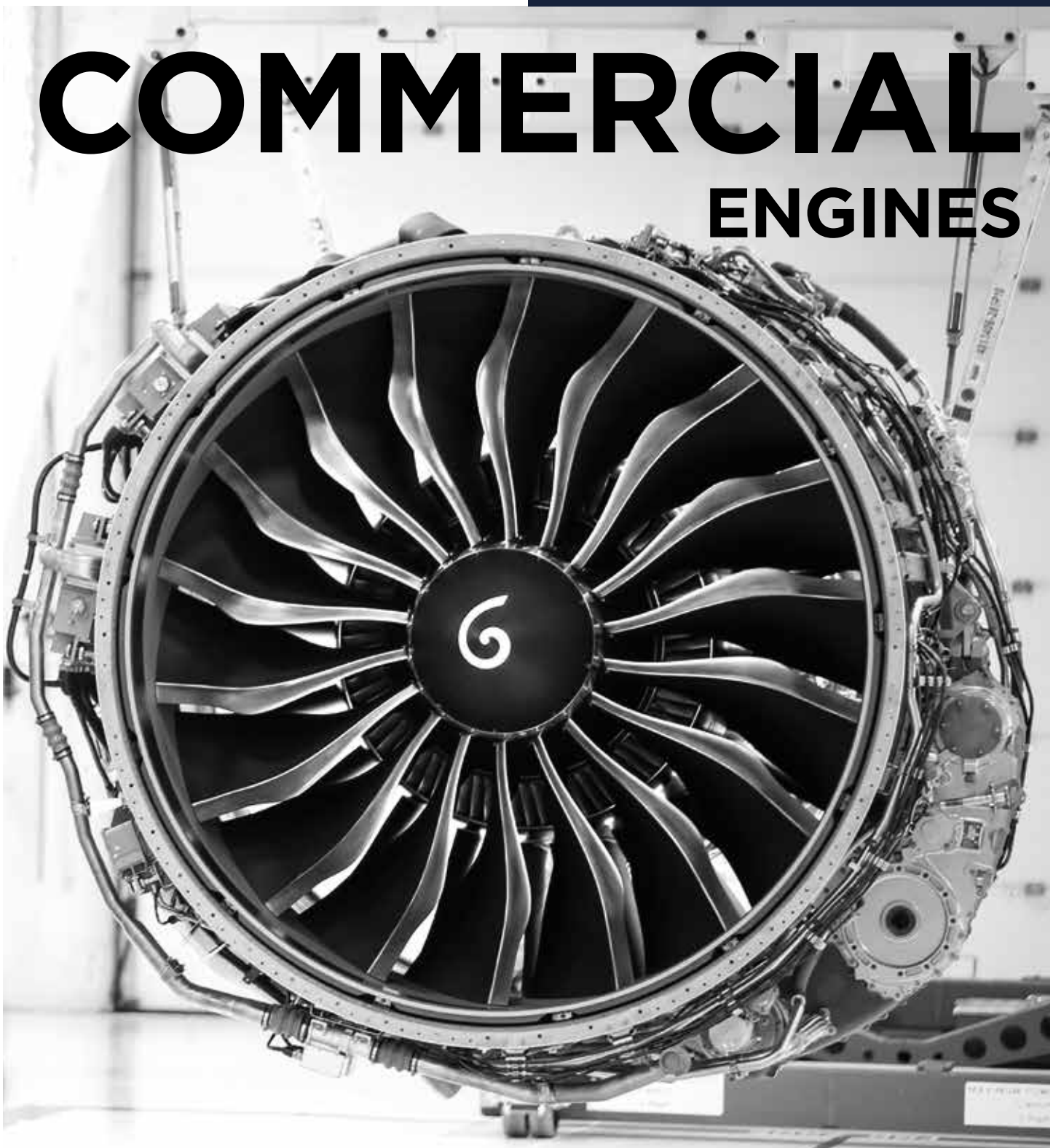
COMMERCIAL ENGINES



Shifting gears

Changing market for turbofans

In focus

Features

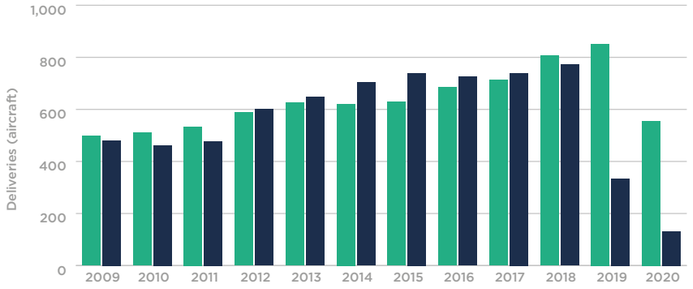
P&W has invested heavily in its GTF programme

Cover: CFM International

Deliveries drop sharply

Amid the Covid-19 crisis and continued 737 Max grounding, Airbus outpaced Boeing again when it came to aircraft deliveries. For the in-service fleet, newer types did better as demand fell

