With IBM's experts now on board, P&W has started building and testing the analytical tools to mine all of that collected information. There are now 14 projects in the demonstration phase, including a key new software algorithm used to predict the most serious engine events.

In P&W's long-term vision, data will be used to detect and prevent uncommanded engine shutdowns. The rate of such events has declined to minuscule levels in modern engines, but P&W believes the rate can be further halved with the analytical tools already in development.

In laboratory testing, a software algorithm applied to data gleaned from the installed fleet of PW4000 engines accurately predicted 90% of the in-flight shutdowns, Bromberg says.
The software model is not yet perfect. The software predicts shutdowns, but it also generates false positives when no threat exists, he says.

"Clearly, there's some false positives in there, meaning sometimes it's going to send you an alert on an engine and in fact the parameter is not out of the design space," Bromberg says. "But I can easily see a 50% reduction based on what we see today. A model that is that accurate means we can go in with operators, do on-wing inspection and prevent the event from happening."

P&W plans to make the analytical tool operational on real engines later early next year, he adds.

The engine supplier is already in discussions with potential airline customers to define the timing of the alerts, says Lynn Fraga, a P&W analytics manager. "For some of the maintenance activities you only need a two-day heads-up," she says. "Other things that require more logistics and scheduling you might want a longer timeframe."

These are still early days in the Big Data era for P&W engines. It is arriving just as the overall business model for aftermarket services is changing. The majority of PW2000 and PW4000 engine maintenance services are provided using a transactional model, in which parts and services are provided as customers order them. That is being replaced by a power-by-the-hour service arrangement, in which airlines pay P&W a fee for maintaining a specified availability rate of engines across a customer's fleet.

About 60% of aftermarket service for the V2500 engine fleet has converted to the power-by-the-hour scheme. The rate is even higher for the family of geared turbofan engines, with only one-fifth of engines covered under the older, transactional method, Bromberg says.

Underpinning the new data-driven aftermarket strategy is access to the data. Every power-by-the-hour service deal signed by P&W includes a clause guaranteeing access to the engine performance information, which is owned by the engine buyer. Although 80% of the geared turbofan fleet is covered by such deals, Bromberg says that number is likely to decline as the fleet ages.

"This is a new technology, new architecture and uncertain maintenance cost," he says. "As our engine matures, the maintenance cost becomes known, competition develops on the scene – which is good for our customers and for us – and alternatives develop. As the industry matures there will be a variety of maintenance options and it will fragment."

As more service providers enter the market, that does not mean that P&W will always lose access to the data streaming off the sensors inside each engine. Most customers using the old transactional service model for engines still freely share the information with P&W, even though there is no contractual requirement to do so.

"Today, the vast majority of airlines share the data with us because they want to perform the business intelligence analytics given current technology and provide the fleet data back on a confidential basis," Bromberg says. "I anticipate going forward the vast majority of customers will be in the same boat."

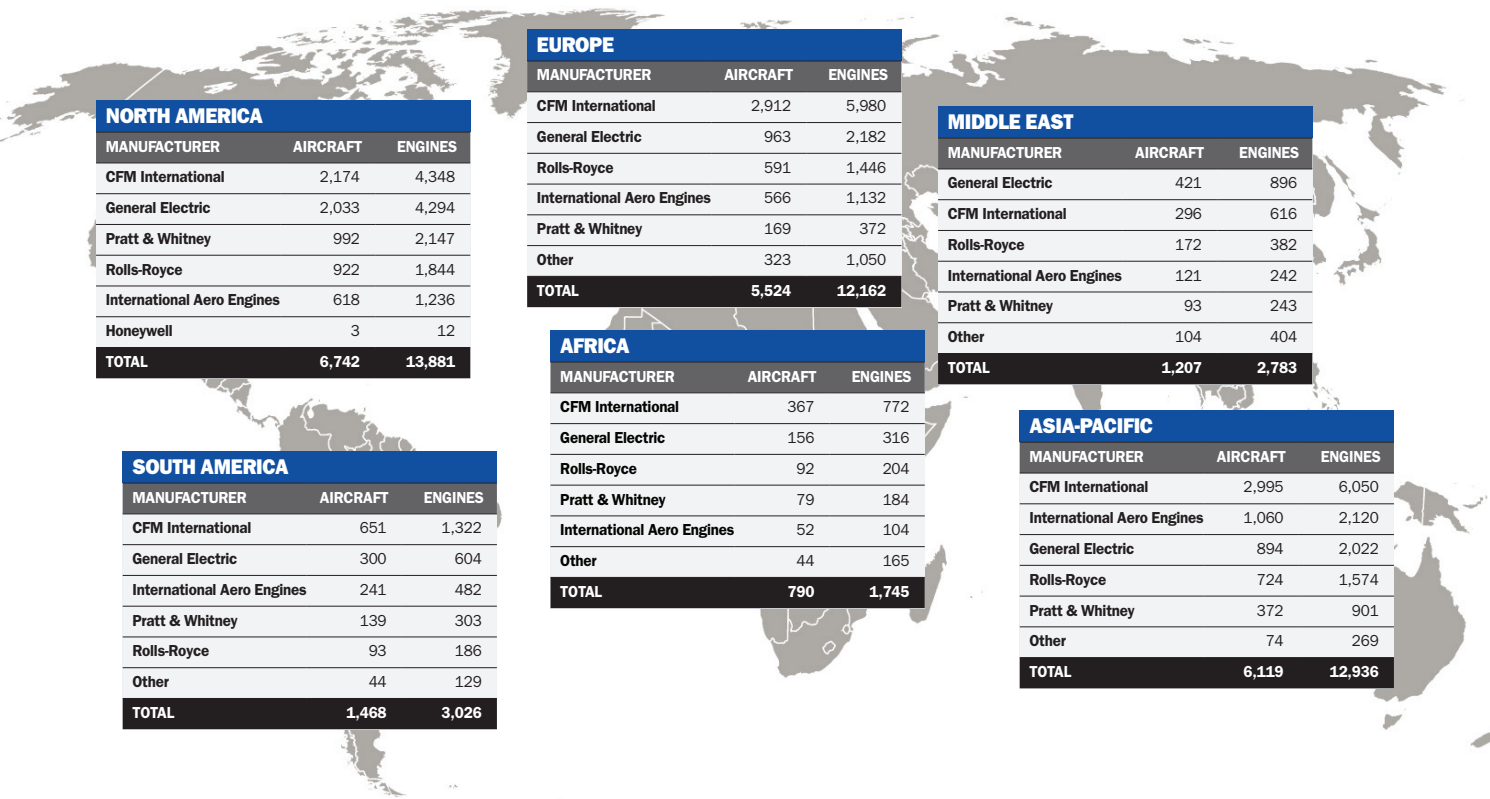
In reality, Bromberg acknowledges, reaching P&W's goal of supporting each engine with only one staff member may be too ambitious. If an airline decides to keep line maintenance and outsource heavy maintenance, for example, that will increase the number of staff required to support the engines, no matter how much data-driven analytics improves the reliability.

"I honestly believe that over the next decade and a half we can drive airlines to a single point of contact within Pratt & Whitney," he says. "I want to have such a comprehensive offering that they are really struggling with how to staff with more than one person because we're going to provide everything to them."

A software algorithm applied to data gleaned from the installed PW4000 fleet has accurately predicted 90% of in-flight shutdowns, P&W says

AT A GLANCE

Commercial engines: manufacturer market share



NORTH AMERICA

MANUFACTURER	AIRCRAFT	ENGINES
CFM International	2,174	4,348
General Electric	2,033	4,294
Pratt & Whitney	992	2,147
Rolls-Royce	922	1,844
International Aero Engines	618	1,236
Honeywell	3	12
TOTAL	6,742	13,881

EUROPE

MANUFACTURER	AIRCRAFT	ENGINES
CFM International	2,912	5,980
General Electric	963	2,182
Rolls-Royce	591	1,446
International Aero Engines	566	1,132
Pratt & Whitney	169	372
Other	323	1,050
TOTAL	5,524	12,162

MIDDLE EAST

MANUFACTURER	AIRCRAFT	ENGINES
General Electric	421	896
CFM International	296	616
Rolls-Royce	172	382
International Aero Engines	121	242
Pratt & Whitney	93	243
Other	104	404
TOTAL	1,207	2,783

AFRICA

MANUFACTURER	AIRCRAFT	ENGINES
CFM International	367	772
General Electric	156	316
Rolls-Royce	92	204
Pratt & Whitney	79	184
International Aero Engines	52	104
Other	44	165
TOTAL	790	1,745

SOUTH AMERICA

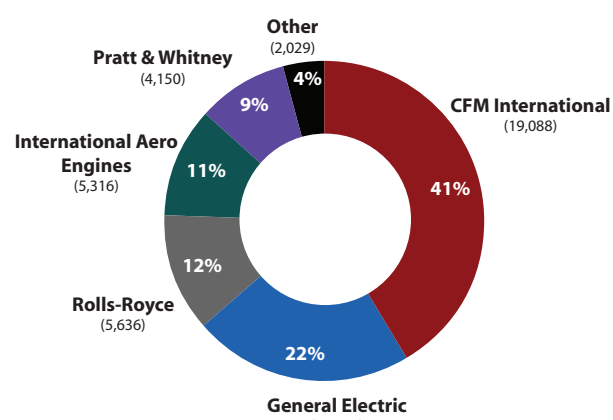
MANUFACTURER	AIRCRAFT	ENGINES
CFM International	651	1,322
General Electric	300	604
International Aero Engines	241	482
Pratt & Whitney	139	303
Rolls-Royce	93	186
Other	44	129
TOTAL	1,468	3,026

ASIA-PACIFIC

MANUFACTURER	AIRCRAFT	ENGINES
CFM International	2,995	6,050
International Aero Engines	1,060	2,120
General Electric	894	2,022
Rolls-Royce	724	1,574
Pratt & Whitney	372	901
Other	74	269
TOTAL	6,119	12,936

WORLD COMMERCIAL JET AIRCRAFT

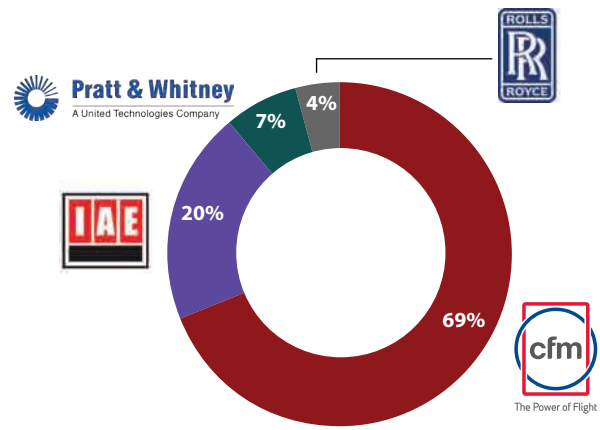
MANUFACTURER	AIRCRAFT	ENGINES
CFM International	9,395	19,088
General Electric	4,767	10,314
Rolls-Royce	2,594	5,636
International Aero Engines	2,658	5,316
Pratt & Whitney	1,844	4,150
Other	592	2,029
TOTAL	21,850	46,533



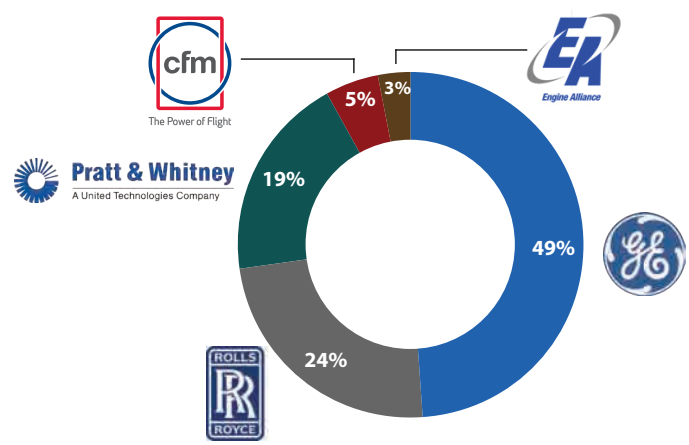
NOTE: Information for active commercial jet aircraft in operation with airlines. Information includes narrowbody, widebody, regional and Russian jets in passenger, freighter, combi and quick change roles **SOURCE:** Flightglobal's Ascend Fleets database (May 2015)

Engine market share by market group

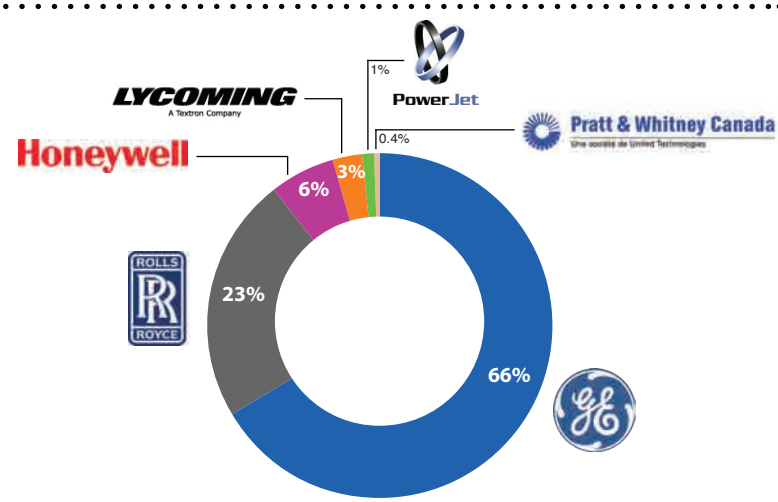
COMMERCIAL NARROWBODY AIRCRAFT		
MANUFACTURER	AIRCRAFT	ENGINES
CFM International	9,248	18,500
International Aero Engines	2,658	5,316
Pratt & Whitney	921	1,912
Rolls-Royce	600	1,200
TOTAL	13,427	26,928