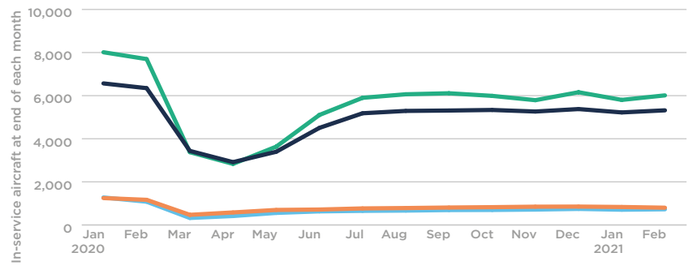
Mainline jet deliveries 2009-2020



Source: Cirium fleets data

● Airbus deliveries ● Boeing deliveries

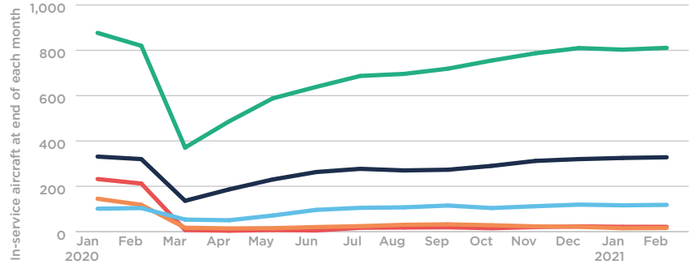
Crisis fleet trend: airline workhorses bounce back, then plateau



Source: Cirium fleets data

● A320 family ● 737 family ● 777 family ● A330/A340 family

Crisis fleet trend: latest jets rebound, largest types lose appeal



Source: Cirium fleets data

● 787 family ● A350 family ● A380 ● 747 family ● A220 family

Top 10 mainline customers 2020

Rank	Airline	Units
1	IndiGo	44
2	Delta Air Lines	30
3	American Airlines	29
4	China Southern Airlines	24
5	Turkish Airlines	23
6	United Airlines	22
7	FedEx	16
8=	Air Canada, Pegasus	14
9=	British Airways, Egyptair, Wizz Air	13
10	SAS	12

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

Mainline deliveries and backlog 2020

	Deliveries	Backlog
Airbus	556	7,163
Boeing	131	4,916

Note: Deliveries 12 months to 31 December 2020. Backlog on 31 December 2020. Source: Cirium fleets data

Top 5 regional customers 2020

Rank	Airline	Units
1	Mesa Airlines	16
2=	Jazz, Envoy Air	8
3	Rossiya Airlines	7
4=	SkyWest Airlines, Chengdu Airlines	6
5=	Aeroflot, Azul, Endeavor Air	5

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

Regional deliveries and backlog 2020

	Deliveries	Backlog
ATR	7	221
Bombardier	17	3
Comac	23	252
De Havilland Canada	12	19
Embraer	44	282
Mitsubishi	0	153
Sukhoi	17	84
Viking Air	6	14

Notes: Deliveries 12 months to 31 December 2020. Backlog on 31 December 2020. Excludes corporate and military customers. Source: Cirium fleets data

Power through the crisis

It was a tough year for the engine sector in 2020, with more than 1,000 units knocked off deliveries compared with 2019, but demand for new powerplants was not totally wiped out

Engine manufacturer rankings 2020

		2020 deliveries		Backlog	
Rank	Manufacturer	Engines	Share	Engines	Share
1	CFM International	540	39%	12,636	52%
2	Pratt & Whitney	478	35%	3,748	16%
3	GE Aviation	188	14%	1,444	6%
4	Rolls-Royce	168	12%	1,794	7%
5	International Aero Engines	0	0%	8	0%
	Undecided			4,528	19%
	Total	1,374		24,158	

Source: Cirium fleets data. Notes: At 31 December 2020. Data for installed engines based on Airbus/Boeing types. Excludes corporate and military operators

787 engine manufacturer share

	2020 deliveries		Backlog	
Manufacturer	Aircraft	Share	Aircraft	Share
GE Aviation	43	81%	300	59%
Rolls-Royce	10	19%	112	22%
Undecided			99	19%
Total	53		511	

Source: Cirium fleets data. Notes: At 31 December 2020. Excludes corporate and military operators

Airbus/Boeing fleet by manufacturer

Manufacturer	Airbus	Boeing	Total
CFM International	5,091	7,882	12,973
GE Aviation	418	2,962	3,380
International Aero Engines	3,026	4	3,030
Rolls-Royce	1,487	1,182	2,669
Pratt & Whitney	1,228	1,271	2,499
Engine Alliance	128	0	128
Total	11,378	13,301	24,679

Source: Cirium fleets data. Notes: In-service and parked fleet at 31 December 2020. Boeing data includes former MDC types. Excludes corporate and military operators. Data is number of aircraft

A320 family engine manufacturer share

	2020 deliveries		Backlog	
Manufacturer	Aircraft	Share	Aircraft	Share
CFM International	242	55%	2,335	40%
Pratt & Whitney	201	45%	1,393	24%
International Aero Engines	0	0%	4	0.1%
Undecided			2,150	37%
Total	443		5,882	

Source: Cirium fleets data. Notes: At 31 December 2020. Excludes corporate and military operators

Backlog for other mainline jets

Manufacturer	C919	MC-21
CFM International	298	-
Aviadvigatel	-	49
Pratt & Whitney	-	83
Undecided	-	43
Total	298	175

Source: Cirium fleets data. Note: At 31 December 2020. Data is number of aircraft

Regional aircraft engine manufacturer share

	2020 deliveries		Backlog	
Manufacturer	Aircraft	Share	Aircraft	Share
GE Aviation	73	58%	391	38%
Pratt & Whitney**	36	29%	553	54%
Powerjet	17	13%	84	8%
Total	126		1,028	

Source: Cirium fleets data. Notes: At 31 December 2020. Excludes corporate and military operators. **Including P&W Canada. Data for firm orders for ATR, Bombardier, Comac, De Havilland Canada, Embraer, Mitsubishi, Sukhoi and Viking Air