COMMERCIAL WIDEBODY AIRCRAFT		
MANUFACTURER	AIRCRAFT	ENGINES
General Electric	2,437	5,654
Rolls-Royce	1,182	2,812
Pratt & Whitney	910	2,212
CFM International	147	588
Engine Alliance	86	344
TOTAL	4,762	11,610



COMMERCIAL REGIONAL JET		
MANUFACTURER	AIRCRAFT	ENGINES
General Electric	2,330	4,660
Rolls-Royce	809	1,618
Honeywell	102	408
Lycoming	58	232
Powerjet	46	92
Pratt & Whitney	13	26
TOTAL	3,358	7,036



NOTE: Information for active commercial aircraft in operation with airlines **SOURCE:** Flightglobal's Ascend Online Fleets (May 2015)

Milestones in commercial turbofan history

1940

1939-40
Hans Von Ohain and Frank Whittle separately develop the turbojet engine

1950

1952
Powered by the Rolls-Royce Avon (first axial flow jet engine), the De Havilland Comet is the first commercial jetliner to enter service with British Overseas Airways Corporation (BOAC)

1955

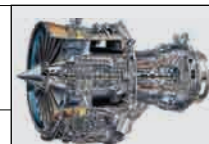
1960

Late 1950s
The General Electric CJ805 and Pratt & Whitney JT3C are the first low-bypass turbofan engines on offer on commercial aircraft including the Convair 880, Boeing 707 and Douglas DC-8

1965

1970

1968-70
The GE TF39 high bypass turbofan fitted on the Lockheed C-5 Galaxy is developed into the CF6



1970
The Rolls-Royce RB211 engine which features titanium fan blades & three-spool technology enters service on the Boeing 747 and the Lockheed L-1011 TriStar

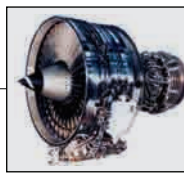
1975

1976
The Rolls-Royce/Snecma Olympus 593-powered supersonic airliner Concorde enters service

1974
The CFM International joint venture between General Electric and Snecma (Safran) is founded

cfm
The Power of Flight

1980



Early 1980s
The CFM56 is selected for the Boeing 737 Classics - 300/400/500

1985

Late 1980s
Open rotor experiments are conducted by GE on the GE36 and P&W/Allison on the 578DX featuring unducted fan (UDF) technology

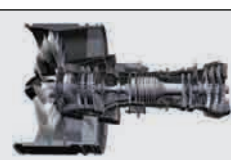
1990

1995

1995
The Boeing 777 powered by the GE90 which features composite fan blades enters service with United Airlines

2000

2005



Late 2000s
The Pratt & Whitney PW1000G geared turbofan is developed

Late 2000s
The Leap-1A features CMC technology on its turbine shroud

2010

2015

Engine options by commercial aircraft

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

BAE SYSTEMS				
Aircraft type	**No of engines**	**Engine option 1**	**Engine option 2**	**Engine option 3**
BAe 146*	4	ALF502	LF507	
Avro RJ*	4	LF507		

BOEING				
Aircraft type	**No of engines**	**Engine option 1**	**Engine option 2**	**Engine option 3**
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		

BOMBARDIER				
Aircraft type	**No of engines**	**Engine option 1**	**Engine option 2**	**Engine option 3**
CSeries	2	PW1500G		
CRJ (all variants)	2	CF34-8		

COMAC				
Aircraft type	**No of engines**	**Engine option 1**	**Engine option 2**	**Engine option 3**
C919	2	Leap-1C	CJ1000A	
ARJ21	2	CF34-10		

EMBRAER				
Aircraft type	**No of engines**	**Engine option 1**	**Engine option 2**	**Engine option 3**
E-170/175/190/195	2	CF34		
ERJ 145 family	2	AE 3007		
E-Jet E2 family	2	PW1100G		

FAIRCHILD DORNIER				
Aircraft type	**No of engines**	**Engine option 1**	**Engine option 2**	**Engine option 3**
328JET*	2	PW300		

FOKKER				
Aircraft type	**No of engines**	**Engine option 1**	**Engine option 2**	**Engine option 3**
F28*	2	Spey		
Fokker 70/100*	2	Tay		

ILYUSHIN				
Aircraft type	**No of engines**	**Engine option 1**	**Engine option 2**	**Engine option 3**
Il-62*	4	D-30		
Il-76*	4	D-30	PS-90	
Il-96*	4	PS-90	PW2000	

IRKUT				
Aircraft type	**No of engines**	**Engine option 1**	**Engine option 2**	**Engine option 3**
MC-21	2	PW1400G	PD-14	

LOCKHEED				
Aircraft type	**No of engines**	**Engine option 1**	**Engine option 2**	**Engine option 3**
L-1011*	3	RB211		

MITSUBISHI REGIONAL JET				
Aircraft type	**No of engines**	**Engine option 1**	**Engine option 2**	**Engine option 3**
MRJ70/90	2	PW1200G		

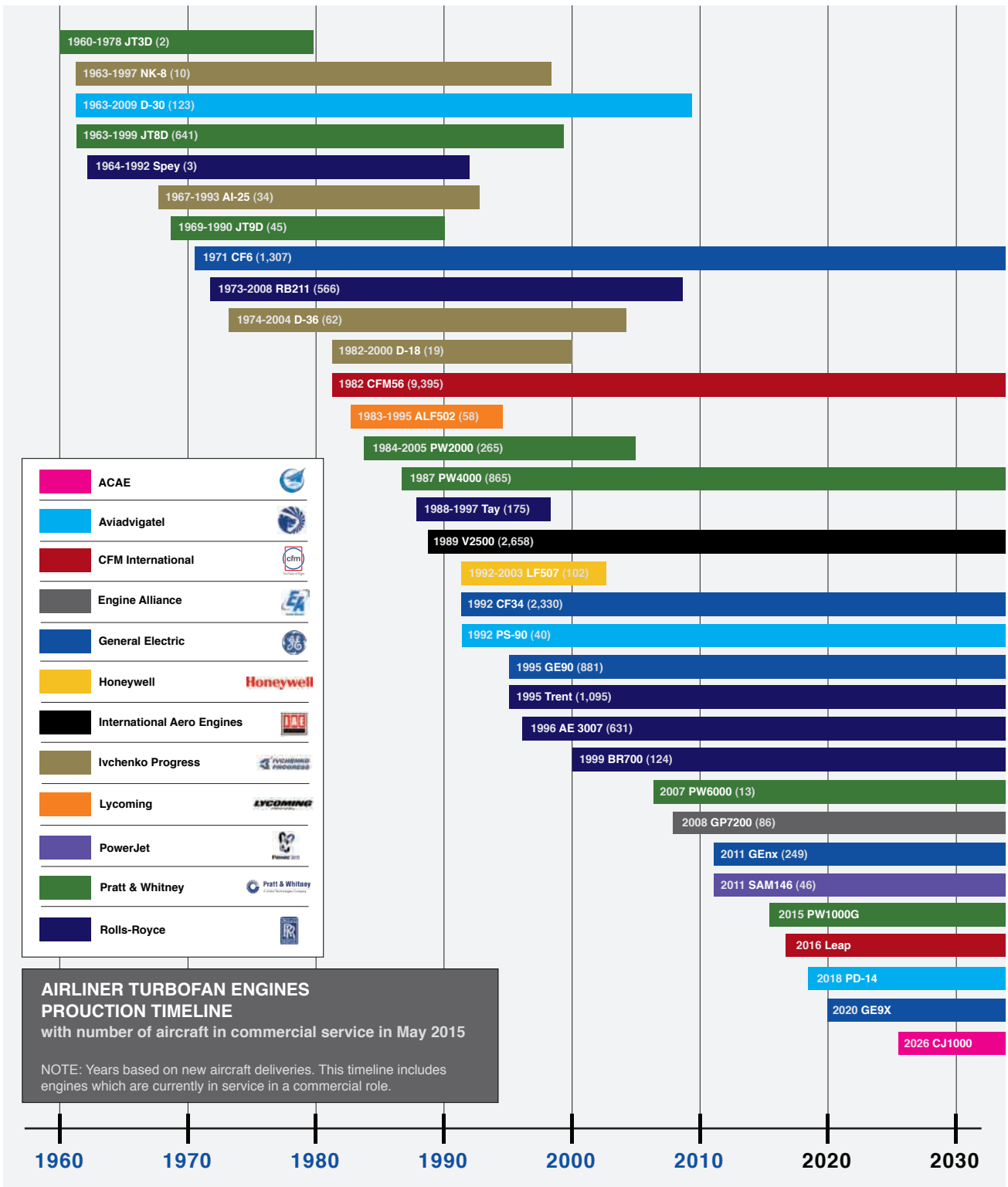
SUKHOI				
Aircraft type	**No of engines**	**Engine option 1**	**Engine option 2**	**Engine option 3**
Superjet 100	2	SaM146		

TUPOLEV				
Aircraft type	**No of engines**	**Engine option 1**	**Engine option 2**	**Engine option 3**
Tu-134*	2	D-30		
Tu-154*	3	D-30	NK-8	
Tu-204	2	PS-90	RB211	

YAKOVLEV				
Aircraft type	**No of engines**	**Engine option 1**	**Engine option 2**	**Engine option 3**
Yak-40*	3	AI-25		

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

Airliner turbofan engines: production timeline



AIRLINER TURBOFAN ENGINES PROUCTION TIMELINE
with number of aircraft in commercial service in May 2015

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

ENGINE 101

The turbofan engine

In late 2014, Bloomberg published a list of the most disruptive inventions in history, and the top entry was, of course, the jet engine.

The physical reaction to channelling the explosive result of an ignited mixture of fuel and compressed air spawned a revolution in the speed of air travel when it entered commercial service on the DeHavilland Comet more than 60 years ago.

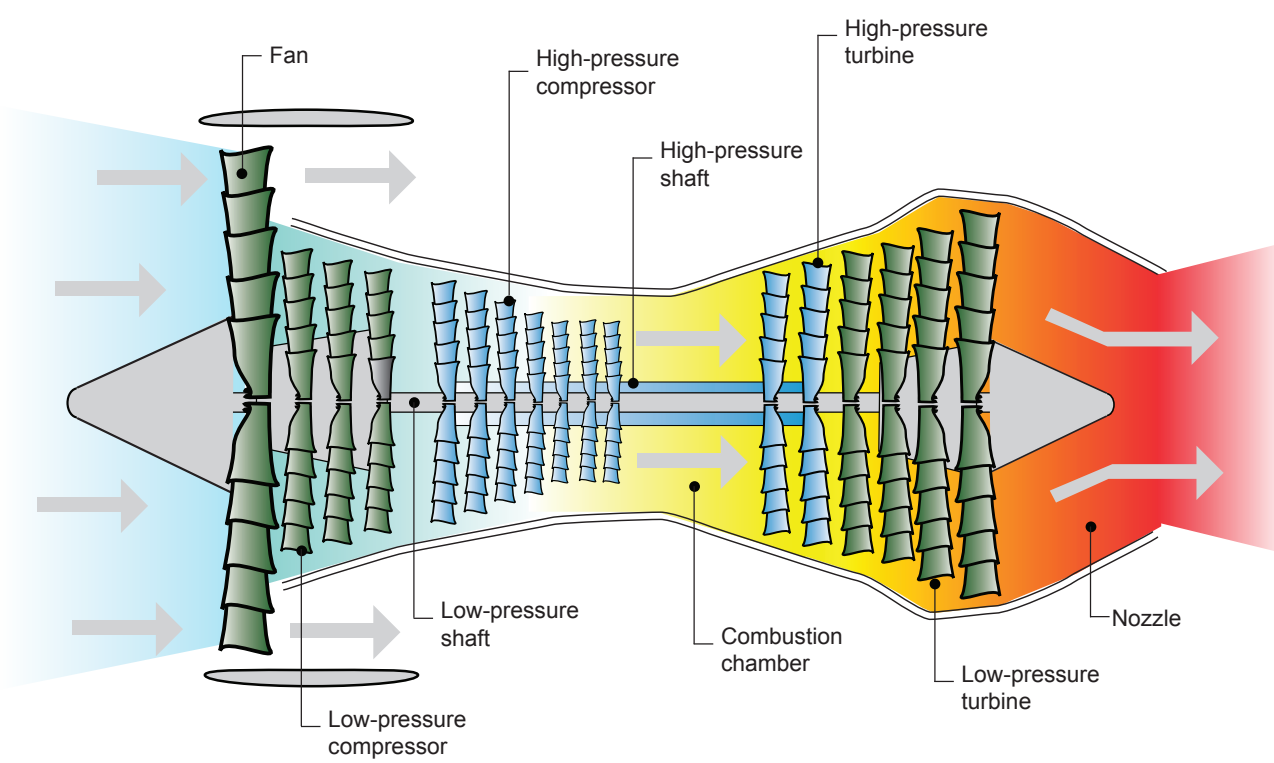
In the decades since, the jet engine has become dramatically quieter and more efficient, but the raw components of the Brayton cycle process – namely: ingestion, compression, combustion and diffusion – remains identical to the first turbojet flown in Nazi Germany in 1939.

The raw material of jet propulsion is a gas both inexhaustible and easily harvested and it is the air we breathe. It is the simple acceleration of this gas that creates the form of force known as thrust.

So how to accelerate the air flow?

It actually starts deep in the engine core. Super-heated exhaust streaming out of the combustion chamber is diffused through multiple stages of turbine blades, which converts the heated gas into energy. The first one or two stages nearest to the combustion chamber is connected by a shaft to an upstream compressor section.