North America view

Alejandro Gonzalez M/Shutterstock

Delta took the most aircraft in 2020, with CFM topping the engine ranking

Engine manufacturer rankings 2020

		2020 deliveries		Backlog	
Rank	Manufacturer	Engines	Share	Engines	Share
1	CFM International	136	38%	2,092	48%
2	Pratt & Whitney	106	30%	1,000	23%
3	GE Aviation	104	29%	278	6%
4	Rolls-Royce	12	3%	244	6%
	Undecided			756	17%
Total		358		4,370	

Notes: Backlog on 31 December 2020. Data for installed engines based on Airbus/Boeing types. Excludes corporate and military operators
Source: Cirium fleets data

Airbus/Boeing fleet by manufacturer

Manufacturer	Airbus	Boeing	Total
CFM International	900	2,335	3,235
GE Aviation	79	948	1,027
International Aero Engines	785	4	789
Rolls-Royce	113	458	571
Pratt & Whitney	255	700	955
Total	2,132	4,445	6,577

Notes: In-service and parked fleet at 31 December 2020. Boeing data includes former MDC types. Excludes corporate and military operators
Source: Cirium fleets data

Regional aircraft engine manufacturer share

	2020 deliveries		Backlog	
Manufacturer	Engines	Share	Engines	Share
GE Aviation	96	89%	282	47%
Pratt & Whitney*	12	11%	324	53%
Total	108		606	

Notes: At 31 December 2020. Excludes corporate and military operators. *Including P&W Canada Data for firm orders for ATR, Bombardier, Comac, De Havilland Canada, Embraer, Mitsubishi, Sukhoi and Viking Air
Source: Cirium fleets data

Mainline aircraft deliveries and backlog 2020

	Deliveries	Backlog
Airbus	102	1,299
Boeing	77	886

Note: Deliveries 12 months to 31 December 2020. Backlog on 31 December 2020
Source: Cirium fleets data

Top 10 mainline customers 2020

Rank	Airline	Units
1	Delta Air Lines	30
2	American Airlines	29
3	United Airlines	22
4	FedEx	16
5	Air Canada	14
6=	Spirit Airlines, UPS Airlines	10
7	Frontier Airlines	9
8	JetBlue Airways	8
9	Southwest Airlines	7
10	DHL	6

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

Regional aircraft deliveries and backlog 2020

	Deliveries	Backlog
ATR	2	48
Bombardier	17	3
Comac	0	5
De Havilland Canada	2	2
Embraer	31	144
Mitsubishi	0	100
Viking Air	2	1
Total	54	303

Notes: Backlog on 31 December 2020. Includes ATR, Bombardier, Comac, De Havilland Canada, Embraer, Mitsubishi, Sukhoi and Viking Air. Excludes corporate and military customers
Source: Cirium fleets data

Top 5 regional customers 2020

Rank	Airline	Units
1	Mesa Airlines	16
2=	Jazz, Envoy Air	8
3	SkyWest Airlines	6
4	Endeavor Air	5
5	PSA Airlines	3

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

Europe view

Turkish carriers head European airline deliveries in 2020

Dux Croatorum/Shutterstock

Engine manufacturer rankings 2020

		2020 deliveries		Backlog	
Rank	Manufacturer	Engines	Share	Engines	Share
1	Pratt & Whitney	122	36%	1,362	26%
2	CFM International	114	34%	2,512	47%
3	Rolls-Royce	66	19%	442	8%
4	GE Aviation	36	11%	168	3%
	Undecided			834	16%
Total		338		5,318	

Notes: Backlog on 31 December 2020. Data for installed engines based on Airbus/Boeing types. Excludes corporate and military operators
Source: Cirium fleets data

Airbus/Boeing fleet by manufacturer

Manufacturer	Airbus	Boeing	Total
CFM International	1,728	1,857	3,585
Engine Alliance	9	0	9
GE Aviation	167	507	674
International Aero Engines	734	0	734
Rolls-Royce	374	300	674
Pratt & Whitney	279	98	377
Total	3,291	2,762	6,053

Notes: In-service and parked fleet at 31 December 2020. Boeing data includes former MDC types. Excludes corporate and military operators
Source: Cirium fleets data

Regional aircraft engine manufacturer share

	2020 deliveries		Backlog	
Manufacturer	Engines	Share	Engines	Share
GE Aviation	4	7%	0	0%
PowerJet	36	62%	156	48%
Pratt & Whitney*	18	31%	166	52%
Total	58		322	

Notes: At 31 December 2020. Excludes corporate and military operators. *Including P&W Canada Data for firm orders for ATR, Bombardier, Comac, De Havilland Canada, Embraer, Mitsubishi, Sukhoi and Viking Air
Source: Cirium fleets data

Mainline aircraft deliveries and backlog 2020

	Deliveries	Backlog
Airbus	146	1,746
Boeing	23	913

Note: Deliveries 12 months to 31 December 2020. Backlog on 31 December 2020
Source: Cirium fleets data

Regional aircraft deliveries and backlog 2020

	Deliveries	Backlog
ATR	2	48
Embraer	7	35
Sukhoi	18	78
Viking Air	2	0
Total	29	161

Notes: Backlog on 31 December 2020. Includes ATR, Bombardier, Comac, De Havilland Canada, Embraer, Mitsubishi, Sukhoi and Viking Air Excludes corporate and military customers
Source: Cirium fleets data

Top mainline customers 2020

Rank	Airline	Units
1	Turkish Airlines	23
2	Pegasus	14
3=	British Airways, Wizz Air	13
4	SAS	12
5	Lufthansa	11
6	EasyJet	8
7=	S7 Airlines, Aegean Airlines	7
8=	Iberia, Swiss, TAP	5
9=	Air Europa, Air France	4

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

Top 5 regional customers 2020

Rank	Airline	Units
1	Rossiya Airlines	7
2	Aeroflot	5
3=	Red Wings, Helvetic	4
4=	Aviashelf, Azimuth, Belavia, Binter Canarias	2
5	Air France HOP	1

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

Asia view

Teamvtaviation/Shutterstock.com

IndiGo in front as Asia-Pacific carriers took the most deliveries of any region

Engine manufacturer rankings 2020

		2020 deliveries		Backlog	
Rank	Manufacturer	Engines	Share	Engines	Share
1	CFM International	214	44%	4,954	62%
2	Pratt & Whitney	188	38%	842	10%
3	Rolls-Royce	58	12%	608	8%
4	GE Aviation	30	6%	388	5%
	Undecided			1,234	15%
Total		490		8,026	

Notes: Backlog on 31 December 2020. Data for installed engines based on Airbus/Boeing types. Excludes corporate and military operators
Source: Cirium fleets data

Mainline aircraft deliveries and backlog 2020

	Deliveries	Backlog
Airbus	225	2,452
Boeing	20	1,561

Note: Deliveries 12 months to 31 December 2020. Backlog on 31 December 2020
Source: Cirium fleets data

Regional aircraft deliveries and backlog 2020

	Deliveries	Backlog
ATR	3	78
Comac	23	245
De Havilland Canada	3	3
Embraer	0	1
Mitsubishi	0	53
Sukhoi	0	6
Viking Air	2	12
Total	31	398

Notes: Backlog on 31 December 2020. Includes ATR, Bombardier, Comac, De Havilland Canada, Embraer, Mitsubishi, Sukhoi and Viking Air Excludes corporate and military customers
Source: Cirium fleets data

Airbus/Boeing fleet by manufacturer

Manufacturer	Airbus	Boeing	Total
CFM International	1,785	2,634	4,419
Engine Alliance	10	0	10
GE Aviation	88	851	939
International Aero Engines	1,132	0	1,132
Rolls-Royce	712	319	1,031
Pratt & Whitney	574	136	710
Total	4,301	3,940	8,241

Notes: In-service and parked fleet at 31 December 2020. Boeing data includes former MDC types. Excludes corporate and military operators
Source: Cirium fleets data

Top mainline customers 2020

Rank	Airline	Units
1	IndiGo	44
2	China Southern	24
3	Loong Air	11
4	China Eastern	10
5=	ANA, Vistara	9
6	Spring Airlines	8
7=	Juneyao Air, Sichuan Airlines, Air China, Singapore Airlines	7
8=	Air Astana, Cathay Pacific, Japan Airlines	6

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

Regional aircraft engine manufacturer share

	2020 deliveries		Backlog	
Manufacturer	Engines	Share	Engines	Share
GE Aviation	46	74%	490	61%
PowerJet	0	0%	12	2%
Pratt & Whitney*	16	26%	294	37%
Total	62		796	

Notes: At 31 December 2020. Excludes corporate and military operators. *Including P&W Canada Data for firm orders for ATR, Bombardier, Comac, De Havilland Canada, Embraer, Mitsubishi, Sukhoi and Viking Air
Source: Cirium fleets data

Top regional customers 2020

Rank	Airline	Units
1	Chengdu Airlines	6
2=	China Eastern, Jiangxi Air, Air China, China Southern	3
3=	Mandarin Airlines, PAL Express, Genghis Kahn Airlines, China Express Airlines	2

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

Middle East view

Rebius/Shutterstock

Larger types prominent, with no regional aircraft activity

Engine manufacturer rankings 2020

		2020 deliveries		Backlog	
Rank	Manufacturer	Engines	Share	Engines	Share
1	CFM International	34	36%	982	39%
2	Rolls-Royce	24	26%	340	13%
3	Pratt & Whitney	22	23%	120	5%
4	GE Aviation	14	15%	544	21%
	Undecided			552	22%
Total		94		2,538	

Notes: Backlog on 31 December 2020. Data for installed engines based on Airbus/Boeing types. Excludes corporate and military operators
Source: Cirium fleets data

Mainline aircraft deliveries and backlog 2020

	Deliveries	Backlog
Airbus	39	688
Boeing	8	581

Note: Deliveries 12 months to 31 December 2020. Backlog on 31 December 2020
Source: Cirium fleets data

Airbus/Boeing fleet by manufacturer

Manufacturer	Airbus	Boeing	Total
CFM International	275	189	464
Engine Alliance	109	0	109
GE Aviation	58	482	540
International Aero Engines	120	0	120
Rolls-Royce	186	29	215
Pratt & Whitney	20	101	121
Total	768	801	1,569

Notes: In-service and parked fleet at 31 December 2020. Boeing data includes former MDC types. Excludes corporate and military operators
Source: Cirium fleets data

Top mainline customers 2020

Rank	Airline	Units
1	Qatar Airways	8
2	Middle East Airlines	7
3=	Kuwait Airways, Flynas	6
4	Wizz Air Abu Dhabi	4
5=	Etihad Airways, Emirates Airline	3
6=	Gulf Air, Jazeera Airways, Air Arabia, Saudia	2
7=	Salam Air, El Al	1

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

Latin America view

Pratt & Whitney

Low-cost carriers dominated data for 2020, with Azul taking the most jets

Mainline aircraft deliveries and backlog 2020

	Deliveries	Backlog
Airbus	25	490
Boeing	1	243

Note: Deliveries 12 months to 31 December 2020. Backlog on 31 December 2020
Source: Cirium fleets data

Engine manufacturer rankings 2020

		2020 deliveries		Backlog	
Rank	Manufacturer	Engines	Share	Engines	Share
1	Pratt & Whitney	30	58%	384	26%
2	CFM International	20	38%	734	50%
3	Rolls-Royce	2	4%	22	2%
4	International Aero Engines	0	0%	8	0.5%
4	GE Aviation	0	0%	6	0.5%
	Undecided			312	21%
Total		52		1,466	