The energy transmitted by the turbine stages drives multiple stages of spinning compressor blades, which progressively squeeze and advance the air flow until it feeds into the combustor. The compression cycle is one of the trickiest parts of the process to manage. Air is predisposed to move in the direction of lower pressure, so each stage of the compressor



Improving the efficiency of the fundamental processes of turbofan engines is still possible, but becomes steadily more difficult

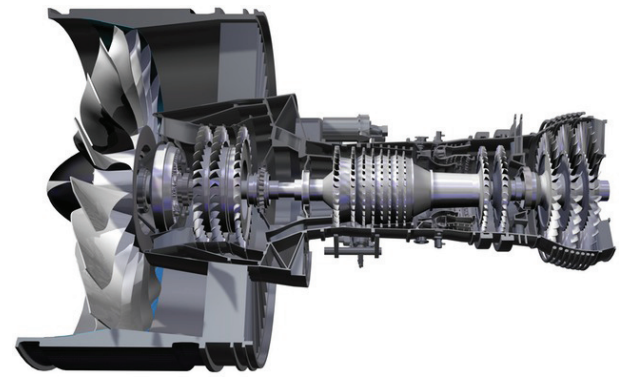
labours to keep the air flowing as pressures climb higher and higher. Bill Gunston, the late-author and Flight International editor, famously likened the compressor's role to using the strokes of a paint brush to push water up a sloping roof.

Beyond the first one or two turbine rotors of the combustor lies another series of turbine stages. The heated exhaust gas has cooled considerably by this time, but it still has more work to do. Here are the low pressure turbine stages. In modern turbofan engines, they are connected along another shaft to a fan usually placed in front of the compressor.

The fan is responsible for drawing air into the engine. As the air enters a turbofan engine, it is divided into streams. A small amount of air channelled axially into the narrow engine core, and is compressed, combusted and defused in the manner described above.

The majority of the airflow that enters through the fan, however, is accelerated around the core of the engine.

The Leap engine will be the first commercial turbofan to incorporate ceramic matrix composites (CMCs)



PW1000G is the designation for P&W's new high-bypass geared turbofan. The manufacturer has invested more than $1 billion in the technology

This bypass air flow generates the majority of the engine's thrust. Newton's third law of motion states that any action causes an equal reaction in the opposite direction. As the air accelerates longitudinally from the front to the back of the engine, a force pushes the aircraft forward in the opposite direction.

Improving the efficiency of these fundamental processes is still possible, but becomes steadily more difficult. Pratt & Whitney invested more than $1 billion to integrate a reduction gear that slows the rotation of the inlet fan, allowing the fan blades to be extended without the tips reaching supersonic speed. A wider inlet fan generally translates into a higher ratio of bypass to core airflow and, consequently, more fuel efficiency.

GE Aviation, meanwhile, has spent three decades moving ceramic matrix composites (CMCs) from the laboratory to materials for engines in serial production. These lighter and stronger materials, though more complex to build, survive in higher temperatures than metallic alloys, allowing the engine to extract more energy from the same amount of airflow.

Jet turbine propulsion will continue to be improved. P&W has already conceived of more efficient reduction gears for higher-thrust engines. GE has revealed plans to introduce hybrid forms of composite materials. And all three manufacturers, including Rolls-Royce, has investigated the possibilities of ole-noise open rotor engines with bypass ratios twice that of the most efficient engines in development today.

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

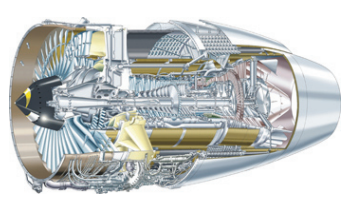
(1963-2009)

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.

There are currently 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 2015, there were 40 aircraft powered by the PS-90 engine in a commercial role and 16 on order.

PD-14

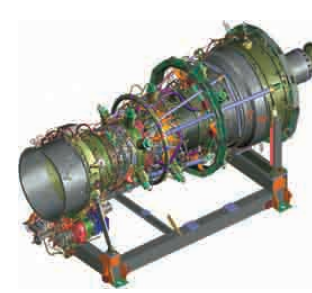
(due in 2018)

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 which is due to enter service in 2017.

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.



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.

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)	2,770-2,850
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) was 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)

In September 2011, ACAE and German manufacturer MTU Aero Engines signed an agreement on key terms for a possible cooperation on developing an alternative powerplant for the Comac C919 narrowbody.

The CJ-1000 will produce thrust of up to 44,000lb and will be built in China. 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.

The AVIC CJ-1000 should enter into service on the C919 in 2026

Avic - 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 51% of all commercial Airbus and Boeing aircraft currently in service.

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 9,395 in-service aircraft in a commercial role. With 660 737s in its fleet in 2015, Southwest Airlines the carrier with the largest number of CFM56-powered aircraft in the world. American Airlines follows with a fleet that includes 401 A320 family and 737 aircraft powered by the CMF56.

Ryanair's fleet includes a total of 313 737s, while United Airlines' in-service fleet of more than 700 aircraft includes 294 737s. EasyJet is the operator with the largest number of CFM56-fitted Airbus aircraft, with a fleet of 212 A320s in service.

In May 2015, a firm order backlog of 1,862 airliners were due to be fitted with the CFM56, with Ryanair leading the customer list with 170 aircraft, followed by Lion Air and Delta Air Lines with 116 and 106 aircraft respectively.

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. These improvements will not sacrifice the reliability and maintenance costs of the CFM56.

The Leap-1A is one of two engine options for the Airbus A320neo, due to enter service in 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 aircraft has received more than 3,300 orders, making it the fastest-selling commercial aircraft in history. The backlog for the A320neo family stood at nearly 3,000 by mid-May 2015, with over 1,250 to be equipped with the Leap-1A. The first Leap-1A was assembled in early 2013 while ground tests began the following month.

The Leap-1A is one of the three variants of the newest CFM engine

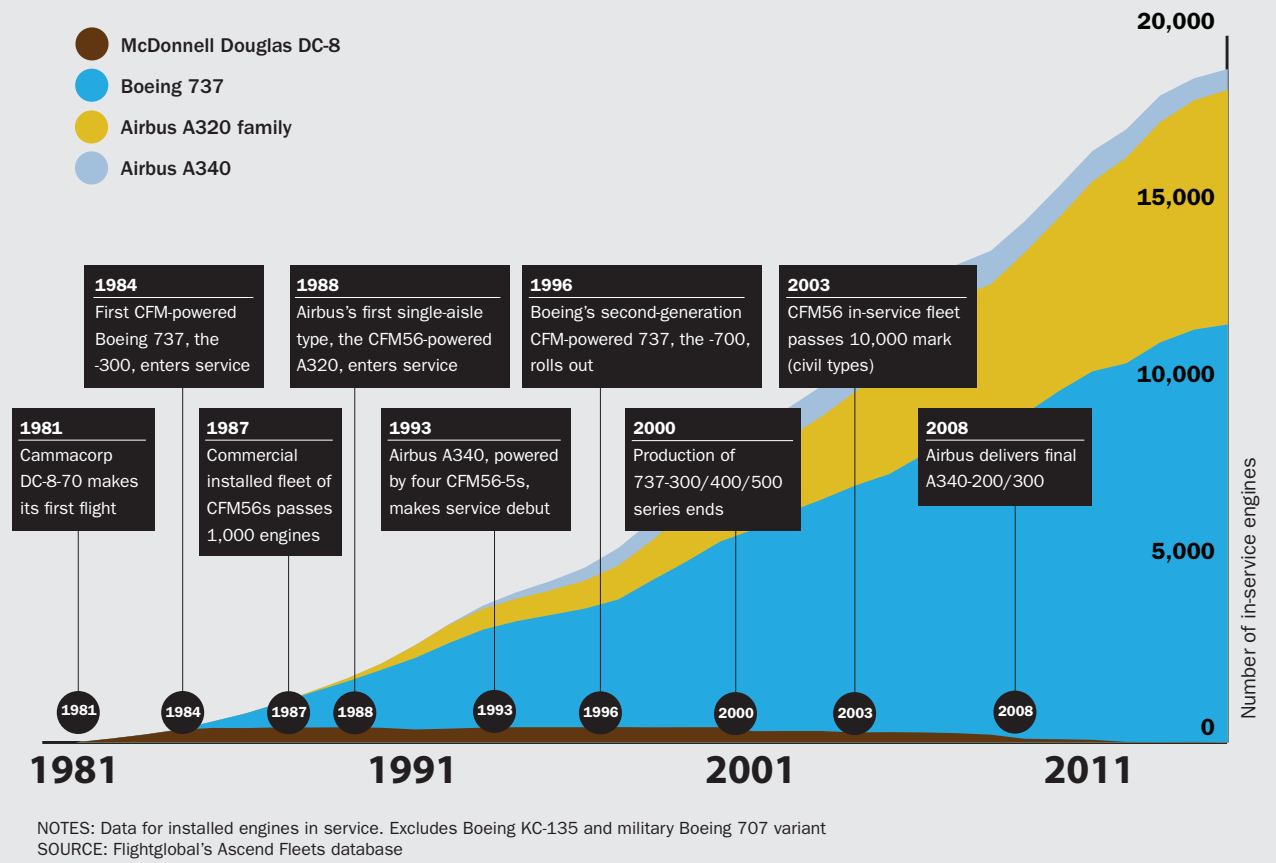
The Leap-1B engine is exclusive to the Boeing 737 Max. In December 2011, Southwest Airlines became the launch customer for the re-engined narrowbody, placing a firm order for 150 737 Max aircraft. At $19 billion at list prices, this was the largest firm order in Boeing's history. The Dallas-based airline, which was also the launch customer for both the Boeing 737 Classic and Next Generation 737 series, now has a backlog of 200 737 Max aircraft and will take delivery of its first in 2017.

AirAsia stood as the leading Leap customer as of May 2015, with an order backlog of 304 A320 neo aircraft followed by Lion Air with 201 737 Max aircraft. The other significant customers for the 737 Max include American Airlines, Norwegian, Ryanair and United Airlines, with an order backlog of 100 each. The firm backlog for the 737 Max stood at more than 2,200 in May 2015.

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 C919's first flight is expected to take place towards the end of 2015, with initial deliveries scheduled for 2017. The C919 order backlog stood at 275 aircraft in May 2015.

The Leap-1A/-1C versions are scheduled for engine certification in 2015, with certification of the Leap-1B currently expected in early 2016.

CFM INTERNATIONAL - CIVIL APPLICATION TIMELINE (1981-2015)



NOTES: Data for installed engines in service. Excludes Boeing KC-135 and military Boeing 707 variant
SOURCE: Flightglobal's Ascend Fleets database

The timeline of CFM International

The union between the USA's General Electric and France's Safran to form CFM International began in the 1970s. The company (CFM), and product line (CFM56), got their names by a combination of the two parent companies' commercial engine designations: GE's CF6 and Snecma's M56.

Boeing had originally chosen the CFM56 to power a version of the ageing 707 while a re-engining effort for the Douglas DC-8 bought the programme more time. But it is Boeing's decision to commission the 18,500lb- to 23,500lb-thrust -3 version of the CFM56 for its 737-300 in the early 1980s that was the breakthrough for an engine that had all along been intended to power a new generation of twin-engined narrowbodies.

It was the start of arguably the most commercially successful pairing in aerospace. The CFM56 went on to exclusively power the Next Generation 737 from the 1990s and its Leap successor will be the sole engine type on the 737 Max. CFM's narrowbody dominance was consolidated in the late 1980s when Airbus selected the CFM56-5A to compete with the International Aero engine's V2500 on its new A320.Since then, more than 7,500 of the CFM engines have powered Airbus narrowbodies.

The engine found another application too in the early 1990s, this time on a widebody. The CFM56-powered Airbus A340 made its service debut in 1993. CFM had the benefit of exclusive supply, powering all of the -200/300 variants produced with the last delivery occurring in 2008.

This decade sees the arrival of new versions of the 737 and A320, as well as a flurry of new narrowbody and large regional contenders. China's Comac was actually the first to select the Leap for its C919 narrowbody. The Leap has been in development since 1999 and will enter service in 2016 on the A320neo, followed in 2017 by the 737 Max.

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, 737 Max, C919

The Leap-powered 737 Max is due to enter service in 2017

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)

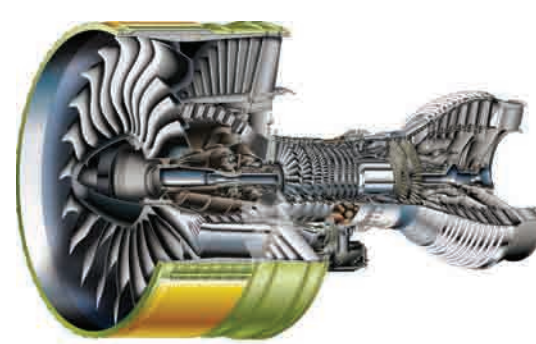
The main application for Engine Alliance's first engine was originally the Boeing 747-500/600X projects, before these were cancelled as a result of a lack of demand from airlines. The engine has since been pushed for the Airbus A380 super-jumbo which carries the largest payload in aviation history.

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.

Airlines including Air Austral, Air France, Emirates, Etihad, Korean Air, Qatar and Transaero have chosen the GP7200 to power their A380s. In May 2015, a total of 158 A380s were in service, of which 86 were powered by the GP7200, while the order backlog stood at 158 aircraft, with 52 assigned to the GP7200.

Emirates is Engine Alliance's primary customer, with a total of 60 A380s currently in its fleet and an additional 30 on order. Air France and Korean Air each operate ten A380s while Qatar Airways and Etihad Airways operate four and two respectively.



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

Emirates Airline has the largest fleet of GP7200-powered aircraft in the world with 60 A380s currently in service

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 widebody 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 fleet, with a share of 46%, and regional aircraft, with a 62% share.

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 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 1,300 CF6-powered airliners are still active.

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 CF34 is installed on regional jets including the Bombardier CRJ series, the Bombardier Challenger, the Embraer E-Jets and the Chinese Comac ARJ21, which is currently under development.

The CF34 was first used on business jets in 1983 and on regional jets in 1992.

Since the first CF34-3A1 engine entered service in 1992, its dispatch reliability rate has remained at 99.95%, with more than 80 million flight hours and 65 million cycles completed.

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

As of May 2015, there were more than 2,300 CF34-powered active commercial aircraft worldwide.