Notes: Backlog on 31 December 2020. Data for installed engines based on Airbus/Boeing types. Excludes corporate and military operators
Source: Cirium fleets data

Top mainline customers 2020

Rank	Airline	Units
1	Volaris	7
2	VivaAerobus	5
3=	Viva Air, Azul	4
4	JetSmart Chile	3
5	Sky Airline	2
6	Copa Airlines	1

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

Airbus/Boeing fleet by manufacturer

Manufacturer	Airbus	Boeing	Total
CFM International	283	455	738
GE Aviation	12	84	96
International Aero Engines	223	0	223
Rolls-Royce	41	40	81
Pratt & Whitney	82	113	195
Total	641	692	1,333

Notes: In-service and parked fleet at 31 December 2020. Boeing data includes former MDC types. Excludes corporate and military operators
Source: Cirium fleets data

Regional aircraft deliveries and backlog 2020

	Deliveries	Backlog
ATR	0	30
Embraer	5	59
Viking Air	0	1
Total	5	90

Notes: Backlog on 31 December 2020. Includes ATR, Bombardier, Comac, De Havilland Canada, Embraer, Mitsubishi, Sukhoi and Viking Air. Excludes corporate and military customers
Source: Cirium fleets data

Regional aircraft engine manufacturer share

	2020 deliveries		Backlog	
Manufacturer	Engines	Share	Engines	Share
Pratt & Whitney*	10	100%	180	100%
Total	10		180	

Notes: At 31 December 2020. Excludes corporate and military operators. *Including P&W Canada
Data for firm orders for ATR, Bombardier, Comac, De Havilland Canada, Embraer, Mitsubishi, Sukhoi and Viking Air
Source: Cirium fleets data

Top regional customer 2020

Airline	Units
Azul	5

Note: Note: Azul was only airline in region to receive regional aircraft in 2020. Includes ATR, Bombardier, Comac, De Havilland Canada, Embraer, Mitsubishi, Sukhoi and Viking Air. Excludes corporate and military customers
Source: Cirium fleets data

Africa view

Airbus

EgyptAir dominated deliveries, with CFM ahead of the pack for engines

Mainline aircraft deliveries and backlog 2020

	Deliveries	Backlog
Airbus	17	60
Boeing	2	66

Note: Deliveries 12 months to 31 December 2020. Backlog on 31 December 2020
Source: Cirium fleets data

Engine manufacturer rankings 2020

		2020 deliveries		Backlog	
Rank	Manufacturer	Engines	Share	Engines	Share
1	CFM International	18	47%	128	51%
2	Pratt & Whitney	10	26%	26	10%
3	Rolls-Royce	6	16%	58	23%
4	GE Aviation	4	11%	4	2%
	Undecided			36	14%
Total		38		252	

Notes: Backlog on 31 December 2020. Data for installed engines based on Airbus/Boeing types. Excludes corporate and military operators
Source: Cirium fleets data

Top mainline customers 2020

Rank	Airline	Units
1	Egyptair	13
2	Ethiopian Airlines	4
3=	Air Seychelles, Uganda Airlines	1

Note: Data for Airbus and Boeing deliveries to airlines
Number of aircraft
Source: Cirium fleets data

Airbus/Boeing fleet by manufacturer

Manufacturer	Airbus	Boeing	Total
CFM International	111	397	508
GE Aviation	16	81	97
International Aero Engines	31	0	31
Rolls-Royce	55	35	90
Pratt & Whitney	17	46	63
Total	230	559	789

Notes: In-service and parked fleet at 31 December 2020. Boeing data includes former MDC types. Excludes corporate and military operators
Source: Cirium fleets data

Regional aircraft deliveries and backlog 2020

	Deliveries	Backlog
ATR	0	7
Comac	0	2
Embraer	1	19
De Havilland Canada	7	12
Viking Air	0	0
Total	8	40

Notes: Backlog on 31 December 2020. Includes ATR, Bombardier, Comac, De Havilland Canada, Embraer, Mitsubishi, Sukhoi and Viking Air. Excludes corporate and military customers
Source: Cirium fleets data

Regional aircraft engine manufacturer share

	2020 deliveries		Backlog	
Manufacturer	Engines	Share	Engines	Share
GE Aviation	0	0%	10	12%
Pratt & Whitney*	16	100%	70	88%
Total	16		80	

Notes: At 31 December 2020. Excludes corporate and military operators. *Including P&W Canada
Data for firm orders for ATR, Bombardier, Comac, De Havilland Canada, Embraer, Mitsubishi, Sukhoi and Viking Air
Source: Cirium fleets data

Top regional customers 2020

Rank	Airline	Units
1	Ethiopian Airlines	3
2=	Jambojet, TAAG Angola Airlines	2
3	Air Peace	1

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

Power supply

Coronavirus has hit jet engine makers' forecasts but has also afforded time to tackle production issues and plan ahead

Leap passes 10 million flight-hour milestone for CFM

CFM International's line of Leap turbofans recently surpassed a combined-engine milestone of 10 million flight hours and 5 million cycles, with nearly 1,400 Leap-powered 737 Max and A320neo-family jets having been delivered.

The engine maker – a joint venture of GE Aviation and Safran Aircraft Engines – has, like competitors, seen deliveries slide amid the pandemic.

Being the only engine option for the 737 Max, the Leap-1B programme also suffered from that jet's 18-month grounding.

But the 737 Max, despite continued electrical issues affecting a portion of the fleet, is now back in the sky, and Boeing has high hopes for the re-engined narrowbody and is expecting to boost deliveries to 31 Max per month in early 2022.

CFM delivered 188 Leap engines in the first quarter of 2021, down 31% from 272 deliveries in the same period of 2020, according to figures from Safran.

9,200

Backlog of turbofan orders as at the end of March 2021, compared with 15,065 at the same point a year ago

The engine maker's backlog of turbofan orders declined by about 40% year on year, from a total of 15,065 at the end of March 2020 to some 9,200 at the end of March this year.

But CFM secured recent notable business, including from Southwest Airlines when it ordered a 100 Boeing 737 Max 7s in March

Leap-1Bs have been hung on the wings of about 850 737 Max aircraft, of which Boeing has delivered about 470 to customers, according to Cirium data. Airlines now have about 160 of those aircraft in service and another 310 in storage.

Additionally, Boeing has another roughly 375 737 Max jets in its inventory, data shows. The airframer produced those aircraft during the grounding and is now working to offload them.

Airbus has delivered over 940 Leap-1A powered A320neo-family jets since handing the first of those aircraft to Turkish carrier Pegasus in July 2016. CFM scored a recent big win from Indian low-cost carrier IndiGo, which chose Leap-1As to power 310 A320neo-family jets.

CFM has also produced a third Leap variant, the Leap-1C, for Chinese airframer Comac's in-development C919.

CFM International

CFM delivered 188 Leap engines in Q1, down 31% on same period in 2020

GE engine unit stays profitable despite demand hit

GE Aviation has been relatively quiet of late, with its largest-ever turbofan – the GE9X – being an additional year from service entry due to Boeing's recent delay of its first 777-9 delivery. Boeing disclosed a one-year delay – to late 2023 – in February.

GE has loudly promoted the engineering advances behind the GE9X, saying it has produced more thrust – 134,300lb (598kN) – during tests than any other commercial aircraft engine.

Composed of 16 carbonfibre blades, the GE9X's fan measures 3.4m (134in) in diameter. Its compressor has a 27:1 pressure ratio, and the engine has an overall pressure ratio of 60:1, which GE has said are the highest ratios for any of its engines.

The 777-9's delay did not surprise industry analysts, who note the extreme degree to which the pandemic has eroded demand for the long-haul routes for which Boeing developed the twinjet.

The pandemic has eaten into GE's sales of commercial aircraft engines, including those made by CFM International.

GE sold 359 civil aircraft engines (including 188 CFM Leaps) in the first quarter, down from 530 engines (including 272 Leaps) in the same period one year earlier.

Its 2020 total engine sales slipped by 48% year on year to 1,487 units.

Still, GE has managed to keep in the black. Its profits were $1.3 billion in 2020, down by 82% from 2019, and $641 million in the first quarter of this year.

Meanwhile, GE has been working on cleaner-energy propulsion development projects. It has been studying lighter-weight materials and advancing cooling methods, which could allow engineers to design powerplants with higher pressures and temperatures.

GE Aviation

New technology will boost efficiency beyond that of current engines

GTFs powering over 1,000 aircraft

The PW1000G geared turbofans (GTFs) manufactured by Pratt & Whitney now power more than 1,000 aircraft, a notable, albeit delayed, milestone for a programme slowed by the ongoing aerospace downturn.

Chinese carrier Sichuan Airlines took delivery of the 1,000th aircraft – a PW1100G-powered Airbus A320neo, the Hartford engine maker said on 17 May.

P&W had hoped, long before anyone had heard of Covid-19, to deliver the 1,000th example much sooner. In 2016, Greg Hayes, chief executive of P&W's then-parent United Technologies, said the engine maker aimed to be delivering 1,200 GTFs annually by 2020.

The pandemic upended those hopes, as it did the plans of manufacturers across the aerospace spectrum. P&W ended up shipping 546 large commercial aircraft engines in 2020, down from 746 in 2019. The company does not break out those shipments by engine type but says the "vast majority" of recent large commercial engines delivered are GTFs.

On a positive note, engine makers are no longer chafing under the same supply chain shortages that, prior to Covid-19, limited their ability to hike production.

P&W's line of PW1000Gs is now powering three aircraft families.

Of the roughly 1,000 aircraft equipped with GTFs, about 800 are PW1100G-powered A320neo-family jets, Cirium data shows. Those aircraft account for about 46% of all A320neos delivered by Airbus, with the balance having CFM International Leap-1A turbofans. PW1100Gs have been in service since 2016, when Airbus delivered the first A320neo.

Another roughly 160 Airbus A220s, powered by PW1500Gs, have been produced, Cirium shows. That aircraft and engine also entered service in 2016.

GTF engines also power about 50 Embraer E-Jet E2s. Embraer handed over the first E190-E2, which has PW1900G engines, in 2018, and the first E195-E2, also with PW1900Gs, in 2019.

But Embraer has now pushed back service entry for a third E2 variant – the PW1700G-powered E175-E2 – to 2024.

Meanwhile, Russian airframer Irkut continues working toward service entry of its MC-21, which is powered by PW1400Gs.

The future of the PW1200G-powered Mitsubishi Aircraft's SpaceJet remains uncertain. That programme had already been badly delayed when parent company Mitsubishi Heavy Industries (MHI) put the programme on hold in 2020. MHI is evaluating a programme restart, it has said.

GTFs have logged 8.9 million flight hours on the wings of aircraft operated by 54 airlines, P&W said on 17 May. The company has taken orders and order commitments for more than 10,000 GTFs since the programme's launch.