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 70% of all the 777s currently in service are powered by a GE90 engine. In May 2015, a total of 881 GE90-powered 777s were in service, while the order backlog stood at 263. Emirates is the carrier with the largest number of GE90-powered 777s with 126 in its fleet.

GEnx

(2011-present)

The GEnx (General Electric Next-generation) is the successor to the CF6 and is based on the GE90's architecture.

The GEnx is intended to replace the CF6 in GE's production line and will deliver 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 is an option on the Boeing 787 and is exclusively used to power the 747-8.

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.

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.

As of May 2015, there were 80 747-8s in service with a backlog of 32.

The GEnx was also fitted on 169 787s and the order backlog for that aircraft/engine pairing stood at 390.

GE9X

(2020-present)

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.

The first full core test of the GE9X is scheduled for 2015. The first engine will be tested in 2016 with flight testing on the engine manufacturer's flying test bed anticipated in 2017. Engine certification is scheduled for 2018. Boeing plans to start delivering the 777-9X to Emirates Airline in 2020, with the latest widebody aircraft propulsion system officially in development.

In May 2015, the 777X had 286 firm orders. Emirates alone has 150 units on order while Qatar Airways, Etihad Aiways and Cathay Pacific show an order backlog of 50, 25 and 21 777X aircraft respectively. All Nippon Airways and Lufthansa each ordered 20 units of the widebody.

The GE9X engine will have the largest fan produced by GE

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, 747, 767, DC-10, MD-11

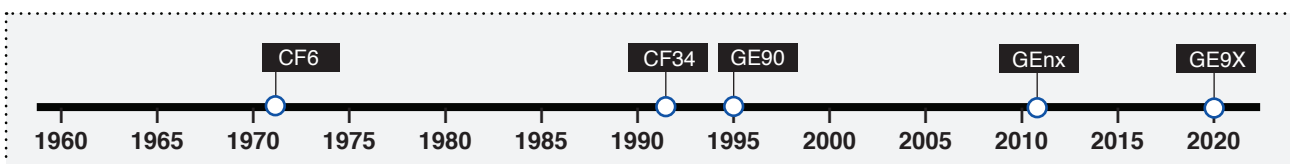
CF34	
Variants	-1, -3A, 3B, -8C, -8E, 10A, 10E
Characteristics (CF34-10A variant)	
Type	twin-spool, high bypass turbofan
Length (cm)	230-370
Fan diameter (cm)	140
Dry weight (kg)	1,700
Components (CF34-10A variant)	
Architecture	axial
Low pressure spool	1-stage fan, 3-stage LPC, 4-stage LPT
High pressure 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



The GEnx is the exclusive engine on the Boeing 747-8

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.

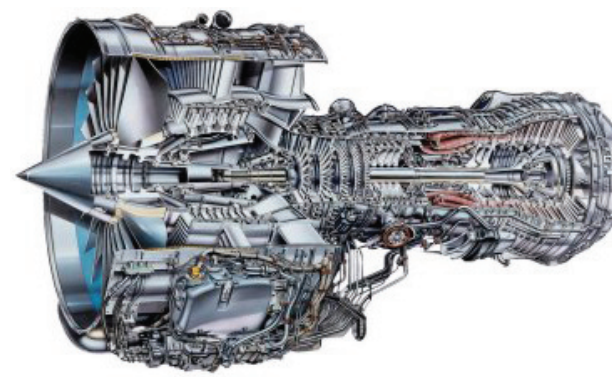
The V2500 features wide-chord, clapperless fan blade design which increases fuel efficiency and provides superior tolerance to foreign-object damage. The high-pressure compressor is a 10-stage design with advanced airfoil aerodynamics.

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 2,600 V2500-powered airliners in service around the world, and the engine has been chosen for approximately 400 A320 family aircraft on order.

American Airlines is the leading IAE user with 184 V2500-powered A320 family aircraft in its fleet followed by China Southern Airlines who has 177. United Airlines and JetBlue Airways operate 152 and 146 A320 family aircraft powered by the V2500 respectively.

Kingfisher Airlines and American Airlines are the V2500 leading customers for with 67 and 65 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

The V2500 entered service in 1989 and currently powers more than 2,400 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.

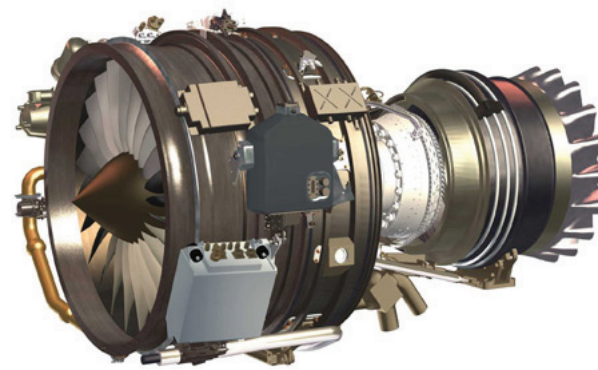
Snecma is responsible for the core engine, control systems, transmission (accessory gearbox, transfer gearbox), overall engine integration and flight testing. NPO Saturn is responsible for the components in the low-pressure section and engine installation on the Superjet 100.

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 2015, 46 Superjet 100s were in service, while the order backlog stood at 105. Aeroflot Russian Airlines operated 19 Superjets and had 11 on order. Mexican carrier Interjet operated 14 units and showed a backlog of 16.

Indonesia's Sky Aviation, Kazakhstan's Bek Air and Russia's Transaero Airlines showed backlogs of nine, seven and six 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

More than 50 SaM146-powered Sukhoi Superjet 100s are currently in service in a passenger role

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 2015, more than 600 JT8D powered aircraft were still in service.

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 45 JT9D powered aircraft were still active in May 2015.

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 265 PW2000-powered 757s were in service in May 2015, with Delta Air Lines as the leading operator with 138 757s in its fleet. The last PW2000 engine was delivered in 2005.

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.

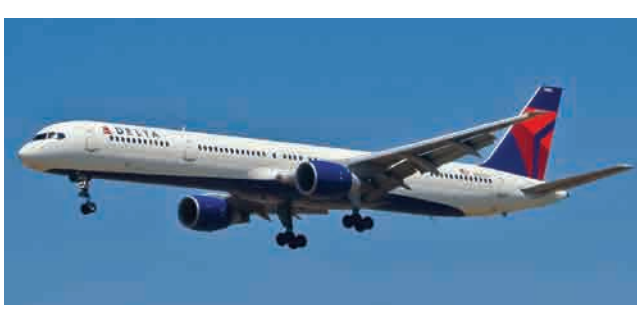
There are three PW4000 families, based on fan diameters: 94in, 100in and 112in. The PW4000 94in fan covers 52,000lb-thrust to 62,000lb-thrust. Approved for 180min ETOPS, equipped with FADEC and featuring single-crystal superalloy materials, it powers the 747-400, 767-200/300, MD-11, A300-600 and A310-300.

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 860 PW4000-powered aircraft were in service in May 2015.



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 13 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

(due in 2015)

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.

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 is scheduled to enter service with customers towards the end 2015.

Back in March 2011, Indian low-cost carrier IndiGo selected the PW1000G to power up to 150 updated A320s. The operator signed a memorandum of understanding with Airbus, becoming the launch customer for the new variant.

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 (PW1400G). It 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.

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 has been pushed back to the end of 2015 while the first delivery of the 78-92 passenger MRJ aircraft has been delayed until 2017. The Bombardier CSeries made its maiden flight in September 2013 and is due to enter service in 2015.

As of May 2015, the overall PW1000G order backlog stood at 1,480 for the A320neo (1,043), MRJ (223), CSeries (236), E-Jet E2 (210) and MC-21 (108) combined. 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 968 A320neo family aircraft on order for which an engine selection had yet to be announced.

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

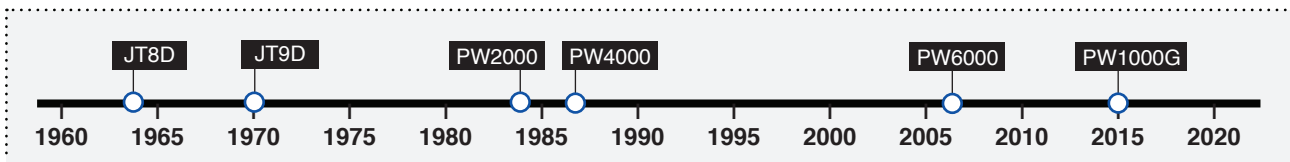
PW2000	
Variants	PW2037, PW2040, PW2043
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	360
Fan diameter (cm)	200
Dry weight (kg)	3,221
Components (PW2037)	
Architecture	axial
Low pressure spool	1-stage fan, 4-stage LPC, 2-stage LPT
High pressure spool	12-stage HPC, 3-stage HPT
Combustors	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, Il-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)	
Fan diameter (cm)	140-210
Dry weight (kg)	
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	
Service entry	due in 2015
Applications	A320neo, CSeries, MRJ, MC-21, E-Jet E2

SERVICE ENTRY TIMELINE



The PW1000G engine will enter service in 2015 on the Bombardier CSeries

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 over 50 million flying hours accumulated.

The Spey engine is now mainly used in the business aviation sector on the Gulfstream II and III.

Only three Spey powerplants are still in service for commercial operation on Fokker F28 aircraft that have been in operation for at least 30 years.

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

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 currently in service with more than 60 operators and powers 566 aircraft including more than 450 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 2015, there were 175 active Tay engines in commercial application in the world, all powering Fokker 70 and 100 aircraft.

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 120 BR700-powered 717s in service in May 2015.

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. The Middle-Eastern carrier expects to take delivery of eight more during 2015.

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 and has picked up 90 orders since. 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 2015, there were 1,095 Trent-powered aircraft in service in the world, with 1,245 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 630 ERJs in commercial operation. ExpressJet Airlines is the main operator of ERJs with 217 units in its fleet. 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 Rolls-Royce Trent 7000 is the exclusive powerplant on the re-engined A330neo

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

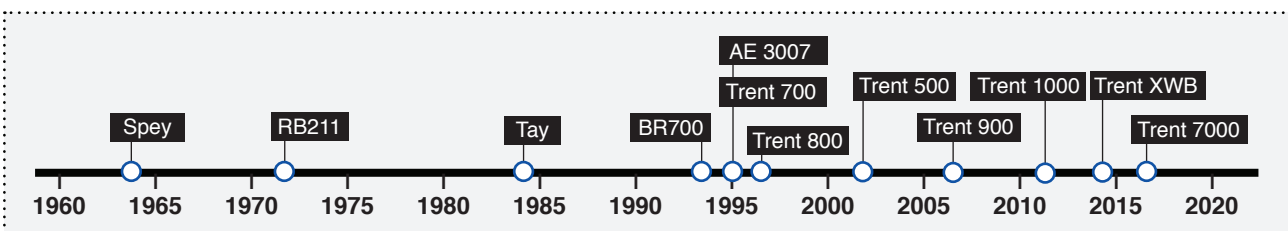
RB.183 Tay	
Variants	611, 620, 650
Characteristics	
Type	twin-spool, high bypass turbofan
Length (cm)	238
Fan diameter (cm)	114
Dry weight (kg)	1,501
Components (620-15 variant)	
Architecture	axial
Low pressure spool	1-stage fan, 3-stage LPC, 3-stage LPT
High pressure spool	12-stage HPC, 2-stage HPT
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



The Trent XWB-powered A350 XWB family was delivered to launch customer Qatar Airways in December 2014

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 airlines worldwide.

The information has been compiled by Flightglobal Insight using the Ascend Online Fleets database.

The information is correct up to 5 May 2015 and excludes non-airline operators, such as leasing companies and the military.

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, and aircraft with, leasing companies are excluded, unless a confirmed end-user is known – in which case the aircraft is shown against the airline concerned.

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 includes airline holding companies.

AVIADVIGATEL

AVIADVIGATEL D-30	TOTAL 445
Africa	**Total 50**
Alfa Airlines	4
Almajara Aviation	4
Badr Airlines	8
CEIBA Intercontinental	4
Delta Air Aviation	4
Dove Air Services	2
El Dinder Aviation	4
Global Air	4
Green Flag Aviation	4
Kush Aviation	4
Lina Congo	4
Victoria Air	4
Asia, Australasia & Middle East	**Total 133**
Air Almaty	8
Air Koryo	22
Air Kyrgyzstan	3
AlNaser Airlines	4
Al-Rafedain Falcon	4
Asia Airways	4
Jordan International Air Cargo	4
Kaz Air Trans	5
Khatlon Air	12
Pouya Air	12
Sayakhat	3
Syrianair	16
TAPC Aviatrans	8
Turkmenistan Airlines	12
Uzbekistan Airways	16
Europe	**Total 262**
223rd State Airline Flight Unit	8
AK Eleron	8
ALROSA Air Company	17
Aviacon Zitotrans	24
Azal Avia Cargo	4
Belavia	9
Center-South Airlines	10
Europa Air	8
Gazpromavia	6
Kosmos Airlines	2
Maximus Airlines	8
Royal Flight	28
Ruby Star	16
Shar ink	12
Silk Way Airlines	20
Sky Prim Air	20
Trans Avia Export Cargo Airlines	24
Turuhan Aviacompany	10
Yuzhmashavia	8
ZetAvia	20
AVIADVIGATEL PS-90	**TOTAL 110 (34)**
Asia, Australasia & Middle East	**Total 12**
Air Koryo	4
Jordan International Air Cargo	8
Europe	**Total 74 (34)**
Aviastar-TU	6
Red Wings Airlines	16 (20)
Rossiya Special Flight Detachment	14 (4)
Silk Way Airlines	8
Transaero Airlines	10
VIM Airlines	(10)
Volga-Dnepr Airlines	20
North/South America	**Total 24**
Cubana	24

cfm
The Power of Flight

CFM INTERNATIONAL CFM56	TOTAL 19,088 (3,056)
Africa	**Total 772 (74)**
AeroContractors	26
Afriqiyah Airways	8
Air Algerie	44 (20)
Air Arabia Egypt	2
Air Arabia Maroc	8
Air Austral	4
Air Cairo	10
Air Cote d Ivoire	6
Air Ghana	2
Air Leisure	8
Air Madagascar	12
Air Mauritius	28
Air Namibia	8
Air Peace	8
Alexandria Airlines	2
Allied Air Cargo	6
AMC Airlines	2
Arik Air	26 (16)
ASKY Airlines	6
Aviator Airlines	2
Azman Air	4
Badr Airlines	6
Buraq Air	4
CAA - Compagnie Africaine d'Aviation	6
Camair Co	4
CEIBA Intercontinental	6
Comair (South Africa)	34 (8)
Daallo Airlines	2
ECAir	4