P&W executives leave no doubt they intend to improve on the GTF's base design rather than, at least in the short term, focusing on developing a wholly new design.

"We think it's the architecture of the future," P&W president Christopher Calio said during parent company Raytheon's investor day on 18 May. "We're working on packages to... improve [fuel burn]. Also, working on a way to maybe just scale it up to the extent that engine bypass ratios get larger, applications get larger."

Despite the pandemic's flattening of demand for new aircraft and for engine aftermarket services, P&W managed to squeak out a $20 million operating profit in the first quarter of 2021.

During those three months it delivered 137 large aircraft engines, down from 211 in the same period one year earlier.

P&W has been also been addressing a metal fatigue concern involving PW4000s powering Boeing 777s. Those engines have suffered several failures, most recently in February, when a United Airlines 777-200 suffered a PW4000 failure shortly after take-off.

Investigators found evidence of fatigue fractures in that powerplant's blade. In response, airlines grounded (and in some cases retired) PW4000-powered 777s and the Federal Aviation Administration ordered inspections, which P&W has said it will complete.

Rolls-Royce

Trent XWB compressor blades have been affected by premature wear on high-cycle powerplants

Rolls-Royce bolstered by A350 sole supplier renewal

Rolls-Royce has taken a particular battering from the Covid-19 crisis as a result of its exposure to the widebody market. Revenue at its civil aerospace unit plunged by £3 billion ($4.2 billion) in 2020, down to £5 billion, leading to an underlying loss of £2.6 billion. Flight hours of its engines fell to 43% of 2019 levels and the company has embarked on a restructuring to right-size it for future demand. This includes cutting around 9,000 roles, mostly from civil aerospace, plus pursuing divestments, including the possible sale of Spanish business ITP Aero.

While the good news does not yet outweigh the bad, the signs are that R-R has at least stopped the bleeding. A recent trading update offered a relatively upbeat tone and saw the progress of vaccination roll-outs as enabling a return to long-haul flying.

Additionally, the UK manufacturer has seen its position reinforced on a key long-haul programme, with the March 2021 announcement that its Trent XWB had secured an exclusive position on the Airbus A350-900 until 2030. That move rules out any immediate prospect of a rival engine manufacturer entering the market for twinjet.

The Trent XWB-84-powered A350-900 has been in revenue service since Qatar Airways debuted the type in January 2015, while the higher-thrust XWB-97, which powers, the A350-1000 entered commercial service with the same airline three years later.

R-R revealed last year that it had found evidence of premature wear on Trent XWB compressor blades in high-cycle engines. But the manufacturer states that it has managed to avoid grounding any A350s, adding that "early identification and action" over the situation meant it did not have to provide for any material additional costs last year.

At its 13 May 2021 annual general meeting, the engine maker said 658 XWB engines were in service, and a further 977 were on order.

R-R has also reported progress in addressing the technical issues around blade durability that have hit the Trent 1000 option for the Boeing 787 Dreamliner.

The problems, mainly centred on premature blade deterioration, had caused a wave of engine removals and aircraft groundings owing to lack of spare engines, bringing R-R under severe pressure prior to the coronavirus crisis.

Last summer, it eliminated the backlog of 787 Dreamliners grounded while they awaited maintenance in relation to Trent 1000 blade-durability issues earlier than expected. It was assisted by low utilisation during the pandemic, as well as progress on retrofits.

658

XWB engines in service, as announced at Rolls-Royce's May 2021 AGM, with a further 977 powerplants on order

This meant that by March, the engine manufacturer lowered its expected overall in-service cash costs relating to Trent 1000 technical issues.

As of May, there were 538 Trent 1000 engines in service on the Dreamliner, with orders for a further 158. R-R also has an exclusive position on another Airbus widebody, where the Trent 7000 equips the A330neo, which entered service with TAP Air Portugal in November 2018. There are now 90 Trent 7000s in service, with a further 535 engines on order.

However, this year sees the end of A380 production, on which the Trent 900 was one of two powerplant options. The other rival engine for the double-decker was the Engine Alliance GP7200, developed by the GE Aviation/Pratt & Whitney joint venture that is now focused on supporting the in-service fleet.

The last production superjumbo will be handed over during 2021 to the A380's biggest customer, Emirates. The Dubai-based carrier ordered both Trent 900 and GP7200 engines to power its A380s.

Delivery of the final unit, powered by Trent engines, comes almost 14 years after the first Trent-powered A380 entered service in 2007 with Singapore Airlines.

Meanwhile, R-R is in talks with Boeing about powering a future commercial aircraft. During the engine maker's annual general meeting, chief executive Warren East said: "It is fairly well documented that Boeing is exploring the opportunity for a new aircraft... We are in dialogue with Boeing about that."

East suggests that the talks cover a potential application of R-R's in-development UltraFan engine programme – the same powerplant it had originally put forward before withdrawing from the race for Boeing's then-proposed New Mid-market Airplane.

R-R in March formally commenced construction of the UltraFan high-bypass engine, with the aim of producing a demonstrator by the end of this year. UltraFan has been intended for large civil aircraft from 2025 onwards, although the air transport crisis – which is particularly affecting the long-haul market – is likely to push back the service entry.

Russian boost from aircraft roll-outs

The consolidated structure of the country's aerospace sector means all of Russia's aerospace propulsion units are held by umbrella company United Engine (UEC), which incorporates such storied names as Aviadvigatel, Klimov, Kuznetsov, and NPO Saturn. UEC itself is a part of the state-owned Rostec holding company. UEC companies have been benefiting from increased Russian focus on domestic substitution of Western products for the country's civil aerospace programmes.