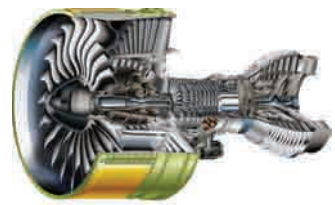
Egyptair	44
Ethiopian Airlines	30 (6)
Fastjet Tanzania	4
First Nation Airways	4
Flyafrica.com	4
flyEgypt	2
Ghadames Air Transport	2
Jambo Jet	6
Jubba Airways	6
Karinou Airlines	2
Kenya Airways	28 (2)
Korongo Airlines	2
Kulula	22
Libyan Airlines	6
Linhas Aereas de Mocambique	6 (6)
Malawian Airlines	2
Mango	18
Mauritania Airlines International	6
Med-View Airline	8
Midwest Airlines (Egypt)	(2)
Nouvelair Tunisie	18
Royal Air Maroc	74
RwandAir	8
Safair	14
Skywise	2
SonAir	4
South African Airways	58
South Supreme Airlines	2
Star Air	2
Sudan Airways	2
Syphax Airlines	4 (6)
TAAG Angola Airlines	10
TACV - Cabo Verde Airlines	4
Tarco Air	6
Tassili Airlines	8
Trans Air Cargo Services	4
Trans Air Congo	4
Tunisair	56 (8)
United Nigeria	2
Asia, Australasia & Middle East	**Total 6,666 (896)**
9 Air	6
Air Arabia	72 (20)
Air Arabia Jordan	4
Air Busan	10
Air China	408 (14)
Air China Inner Mongolia	4
Air Do	18
Air Incheon	4
Air India	92 (8)
Air India Express	34 (6)
Air Indus	4
Air Kyrgyzstan	4
Air New Zealand	6
Air Niugini	6
Air Tahiti Nui	20
Air Vanuatu	2
AirAsia	160 (10)
AirAsia India	10
AirAsia Japan	(4)
AirAsia X	4
AirAsia Zest	12
Airblue	10
Airwork (NZ)	4
Al Maha Airways	-8
AlNaser Airlines	2
ANA - All Nippon Airways	112 (10)
ANA Wings	32
Ariana Afghan Airlines	4
Asian Wings Airways	2
Avia Traffic Company	8
Bassaka Air	4
Batik Air	52 (2)
Bhutan Airlines	4
Biman Bangladesh Airlines	4 (4)
Capital Airlines	38 (8)
Cardig Air	6
Cathay Pacific	40
Cebu Pacific Air	74 (14)
Cham Wings	2
Chang An Airlines	8
Chengdu Airlines	32
China Airlines	52 (6)
China Eastern Airlines	296 (72)
China Eastern Airlines Jiangsu	60
China Eastern Yunnan	126
China Postal Airlines	44
China Southern Airlines	412 (22)
China United Airlines	62
China Xinhua Airlines	12
Chongqing Airlines	2
Citilink	56 (22)
City Airways	2
Dalian Airlines	14
Donghai Airlines	22
Druk Air	8
Eastar Jet	20
Eastern Skyjets	2
El Al	36 (6)
Emirates Airline	16
Etihad Airways	2
EVA Air	28 (8)
Express Air	12
Express Freighters Australia	8
Fiji Airways	8
flydubai	94 (30)
Flynas	48 (40)
Fuzhou Airlines	10
Gading Sari Aviation Services	4
Garuda Indonesia	164 (2)
GoAir	38
Grand China Air	6
Gulf Air	32
Hainan Airlines	212 (14)
Hebei Airlines	12
Hong Kong Airlines	16 (8)
Hong Kong Express Airways	10
Indonesia AirAsia	58
Iran Air	6
Iran Aseman Airlines	4
Iraqi Airways	30 (38)
Japan Airlines	100
Japan TransOcean Air	22 (12)
Jazeera Airways	14
Jeju Air	40 (10)
Jet Airways	150
JetConnect	16
Jin Air	24
Jordan Aviation	14
Juneyao Airlines	84 (4)
Kalstar Aviation	6
Kam Air	6
K-Mile Air	2
Korean Air	78 (12)
Kunming Airlines	26 (4)
Kuwait Airways	34 (2)
Lao Airlines	8
Lion Air	202 (232)
Loong Air	14
Lucky Air	52
Mahan Air	12
Malaysia Airlines	114 (20)
Maldivian	4
Malindo Air	16
MIAT - Mongolian Airlines	6 (4)
Middle East Airlines	8
Mihin Lanka	(4)
My Indo Airlines	2
Myanmar Airways International	8
Myanmar National Airlines	(12)
Nam Air	4
Nauru Airlines	10
Neptune Air	2
New Jatayu Air	2
NewGen Airways	6
Nok Air	36 (14)
Okay Airways	30 (24)
Oman Air	42 (6)
Orient Thai Airlines	18
Pakistan International Airlines	12
PAL Express	22
Palau Pacific Airways	2
Peach	28 (6)
Pegasus Asia	4
Philippine Airlines	44
Philippines AirAsia	2
Qantas	134
Qatar Airways	8
Qeshm Airlines	4
Qingdao Airlines	10 (4)
R Airlines	4
Regent Airways	4
Rotana Jet	2
Royal Falcon Airlines	4
Royal Wings	2
Ruili Airlines	10
Safi Airways	6
Saudia	100
SCAT	14
SF Airlines	18
Shaheen Air International	12
Shandong Airlines	156 (4)
Shanghai Airlines	118
Shenzhen Airlines	248
Siam Air	4
Sichuan Airlines	10 (8)
SilkAir	20 (26)
Sky Angkor Airlines	2
Sky Bishkek	2
Skymark Airlines	54
Solaseed Air	24
Solomon Airlines	2
Somon Air	12
SpiceJet	38
Spring Airlines	96 (2)
Spring Airlines Japan	6
SriLankan Airlines	22
Sriwijaya Air	74
Star Flyer	18 (2)
Tajik Air	6
Texel Air	4
Thai AirAsia	86 (6)
Thai Airways International	2
Thai Express Cargo	2
Thai Lion Air	20 (2)
Thai VietJet Air	2
Tianjin Airlines	12
Tibet Airlines	24 (2)
Tigerair Philippines	8
Toll Priority	6
Tri MG Airlines	4
Trigana Air	10
Turkmenistan Airlines	16 (6)
T'way Air	20
Union Express Charter Airline	2
Up	8
Urumqi Airlines	6
Uzbekistan Airways	18
Vanilla Air	16
VietJet Air	44 (32)
Virgin Australia	114 (40)
Virgin Australia International	36
West Air (China)	8
Wings of Lebanon	2
Xiamen Airlines	214 (20)
Yangtze River Express	40
YTO Express Airlines	2
Zagros Airlines	8
Europe	**Total 5,980 (1,192)**

Aer Lingus	72
Aeroflot Russian Airlines	208 (176)
Aigle Azur	20
Air Bridge Cargo Express	6
Air Contractors	8
Air Corsica	10
Air Europa	40 (16)
Air France	296 (6)
Air Malta	20
Air Mediterranee	12
Air Moldova	4
Air Serbia	2
airBaltic	26
airberlin	166 (18)
AirExplore	4
Airzena - Georgian Airways	6
Alba Star	6
Alitalia	170
ALROSA Air Company	2
Anadolu Jet	56
Arkefly	10
Atlantic Airlines	14
Atlantic Airways (Faroe Islands)	6
AtlasGlobal	18
Aurora	20
Austrian	58
Aviolet	6
Azerbaijan Airlines	20
B&H Airlines	(4)
Belair	16
Belavia	34 (6)
BH Air	2
Blue Air	22
Bluebird Airways	2
Bluebird Cargo	10
Blu-Express	10
Bravo Air	2
Bravo Cargo Air	4
British Airways	14
Brussels Airlines	48
Bulgaria Air	8
Cargo Air	10
Condor	30 (4)
Corendon Airlines	22
Corendon Dutch Airlines	6
Croatia Airlines	12 (8)
Czech Airlines	18 (14)
Donavia	20
easyJet	424 (114)
easyJet Switzerland	46
Edelweiss Air	10
Enter Air	30
Europe Airpost	32
Eurowings	10 (26)
Evelop Airlines	4
Farnair Hungary	4
Finnair	78
Freebird Airlines	8
Gazpromavia	4
Germania	44
Germanwings	70
Globus	28
Go2sky	4
Grand Cru Airlines	4
Hamburg International	(4)
Helvetic Airways	2
Hermes Airlines	2
Hi Fly	8
HolidayJet	4
Iberia	114
Iberia Express	38
Izair	14
Jet Time	24
Jet Time Finland	4
Jet2	88
Jetairfly	32
KLM Royal Dutch Airlines	96
LOT Polish Airlines	6
Lufthansa	272 (28)
Luxair	12
Meridiana	16
MetroJet	2
Mistral Air	10
Monarch Airlines	18
NEOS	12
Niki	40
Nordavia - Regional Airlines	18
Nordwind Airlines	12
Norwegian	158 (88)
Norwegian Air International	18
Onur Air	4
Orenair	30
Pegasus	104
Pobeda	22 (4)
Primera Air Nordic	8
Primera Air Scandinavia	8
Rossiya - Russian Airlines	54
Ryanair	630 (340)
S7 Airlines	86 (62)
SAS	200
SATA International	8
Small Planet Airlines (Lithuania)	4
Small Planet Airlines (Poland)	4
Smartlynx	2
Smartwings	14
Solinair	4
SunExpress	40 (50)
SunExpress Germany	28
Swiftair	18
Swiss	132 (2)
Tailwind Airlines	14
Taimyr Air - NordStar	20
TAP Portugal	102
TAROM	24
Thomas Cook Airlines	40 (4)
Thomas Cook Airlines Belgium	8
Thomas Cook Airlines Scandinavia	16 (8)
Thomson Airways	62
Titan Airways	6
TNT Airways	32
Transaero Airlines	94 (22)
Transavia Airlines	70 (8)
Transavia France	36 (36)
Travel Service Airlines	20
Travel Service Hungary	2
Travel Service Poland	2
Travel Service Slovakia	2
TUIfly	44
TUIFly Nordic AB	12
Turkish Airlines (THY)	190 (44)
Ukraine International Airlines	40 (2)
Ural Airlines	66 (14)
UTAir	92 (84)
UTAir Ukraine	6
VIM Airlines	8
Virgin Atlantic Airways	6
Vista Georgia	2
Vueling Airlines	130
White	2
Wind Rose Aviation Company	4
WOW air	4
XL Airways France	2
Yakutia Airlines	8
Yamal Airlines	14
YanAir	4
North/South America	**Total 5,670 (226)**
Aerolineas Argentinas	104 (46)
Aeromexico	106
Air Canada	126
Air Canada Jetz	14
Air Canada Rouge	42
Air North	10
Air Panama	4
Air Transat	14 (8)
Alaska Airlines	276 (82)
Albatros Airlines	2
Allegiant Air	30
Aloha Air Cargo	4
American Airlines	802 (108)
Avianca	116 (42)
Avianca Brazil	42 (6)
Avianca Costa Rica	4
Avianca Ecuador	18
Avior Airlines	6
Bahamasair	6
Boliviana de Aviacion	26
Canadian North	20
Canjet Airlines	8
Caribbean Airlines	28
Cayman Airways	8
Colt Cargo	4
Conviasa	4
Copa Airlines	138 (46)
Copa Airlines Colombia	8
Cubana	8
Delta Air Lines	496 (212)
Eastern Air Lines	2 (20)
EasySky	2
EG&G Special Projects	12
Enerjet	6
Estafeta Carga Aerea	8
First Air	6
Flair Airlines	10
Frontier Airlines	110
GOL	260 (38)
Havana Air	2
Interjet	78
Kalitta Charters II	2
LAN Airlines	72 (16)
LAN Colombia	20
LAN Peru	6
Magnicharters	18
Miami Air International	12
Northern Air Cargo	4
One Airlines	2
Peruvian Airlines	14
Rio Linhas Aereas	2
Rutaca	2
Sideral Air Cargo	6
Sky Airline	26
Sky King	2
Southern Air	8
Southwest Airlines	1,320 (132)
Sudamericana de Aviacion	2
Sun Country Airlines	40
Sunwing Airlines	48 (6)
Surinam Airways	10
TACA International Airlines	6
TAM - Transporte Aereo Militar	2
TAM Linhas Aereas	106 (34)
TAME	4
United Airlines	588 (46)
Vensecar Internacional	4
Virgin America	106 (20)
Vision Airlines	4
VivaAerobus	26 (4)
VivaColombia	14
WestJet	214 (28)
Xtra Airways	10
CFM INTERNATIONAL LEAP	**TOTAL (5,428)**
Africa	**Total (62)**
Comair (South Africa)	(16)
Ethiopian Airlines	(40)
Syphax Airlines	(6)
Asia, Australasia & Middle East	**Total (1,886)**
Air China	(10)
AirAsia	(608)
China Eastern Airlines	(10)

China Southern Airlines	(10)
Citilink	(20)
Etihad Airways	(52)
flydubai	(150)
Garuda Indonesia	(100)
Hainan Airlines	(40)
Jetstar	(198)
Lion Air	(402)
Myanmar National Airlines	(8)
Nok Air	(16)
Okay Airways	(12)
Sichuan Airlines	(40)
SilkAir	(62)
SpiceJet	(84)
SriLankan Airlines	(4)
Virgin Australia	(46)
Vistara	(14)
Europe	**Total (1,282)**
easyJet	(200)
Icelandair	(32)
Lufthansa	(82)
Monarch Airlines	(60)
Norwegian	(200)
Pegasus	(150)
Ryanair	(200)
SAS	(60)
SunExpress	(30)
Thomson Airways	(94)
Travel Service Airlines	(18)
TUI Travel PLC	(26)
Turkish Airlines (THY)	(130)
North/South America	**Total (882)**
Aeromexico	(120)
Air Canada	(122)
Alaska Airlines	(74)
American Airlines	(400)
Avianca	(66)
Azul	(126)
Copa Airlines	(122)
Frontier Airlines	(160)
GOL	(120)
Interjet	(80)
Jetlines	(10)
Southwest Airlines	(400)
Sunwing Airlines	(8)
United Airlines	(200)
Virgin America	(60)
WestJet	(130)

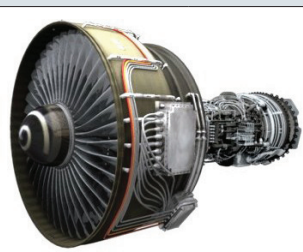
Engine Alliance

ENGINE ALLIANCE GP7200	TOTAL 344 (208)
Africa	**Total (8)**
Air Austral	(8)
Asia, Australasia & Middle East	**Total 304 (176)**
Emirates Airline	240 (120)
Etihad Airways	8 (32)
Korean Air	40
Qatar Airways	16 (24)
Europe	**Total 40 (24)**
Air France	40 (8)
Transaero Airlines	(16)



GENERAL ELECTRIC CF34	TOTAL 4,660 (792)
Africa	**Total 156 (6)**
Air Burkina	6
Air Cote d Ivoire	2
Air Tanzania	2
Arik Air	10 (4)
CemAir	4
DAC Aviation East Africa	2
Egyptair Express	24
Fly540	6
Fly-SAX	2
Interstate Airways	4
Kenya Airways	30
Libyan Airlines	2
Linhas Aereas de Mocambique	4
MGC Airlines (Matekane Air)	4
Nova Airways	6
Petroleum Air Services	2 (2)
Proflight Zambia	2
Royal Air Maroc	8
RwandAir	4
SA Express	28
Skyward International Aviation	2
Tunisair Express	2
Asia, Australasia & Middle East	**Total 484 (278)**
7th Sky	4
Afghan Jet International Airlines	4
Air Astana	18
Air Costa	8
Air India Regional	6
Airnorth	8
Arkia	4
Chengdu Airlines	(60)
China Express Airlines	28 (28)
China Southern Airlines	40
Felix Airways	2 (12)
Fuji Dream Airlines	18 (4)
Garuda Indonesia	30 (6)
GX Airlines	8
Hebei Airlines	10 (4)
Henan Airlines	(100)
Ibex Airlines	18
Iraqi Airways	12
J-Air	48 (30)
Kalstar Aviation	2
Mandarin Airlines	16
Myanmar Airways International	(4)
Myanmar National Airlines	4
National Jet Express	2
Oman Air	8
Royal Jordanian	10
Saudia	30
Saurya Airlines	2
SCAT	12
Shandong Airlines	4 (20)
Shanghai Airlines	(10)
Tianjin Airlines	92
Virgin Australia	36
Europe	**Total 846 (96)**
Adria Airways	18
Air Dolomiti	20
Air Europa	22
Air Lituanica	2
Air Moldova	4
Air Nostrum	64 (50)
Airzena - Georgian Airways	8
Alitalia Cityliner	40
Anadolu Jet	6
Aurigny Air Services	2
Azerbaijan Airlines	10 (4)
BA CityFlyer	34
Belavia	16
Binter Canarias	2
BoraJet	10
Bulgaria Air	8
Estonian Air	12
Flybe	32 (8)
Flybe Nordic	28
Germanwings	38
HOP!	112
IrAero	10
Jetairfly	6
KLM cityhopper	56 (34)
LOT Polish Airlines	52
Lufthansa CityLine	98
Montenegro Airlines	8
Niki	4
People's Vienna Line	2
Rusline	34
Saravia	4
SAS	26
Severstal Aircompany	12
Swiss	8
Ukraine International Airlines	10
UTAir	4
West Air Europe	6
Yamal Airlines	18
North/South America	**Total 3,174 (378)**
Aerolineas SOSA	2
Aeromexico Connect	80
Air Canada	90
Air Georgian	12
Air Wisconsin	142
Amaszonas	16
American Airlines	38
Austral Lineas Aereas	44
Azul	164 (12)
Compass Airlines	92 (32)
Conviasa	30
Copa Airlines	24
Copa Airlines Colombia	28
Endeavor Air	252
Envoy	94 (80)
Estafeta Carga Aerea	4
ExpressJet Airlines	302
Flair Airlines	2
GoJet Airlines	92
Jazz	84

JetBlue Airways	120 (48)
LAC - Linea Aerea Cuencana	2
Mesa Airlines	204 (26)
PSA Airlines	154 (52)
R1 Airlines	4
Republic Airlines	224 (10)
SATENA	2
Shuttle America	132 (110)
Sky Regional Airlines	30
SkyWest Airlines	662 (32)
TACA International Airlines	24
TAME	8
United Airlines	(10)
Voyageur Airways	16
GENERAL ELECTRIC CF6	**TOTAL 3,232 (154)**
Africa	**Total 56 (6)**
Air Algerie	18 (4)
Air Mauritius	4
CEIBA Intercontinental	2
ECAir	2
Egyptair	2
Ethiopian Airlines	8
Libyan Airlines	2 (2)
Royal Air Maroc	12
Services Air	2
Tradecraft Air Nigeria	2
Tristar Air	2
Asia, Australasia & Middle East	**Total 1,028 (14)**
AHS Air International	8
Air Do	8
Air Hong Kong	16
Air Japan	20
Air New Zealand	10
Air Niugini	2
AirAsia X	2
AirCalin	4
ANA - All Nippon Airways	82
Asiana Airlines	72
Cargo Air Lines	4
China Airlines	136
China Cargo Airlines	8
Emirates Airline	8
Etihad Airways	12
EVA Air	72 (4)
Express Freighters Australia	2
Flynas	4
Garuda Indonesia	8
Global Charter Services	6
Global Jet Airlines	2
Iran Air	24
Iraqi Airways	10
Japan Airlines	82
Jet Airways	14 (10)
Jetstar	6
Jordan Aviation	4
Kam Air	8
Kuwait Airways	16
Mahan Air	48
Mega Maldives Airlines	4
MIAT - Mongolian Airlines	2
Midex Airlines	12
Nippon Cargo Airlines	20
Orient Thai Airlines	8
Pakistan International Airlines	4
Qantas	90



Qatar Airways	58
Qeshm Airlines	6
Raya Airways	2
Royal Jordanian	4
Saudia	44
Shaheen Air International	8
Sunday Airlines	2
Taban Air	4
Thai Airways International	48
Unique Air	2
Yangtze River Express	12
Europe	**Total 766 (34)**
Aer Lingus	18
Air Cargo Global	4
Air Europa	12
Air France	54
AirBridgeCargo	32
Airbus Transport International	10
Alitalia	24
Azerbaijan Airlines	4
Blue Panorama Airlines	6
Brussels Airlines	6
Cargolux	4
Condor	6
Continental Airways	4
DHL Air	8
EuroAtlantic airways	4
Finnair	16
Hi Fly	2
Iberia	16 (16)
Ikar Airlines	2
Jetairfly	2
Katekavia	4
KLM Royal Dutch Airlines	122
Lufthansa	68
Lufthansa Cargo	42
Martinair	12
Meridiana	6
MNG Airlines	8
NEOS	4
Nordic Global Airlines	6
Nordwind Airlines	8
Privilege Style	2
Rossiya - Russian Airlines	2
S7 Airlines	4
SATA International	4
Star Air	24
TAP Portugal	14
Thomas Cook Airlines	6
Thomson Airways	8
Titan Airways	2
TNT Airways	10
Transaero Airlines	56
TUIFly Nordic AB	4
Turkish Airlines (THY)	48 (18)
ULS Airlines Cargo	2
UTAir	6
Veteran Avia	4
Virgin Atlantic Airways	48
Wamos Air	4
White	2
XL Airways France	2
North/South America	**Total 1,382 (100)**
21 Air	4
ABX Air	50
Aerolineas Argentinas	4 (4)
AeroUnion	4
Air Canada	36
Air Canada Rouge	4
Air Transat	18
American Airlines	114
Amerijet International	12
ATI - Air Transport International	4
Atlas Air	80
Boliviana de Aviacion	4
Cargojet Airways	22

Centurion Air Cargo	25
Delta Air Lines	122 (20)
Dynamic Airways	2
FedEx	421 (76)
Fly Jamaica	2
Hawaiian Airlines	2
Kalitta Air	36
KF Aerospace	6
LAN Airlines	38
LAN Argentina	4
LAN Cargo	4
LAN Cargo Colombia	2
LAN Colombia	6
MasAir	2
National Airlines	4
Omni Air International	16
Polar Air Cargo	32
SBA Airlines	4
Solar Cargo	3
TAB Airlines	9
TAM Cargo	8
TAM Linhas Aereas	30
Transcarga International Airways	2
United Airlines	32
UPS Airlines	203
Vision Airlines	2
Western Global Airlines	9
GENERAL ELECTRIC GE90	**TOTAL 1,762 (458)**
Africa	**Total 64 (16)**
Air Austral	8 (4)
CEIBA Intercontinental	2
Egyptair	12
Ethiopian Airlines	24 (8)
Kenya Airways	6
TAAG Angola Airlines	12 (4)
Asia, Australasia & Middle East	**Total 1,070 (324)**
Air China	40
Air China Cargo	12 (4)
Air India	26 (6)
Air New Zealand	14
ANA - All Nippon Airways	42 (14)
Biman Bangladesh Airlines	8
Cathay Pacific	100 (6)
China Airlines	8 (12)
China Cargo Airlines	12
China Eastern Airlines	10 (30)
China Southern Airlines	36 (16)
Emirates Airline	252 (98)
Etihad Airways	66 (2)
EVA Air	38 (18)
Garuda Indonesia	12 (8)
Hong Kong Airlines	(12)
Iraqi Airways	2
Japan Airlines	48
Jet Airways	8
Korean Air	36 (32)
Kuwait Airways	4 (20)
Pakistan International Airlines	18 (10)
Philippine Airlines	12
Qatar Airways	90 (20)
Saudia	80 (8)
Singapore Airlines	50 (4)
Thai Airways International	24 (4)

Turkmenistan Airlines	4
Vietnam Airlines	8
Virgin Australia International	10
Europe	**Total 390 (66)**
Aeroflot Russian Airlines	24 (16)
AeroLogic	16
Air France	130 (6)
Alitalia	20
Austrian	10
British Airways	78
KLM Royal Dutch Airlines	50 (8)
Lufthansa Cargo	10
Nordwind Airlines	6
Swiss Global Air Lines	(12)
TNT Airways	6
Turkish Airlines (THY)	40 (24)
North/South America	**Total 238**
Aeromexico	8
Air Canada	46 (4)
American Airlines	34 (6)
Delta Air Lines	20
FedEx	50 (18)
LAN Cargo	8
Southern Air	8
TAM Cargo	(4)
TAM Linhas Aereas	20
United Airlines	44 (20)

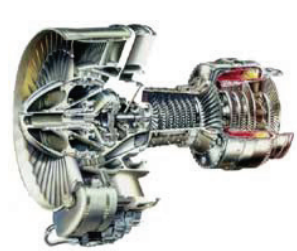
GENERAL ELECTRIC GE9X	TOTAL (572)
Asia, Australasia & Middle East	**Total (532)**
ANA - All Nippon Airways	(40)
Cathay Pacific	(42)
Emirates Airline	(300)
Etihad Airways	(50)
Qatar Airways	(100)
Europe	**Total (40)**
Lufthansa	(40)

GENERAL ELECTRIC GENX	TOTAL 658 (802)
Africa	**Total 40 (36)**
Arik Air	(22)
Ethiopian Airlines	24 (2)
Kenya Airways	12 (6)
Royal Air Maroc	4 (6)
Asia, Australasia & Middle East	**Total 336 (420)**
Air China	20 (4)
Air India	40 (14)
Cathay Pacific	52 (4)
China Southern Airlines	20
Etihad Airways	8 (138)
Hainan Airlines	20 (2)
Japan Airlines	40 (50)
Jetstar	16

Korean Air	20 (68)
Nippon Cargo Airlines	32 (24)
Oman Air	(12)
Qantas	(12)
Qatar Airways	42 (18)
Royal Jordanian	10 (12)
Saudia	8 (16)
Uzbekistan Airways	(4)
Vietnam Airlines	(38)
Xiamen Airlines	8 (4)
Europe	**Total 178 (118)**
Air France	(18)
Air France-KLM Group	(4)
AirBridgeCargo	24
Arkefly	6
Azerbaijan Airlines	4
Cargolux	44 (8)
Jetairfly	2
KLM Royal Dutch Airlines	(52)
Lufthansa	76
Silk Way West Airlines	8 (12)
Thomson Airways	14 (8)
Transaero Airlines	(16)
North/South America	**Total 104 (224)**
Aeromexico	14 (18)
Air Canada	16 (58)
American Airlines	8 (76)
Atlas Air	8
Polar Air Cargo	24
United Airlines	34 (76)

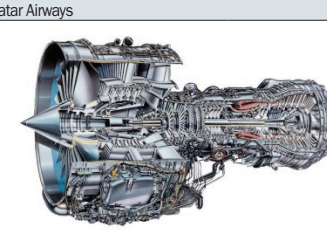
Honeywell

HONEYWELL LF507	TOTAL 408
Africa	**Total 60**
Air Annobon	4
Air Botswana	8
Airlink	48
Asia, Australasia & Middle East	**Total 80**
Anugrah Mandiri Walesi	4
Mahan Air	28
National Jet Express	32
Qeshm Airlines	12
Taban Air	4
Europe	**Total 240**
Brussels Airlines	48
CityJet	64
Ellinair	8
Malmo Aviation	48
Swiss Global Air Lines	72
North/South America	**Total 28**
Aerovias DAP	4
Eco Jet	12
First Air	4
North Cariboo Air	8



IAE

INTERNATIONAL AERO ENGINES V2500	TOTAL 5,316 (798)
Africa	**Total 104 (20)**
Air Cairo	2
Air Cote d Ivoire	2
Air Go Airlines	4
Air Seychelles	4
Almasria Universal Airlines	6
Egyptair	28
Fastjet Tanzania	2
Nesma Airlines	6
Nile Air	6
Nouvelair Tunisie	2
Senegal Airlines	2
South African Airways	40 (20)
Asia, Australasia & Middle East	**Total 2,362 (260)**
Air Astana	26
Air Bishkek	2
Air Busan	18
Air China	76
Air India	26
Air Macau	32
Air New Zealand	52 (4)
AirAsia Zest	16
Airblue	6
AirCalin	4
Ariana Afghan Airlines	2
Asiana Airlines	64
ATA Air	6
Atrak Air	4
Bangkok Airways	38
Cambodia Angkor Air	8
Capital Airlines	64 (2)
China Eastern Airlines	166 (20)
China Eastern Airlines Jiangsu	12
China Southern Airlines	354 (12)
Chongqing Airlines	20
Citilink	12
Dragonair	46
Etihad Airways	60 (8)
EVA Air	6
Golden Myanmar Airlines	2
Gulf Air	12
Hong Kong Express Airways	10
IndiGo	190
Iran Air	4
Iran Aseman Airlines	4
Iraqi Airways	4
Israir	4 (2)
Jetstar	118
Jetstar Asia	36
Jetstar Japan	40
Jetstar Pacific	20
Kam Air	2
Kingfisher Airlines	(134)
Middle East Airlines	18
Mihin Lanka	8
Nepal Airlines	4
Pakistan International Airlines	4
Philippine Airlines	34 (12)
Qatar Airways	82



Royal Brunei Airlines	12 (4)
Royal Jordanian	24
Saudia	4
SaudiGulf Airlines	(8)
Shaheen Air International	12
Shenzhen Airlines	56
Sichuan Airlines	172 (6)
SilkAir	36
Sky Angkor Airlines	4
SriLankan Airlines	6
Syrianair	12
Thai Airways International	10
Thai Smile	26 (4)
Tianjin Airlines	22
Tigerair	48 (6)
Tigerair Australia	26
Tigerair Taiwan	6 (2)
TransAsia Airways	18 (8)
UNI Air	6
V air	2
Vietnam Airlines	98 (6)
Virgin Australia Regional Airlines	4
Vistara	12 (14)
West Air (China)	26
Yemenia	(8)
Zagros Airlines	2
Zagrosjet	2
Europe	**Total 1,132 (162)**
Adria Airways	6
Aegean Airlines	72 (14)
Air Moldova	2
Air Serbia	20
Astra Airlines	2
AtlasGlobal	22
BH Air	2
British Airways	248
Condor	2
Corendon Airlines	2
DAT - Danish Air Transport	2
Finnair	10
Freebird Airlines	8
Germanwings	52
Hermes Airlines	2
Hi Fly	2
Lufthansa	128
MetroJet	8
Monarch Airlines	48
Nordwind Airlines	12
Novair	6
Onur Air	28
SAS	50
Small Planet Airlines (Lithuania)	8
Small Planet Airlines (Poland)	8
Smartlynx	2
Thomas Cook Airlines	6
Thomas Cook Airlines Belgium	2
Titan Airways	6
Turkish Airlines (THY)	172 (46)
Ural Airlines	2
Vueling Airlines	62 (48)
Wizz Air	114 (54)
WOW air	6
Yamal Airlines	10
North/South America	**Total 1,718 (350)**
American Airlines	368 (130)
Aruba Airlines	4
Avianca	4 (6)
Avianca Costa Rica	20
Cubana	2
Delta Air Lines	130
Dominican Wings	2
JetBlue Airways	292 (60)
LAN Airlines	34
LAN Argentina	24
LAN Ecuador	12
LAN Peru	40
Mexicana	(8)
Sky Airline	6
Spirit Airlines	142 (90)
TACA International Airlines	46 (2)
TACA Peru	6
TAM Linhas Aereas	148 (10)
TAME	14
United Airlines	304
VECA	4
VivaAerobus	12 (20)
Volaris	104 (30)

IVCHENKO PROGRESS

IVCHENKO-PROGRESS AI-25	TOTAL 93
Asia, Australasia & Middle East	**Total 33**
Bek Air	6
East Kazakhstan Region Air Enterprise	6
Syrianair	12
Zhetysu Aviakompania	6
Zhezair	3
Europe	**Total 57**
Aerobratsk	3
Amur Airlines	9
Avialift-DV	3
Gazpromavia	12
Khabarovsk Airlines	9
Petropavlovsk-Kamchatsky Air Enterprise	9
Rossiya Special Flight Detachment	3
Severstal Aircompany	3
Tulpar Air	3
Vologda Air Enterprise	3
North/South America	**Total 3**
Aerocaribbean	3

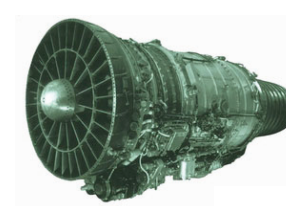
IVCHENKO-PROGRESS D-18	TOTAL 78
Europe	**Total 78**
Antonov Airlines	34
Maximus Airlines	4
Volga-Dnepr Airlines	40

The Yakovlev Yak-40 is powered by three Ivchenko AI-25 turbofans

IVCHENKO-PROGRESS D-36	TOTAL 160
Africa	**Total 13**
Green Flag Aviation	4
Tarco Air	9
Asia, Australasia & Middle East	**Total 6**
Asia Airways	2
Pouya Air	2
Yas Air	2
Europe	**Total 141**
Aerom	2
Antonov Airlines	2
Ayk Avia	4
Cavok Air	2
FGUAP MCHS Rossii	4
Gazpromavia	12
Grozny-Avia	27
Izhavia Udmurtia	21
KrasAvia	9
Motor Sich Airlines	2
Saravia	21
Shar ink	4
Skiva Air	2
South Airlines (Armenia)	6
Tulpar Air	9
Uktus Avia Company	2
UTAir Cargo	12

IVCHENKO-PROGRESS D-436-148	TOTAL 24 (4)
Asia, Australasia & Middle East	**Total 4**
Air Koryo	4
Europe	**Total 10 (2)**
Angara Airlines	10
Rossiya Special Flight Detachment	(2)
North/South America	**Total 10 (2)**
Cubana	10 (2)

KUZNETSOV DESIGN NK-8	TOTAL 30
Asia, Australasia & Middle East	**Total 6**
Air Koryo	6
Europe	**Total 24**
223rd State Airline Flight Unit	24



LYCOMING
A Textron Company

LYCOMING ALF502	TOTAL 232
Africa	**Total 32**
Air Annobon	8
Air Libya	4
Cronos Airlines	12
Starbow	8

Asia, Australasia & Middle East	**Total 92**
Avia Traffic Company	4
Aviastar Mandiri	8
Mahan Air	32
National Jet Express	32
Nusantara Air Charter	4
Skyforce Aviation	4
Skyjet Airlines	4
Tez Jet Airlines	4
Europe	**Total 60**
Astra Airlines	4
Bulgaria Air	4
Pan Air	32
TNT Airways	8
WDL	12
North/South America	**Total 48**
Aerovias DAP	8
Star Peru	32
TAM - Transporte Aereo Militar	8

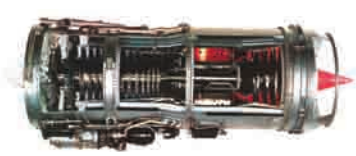
PowerJet

POWERJET SAM146	TOTAL 92 (116)
Asia, Australasia & Middle East	**Total (36)**
Bek Air	(14)
Lao Central Airlines	(4)
Sky Aviation	(18)
Europe	**Total 64 (48)**
Aeroflot Russian Airlines	38 (22)
Center-South Airlines	4
Donavia	(10)
Gazpromavia	12 (4)
Red Wings Airlines	6
Transaero Airlines	(12)
Yakutia Airlines	4
North/South America	**Total 28 (32)**
Interjet	28 (32)

Pratt & Whitney
A United Technologies Company

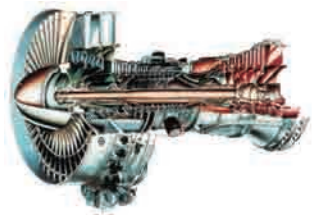
PRATT & WHITNEY JT3D	TOTAL 8
Africa	**Total 8**
Airlift International of Ghana	4
Trans Air Cargo Services	4
Starbow	8

PRATT & WHITNEY JT8D	TOTAL 1,348
Africa	**Total 100**
Africa Charter Airline	8
African Express Airways	7
Air Zimbabwe	2
Allegiance Airways - Gabon	2
Astral Aviation	2
Blue Sky Airways	2
CAA - Compagnie Africaine d'Aviation	2
Canadian Airways Congo	6
DANA Air	8
Emirate Touch Aviation Services	3
Fly-SAX	2
Ghadames Air Transport	2
Global Aviation Operations	2
Gomair	5
Interair	2
ITAB - International Trans Air Business	2
JedAir	2
Jubba Airways	2
Karinou Airlines	2
Niger Airlines	2
Services Air	15
Star Air	6
TAAG Angola Airlines	4
Trans Air Congo	10
Asia, Australasia & Middle East	**Total 184**
AIRFAST Indonesia	10
Airstream Aviation	2
ATA Air	12
Caspian Airlines	10
Express Air	6
Far Eastern Air Transport	16
FitsAir	2
Gryphon Airlines	2
Iran Air	6
Iran Airtours	16
Iran Aseman Airlines	12
Iraqi Airways	2
Jayawijaya Dirgantara	2
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	8
TAC Airlines	2
Tri MG Airlines	2
Trigana Air	6
United Airways	4
Zagros Airlines	18
Europe	**Total 42**
Bravo Air	2
Bulgarian Air Charter	14
Dart Airlines	6
DAT - Danish Air Transport	4
Meridiana	10
Mistral Air	6
North/South America	**Total 1,022**
Aeronaves TSM	16
Aeropostal	12
Aerosucre Colombia	13
Aerovias DAP	4
Air Class Lineas Aereas	3
Air Inuit	4
Air North	2
Allegiant Air	106
Aloha Air Cargo	4
American Airlines	250
Amerijet International	15
Ameristar Charters	14
Andes Lineas Aereas	8
ARjet Airlines	2
Aserca Airlines	14
Asia Pacific Airlines	9
Avior Airlines	8
C & M Airways	2
Canadian North	14
Cargojet Airways	18
Conviasa	2
Delta Air Lines	232
EasySky	4
Everts Air Alaska	8
Falcon Air Express	12
First Air	10
Global Air	4
Gulf & Caribbean Cargo	9
Havana Air	2
InselAir	8
InselAir Aruba	4
Kalitta Charters II	24
LASER	20
Lineas Aereas Suramericanas	21
Nolinor Aviation	8
Northern Air Cargo	6
Orange Air	2
PanAir Cargo	3
PAWA Dominicana	4
Perla Airlines	4
Peruvian Airlines	6
Rio Linhas Aereas	15
Rutaca	12
SELVA Colombia	3
Sierra Pacific Airlines	4
SkyWay Enterprises	2
TAM - Transporte Aereo Militar	13
Total Linhas Aereas	18
TransAir	8
Uniworld Air Cargo (1)	2
USA Jet Airlines	16
Venezolana	8
World Atlantic Airlines	10

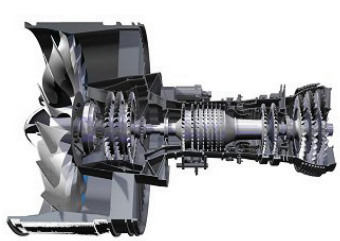


PRATT & WHITNEY JT9D	TOTAL 128
Africa	**Total 28**
Eritrean Airlines	2
Interair	2
Kabo Air	12
MaxAir	12
Asia, Australasia & Middle East	**Total 58**
Asian Air	2
Caspian Airlines	8
Iran Air	4
Iran Aseman Airlines	2
Japan Airlines	8
Jet Asia Airways	6
Orient Thai Airlines	12
Uni-Top Airlines	12
Vision Air International	4
North/South America	**Total 42**
Atlas Air	8
Dynamic Airways	4

FedEx	8
Kalitta Air	20
Vision Airlines	2

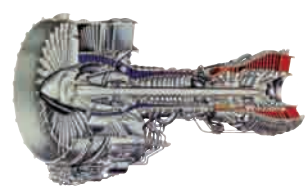


PRATT & WHITNEY PW1000G	TOTAL (2,960)
Asia, Australasia & Middle East	**Total (1,218)**
Air Costa	(100)
Air Mandalay	(12)
Air New Zealand	(36)
ANA - All Nippon Airways	(96)
Cebu Pacific Air	(60)
China Southern Airlines	(48)
GoAir	(144)
Gulf Air	(20)
IndiGo	(360)
Iraqi Airways	(10)
J-Air	(64)
Korean Air	(20)
Mihin Lanka	(4)
Qatar Airways	(100)
Royal Brunei Airlines	(14)
SaudiGulf Airlines	(32)
Tigerair	(74)
TransAsia Airways	(24)
Europe	**Total (536)**
Aeroflot Russian Airlines	(100)
airBaltic	(26)
Lufthansa	(120)
Malmo Aviation	(20)
Norwegian	(100)
Novair	(6)
Odyssey Airlines	(20)
Red Wings Airlines	(20)
Swiss	(60)
Transaero Airlines	(24)
UTAir	(20)
UTAir Ukraine	(10)
VIM Airlines	(10)
North/South America	**Total (1,206)**
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)

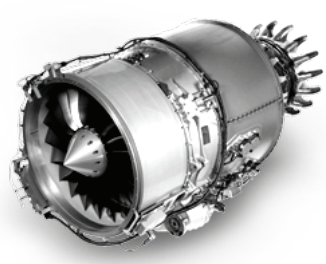


PRATT & WHITNEY PW2000	TOTAL 530
Africa	**Total 8**
Ethiopian Airlines	6
TACV - Cabo Verde Airlines	2
Asia, Australasia & Middle East	**Total 16**
China Cargo Airlines	2
Taban Air	2
Tajik Air	2
Uzbekistan Airways	10
Europe	**Total 34**
Aer Lingus	6
Katekavia	12
OpenSkies	4
VIM Airlines	12
North/South America	**Total 472**
ATI - Air Transport International	10
Delta Air Lines	276
DHL Aero Expreso	6
FedEx	50
United Airlines	60
UPS Airlines	70

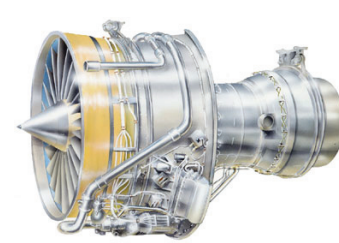
PRATT & WHITNEY PW300	TOTAL 26
Asia, Australasia & Middle East	**Total 2**
Express Air	2
Europe	**Total 18**
Sun-Air of Scandinavia	18
North/South America	**Total 6**
Calm Air	2
Key Lime Air	4



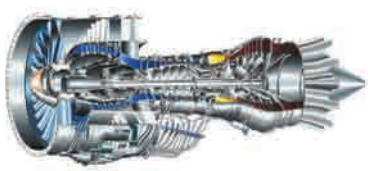
PRATT & WHITNEY PW4000	TOTAL 2,084 (48)
Africa	**Total 40**
Air Zimbabwe	4
Arik Air	4
Camair Co	2
Egyptair	6
Ethiopian Airlines	14
Global Africa Aviation	6
Sudan Airways	4
Asia, Australasia & Middle East	**Total 884 (48)**
Air Astana	6



Air China	32
Air China Cargo	12
Air Hong Kong	4
Air India	20
Air Niugini	2
Airblue	2
ANA - All Nippon Airways	70
Asia Atlantic Airlines (Thailand)	4
Asiana Airlines	54
Biman Bangladesh Airlines	8
Cargo Air Lines	4
Cathay Pacific	28
China Airlines	28
China Cargo Airlines	8
China Southern Airlines	38 (14)
El Al	40
Hainan Airlines	6
Hong Kong Airlines	12
Iraqi Airways	4
Japan Airlines	38
Jet Asia Airways	2
Jin Air	2
Kingfisher Airlines	-30
Korean Air	216 (4)
Lion Air	8
Mahan Air	2
Malaysia Airlines	44
Orient Thai Airlines	8
Pakistan International Airlines	6
Royal Jordanian	4
Saudia	68
Shanghai Airlines	12
Silk Road Cargo Business	2
Singapore Airlines Cargo	32
Thai Airways International	8
United Airways	2
Uzbekistan Airways	20
Vietnam Airlines	28
Europe	**Total 278**
Aerotranscargo	4
Air Cargo Global	4
Air Contractors	2
Air Greenland	2
airberlin	28
Austrian	12
BH Air	2
Brussels Airlines	10
Cargolux	8
Condor	18
Corsair	12
Czech Airlines	2
Edelweiss Air	2
EuroAtlantic airways	6
European Air Transport	40
Hi Fly	2
Ifly	4
Ikar Airlines	8
Katekavia	2
Martinair	22
MNG Airlines	4
myCARGO Airlines	4
Orenair	4
SATA International	2
SkyGreece Airlines	2
TAP Portugal	14
TAROM	2
Transaero Airlines	34
Turkish Airlines (THY)	10
Ukraine International Airlines	8
Wamos Air	4
North/South America	**Total 882**
ABX Air	6
Aerolineas Argentinas	8
Aeromexico	8

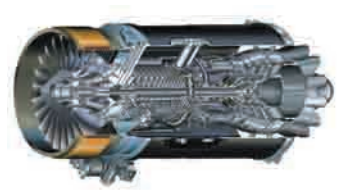


Air Canada Rouge	16
Air Caraibes	10
American Airlines	18
Atlas Air	16
Caribbean Airlines	4
Delta Air Lines	184
FedEx	115
Hawaiian Airlines	16
Omni Air International	4
Sky Lease Cargo	12
TAM Linhas Aereas	10
United Airlines	270
UPS Airlines	185
PRATT & WHITNEY PW6000	**TOTAL 26**
North/South America	**Total 26**
Avianca Brazil	26

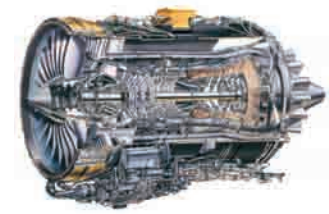


Avianca Brazil is the world's only carrier who operates PW6000-powered A318 aircraft

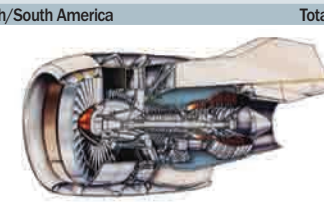
ROLLS-ROYCE AE 3007	**TOTAL 1,262**
Africa	**Total 88**
Afric Aviation	2
Africa World Airlines	6
Air 26	6
Air Namibia	8
Air Taraba	2
Airlink	30
ALS Limited	6
Diexim Expresso	2
Equaflight Service	2
Mauritania Airlines International	2
Mocambique EXpresso	4
Punto Azul	4
Solenta Aviation	8
Swaziland Airlink	6
Asia, Australasia & Middle East	**Total 72**
China Eastern Airlines	10
JetGo Australia	6
NovoAir	6
Rotana Jet	6
Tianjin Airlines	44
Europe	**Total 138**
Air Europa	2
BMI Regional	34
Brussels Airlines	2
Denim Air	2
Dniproavia	12
Eastern Airways	8
HOP!	36
Komiaviatrans	8
Luxair	12
Pan Europeenne Air Service	4
PGA - Portugalia Airlines	16
Regional	2
North/South America	**Total 964**
ADI Charter Services	4
Aereo Calafia	2
Aeromexico Connect	50
BizCharters Inc	4
Envoy	290
ExpressJet Airlines	434
IBC Airways	4
SATENA	4
Shuttle America	86
TAR Aerolineas	6
Tortug Air	6
Trans States Airlines	74



ROLLS-ROYCE BR700	**TOTAL 248**
Asia, Australasia & Middle East	**Total 46**
QantasLink	36
Turkmenistan Airlines	10
Europe	**Total 40**
Blue1	8

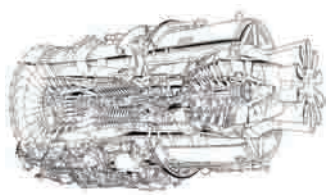


Volotea	32
North/South America	**Total 162**
Delta Air Lines	126
Hawaiian Airlines	36
ROLLS-ROYCE RB211	**TOTAL 1,270**
Africa	**Total 20**
Cairo Aviation	6
ECAir	4
Ethiopian Airlines	6
MaxAir	4
Asia, Australasia & Middle East	**Total 172**
Air Astana	10
Air China Cargo	8
Air Hong Kong	12
Arkia	4
Blue Dart Aviation	10
Cathay Pacific	16
China Southern Airlines	24
DHL International Aviation EEMEA	6
Jet Asia Airways	2
Mega Maldives Airlines	2
MIAT - Mongolian Airlines	2
Nepal Airlines	4
Orient Thai Airlines	2
Pakistan International Airlines	4
Qantas	20
SCAT	4
SF Airlines	18
Sunday Airlines	4
Tasman Cargo Airlines	2
Turkmenistan Airlines	6
Xiamen Airlines	12
Europe	**Total 504**
Azerbaijan Airlines	8
British Airways	196
Cargolux	24
Cargolux Italia	8
Condor	26
Cygnus Air	4
DHL Air	44
European Air Transport	22
Icelandair	48
Ifly	6
Jet2	22
Katekavia	6
La Compagnie	4
OpenSkies	2
Privilege Style	4
Royal Flight	10
Silk Way Italia	4
Silk Way West Airlines	8
Thomas Cook Airlines	14
Thomson Airways	28
Titan Airways	4
TNT Airways	2
Transaero Airlines	8
Yakutia Airlines	2
North/South America	**Total 574**



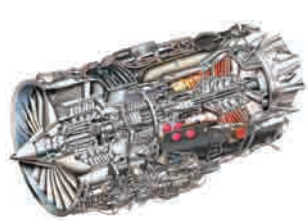
COMMERCIAL ENGINES 2015

Allegiant Air	12
American Airlines	180
ATI - Air Transport International	6
Cargojet Airways	10
Dynamic Airways	2
FedEx	138
Fly Jamaica	2
Morningstar Air Express	10
National Airlines	6
SBA Airlines	4
United Airlines	124
UPS Airlines	80

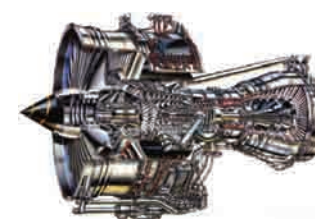


ROLLS-ROYCE SPEY	TOTAL 6
Africa	**Total 4**
Fly-SAX	2
Toumai Air Tchad	2
Asia, Australasia & Middle East	**Total 2**
Myanmar National Airlines	2

ROLLS-ROYCE TAY	TOTAL 350
Africa	**Total 6**
ECAir	2
Golden Wings Aviation	2
Kush Air	2
Asia, Australasia & Middle East	**Total 188**
Air Niugini	16
Alliance Airlines	44
Bek Air	14
Iran Air	22
Iran Aseman Airlines	14
Iranian Naft Airlines	6
Kish Air	6
Network Aviation	24
Pelita Air Service	4
Qeshm Airlines	8
TransNusa Air Services	2
Transwisata Air	2
Virgin Australia Regional Airlines	26
Europe	**Total 120**
Austrian	42
Avantiair	2
Carpatair	6
Denim Air	2
Helvetic Airways	12
KLM cityhopper	38
Montenegro Airlines	4
PGA - Portugalia Airlines	12
Trade Air	2
North/South America	**Total 36**
Air Panama	8
Avianca Brazil	22
InselAir Aruba	6



ROLLS-ROYCE TRENT	TOTAL 2,500 (2,638)
Africa	**Total 86 (76)**
Afriqiyah Airways	(20)
Air Mauritius	(12)
Air Namibia	4
Air Seychelles	4
Egyptair	22 (2)
Ethiopian Airlines	(24)
Kenya Airways	8
Libyan Airlines	(12)
South African Airways	48
Tunisair	(6)
Asia, Australasia & Middle East	**Total 1,476 (1,620)**
Air Astana	(6)
Air China	98 (58)
Air New Zealand	22 (18)
Air Niugini	(2)
Air Tahiti Nui	(4)
AirAsia X	34 (162)
AlNaser Airlines	12
ANA - All Nippon Airways	70 (96)
Asiana Airlines	8 (76)
Cathay Pacific	120 (96)
Cebu Pacific Air	12
China Airlines	(28)
China Eastern Airlines	80 (10)
China Eastern Yunnan	6
China Southern Airlines	48
Dragonair	36
El Al	12
Emirates Airline	84 (200)
Etihad Airways	100 (126)
Fiji Airways	6 (2)
Flynas	4
Garuda Indonesia	44 (26)
Gulf Air	12 (12)
Hainan Airlines	34 (12)
Hong Kong Airlines	22 (32)
Indonesia AirAsia Extra	4
Japan Airlines	-62
Kuwait Airways	(24)
Lion Air	(6)
Malaysia Airlines	50
Middle East Airlines	8
NokScoot	4
Oman Air	20
Philippine Airlines	30
Qantas	44 (32)
Qatar Airways	32 (160)
Royal Brunei Airlines	8 (2)
Saudia	26
Scoot	16 (34)
Shanghai Airlines	10
Sichuan Airlines	14
Singapore Airlines	200 (226)
SriLankan Airlines	20 (20)
Thai AirAsia X	6 (2)
Thai Airways International	104 (30)
TransAsia Airways	4 (8)
Vietnam Airlines	(28)
Virgin Australia	12
Yemenia	(20)
Europe	**Total 644 (512)**
Aer Lingus	(18)
Aeroflot Russian Airlines	44 (44)
Air Europa	18 (44)
Air France	(50)
Azerbaijan Airlines	8
British Airways	90 (116)
Corsair	8
Edelweiss Air	2
EuroAtlantic airways	2
Evelop Airlines	2
Finnair	2 (38)
Hi Fly	2
Iberia	68 (16)
Icelandair	(2)
KLM Royal Dutch Airlines	(2)
LOT Polish Airlines	8 (4)
Lufthansa	190 (50)
MNG Airlines	2 (6)
NEOS	(4)
Norwegian	(12)
Norwegian Air International	16
SAS	8 (24)
Swiss	28 (2)
TAP Portugal	(24)
Thomas Cook Airlines	10
Thomas Cook Airlines Scandinavia	8
Transaero Airlines	18
Turkish Airlines (THY)	32 (6)
Virgin Atlantic Airways	72 (50)
XL Airways France	6
North/South America	**Total 294 (426)**
Air Canada	16
Air Caraibes	(12)
Air Transat	22
American Airlines	124 (44)
Avianca	26 (24)
Avianca Brazil	2 (22)
Avianca Cargo	10 (2)
Azul	8 (10)
Conviasa	2
Delta Air Lines	16 (136)
Hawaiian Airlines	40 (16)
LAN Airlines	24 (40)
TACA Peru	2
TAM Linhas Aereas	-54
TAME	2
United Airlines	(70)



Delta Air Lines is the launch customer for the A330neo which will be powered exclusively by the Trent 7000

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