So while the Irkut MC-21 is to enter service powered by Pratt & Whitney PW1400Gs, Aviadvigatel is also developing a domestic alternative, the PD-14. The engine's first flight on board the Russian narrowbody took place in December 2020, with the PD-14-powered variant designated the MC-21-310, against the baseline -300.

Flight testing is continuing. Five MC-21s make up the flight-test fleet, of which four are powered by the PW1400G.

In February, Rostec said the PD-14, originally certificated by Russian regulator Rosaviatsia in 2018, "fully meets" a new ICAO standard on emissions criteria introduced last year, meaning it can be offered to the international market.

Meanwhile, tests are to begin shortly of the first prototype core for the Aviadvigatel PD-8 powerplant, a lower-thrust variant of the PD-14, which is intended to equip a "Russified" Sukhoi Superjet 100.

The PD-8 is a fully domestic alternative to the SaM146 that currently equips the regional jet. It is produced by the PowerJet consortium, which comprises NPO Saturn and Safran Aircraft Engines, with the French firm responsible for the engine's hot section.

United Aircraft – parent company of Irkut and Sukhoi, and another Rostec subsidiary – is developing a version of the Superjet 100 designated the "SSJ-New", which will have a higher proportion of Russian-built components, including the PD-8 engine.

UEC plans to exhibit the PD-8 at the upcoming MAKS Moscow air show in July. The company is also developing a high-thrust version of the engine family designated the PD-35 for future widebody applications.

Also in December, the modernised Ilyushin Il-114-300 carried out its maiden flight. The twin-turboprop resurrects the older Il-114 airframe and combines it with new Klimov TV7-117ST-01 engines and an updated digital cockpit.

The powerplants include a new high-thrust propeller, as well as an automatic propeller control unit to maximise efficiency.

Certification of the aircraft is scheduled for 2022 and delivery of serially produced aircraft should start in 2023.

Irkut

Flight tests continue on the Irkut MC-21, which features PW1400G and PD-14 powerplant options

As commercial engine MRO providers await the recovery in demand that should come with rising traffic levels, leading players are still unsure quite how deep the pandemic's business impact will be

Needing support

Mark Pilling London

In aviation's engineering, maintenance and aftermarket world, there is only one currency that really matters – aircraft utilisation.

The pandemic has shown how frail the aviation ecosystem is when that revenue is shut off. Aircraft in the air equal dollars flowing into flight-hour plans for engine OEMs and others, demand for airframe checks and engine shop visits, and a relatively predictable demand for new, repaired and used spares.

That demand and predictability has collapsed along with traffic levels. In its wake lies a sorry aftermarket sector reeling from its revenue source evaporating.

"Right now, airlines are not spending a dollar on MRO," said Dick Forsberg, a leading aviation finance expert and consultant to PwC Ireland, during a recent Cirium webinar.

After the initial shock of the pandemic's impact on aviation, airlines "went into survival mode, working out rapidly how to keep afloat", explains David Stewart, a partner in Oliver Wyman's specialist airline MRO consultancy.

A Raytheon Technologies financial filing of its 2020 results, explaining the impact of the crisis on subsidiary Pratt & Whitney, summed up what all carriers have been asking for: "Airlines have shifted to cash-conservation behaviours such as deferring engine maintenance due to lower flight hours and aircraft utilisation, requesting extended payment terms, deferring delivery of new aircraft and spare engines and requesting discounts on engine maintenance."

As the new year of 2020 dawned, such tactics were unimaginable. The aviation aftermarket industry had been rolling along steadily pre-pandemic, driven by a decade of strong traffic growth. The big two airframers had been striving for a greater chunk of this market via their burgeoning services businesses, either for aircraft lifetime maintenance and parts support or with digital services and products aimed at operational efficiency.

For years, the major engine makers had relentlessly sought a dominant slice of the services market for their home-built models.

The biggest were getting bigger. On 23 March 2020, Lufthansa Technik (LHT) chairman Johannes Bussmann was reporting bumper results with record revenue and earnings. At that time, he knew the crisis was going to be bad – just not how bad.

"The full extent will hit us with a delay, which means a forecast is currently not possible, but first impacts are massive," Bussmann said.

A.JW Group

Parts providers have been frustrated by stalled supply deals

MTU Aero Engines

OEMs are keen to make up for lost time as carriers bring their aircraft back into service

A year later, at LHT's 2021 results presentation, Bussmann was reporting a revenue drop in 2020 of 43%, to €3.7 billion ($4.4 billion), and the industry's biggest airline MRO made a €383 million loss.

Similar incredible revenue falls and losses have been witnessed across the sector. Oliver Wyman expects the global commercial air transport MRO market to suffer a reduction in demand of more than $60 billion over 2020 and 2021 combined, according to its Global Fleet and MRO Market Forecast 2021-2031. This is a fall of 33% compared with pre-pandemic projections.

Grim numbers

For the engine OEMs and others with servicing deals based on flying hours, the business model has been shattered, says Phil Seymour, chairman of IBA, the global industry consultant and appraisal firm. "For them, the issue is how rapidly will flying come back – and if it will come back at all."

The huge financial impact on the engine OEMs is clear in their grim 2020 numbers. P&W's overall sales in 2020 fell by 20%, to $16.8 billion. The organic sales decrease of $4.1 billion in 2020 compared with 2019 "primarily reflects lower commercial aftermarket sales of $3.8 billion, due to a significant reduction in shop visits and related spare part sales", according to US financial filings.

Rolls-Royce reported that large engine flying hours were down by 57% in 2020, contributing to a pre-tax loss of £2.9 billion ($4 billion) for the year. The company recorded one-time charges of £1.3 billion, including a £974 million impact from service agreement "catch-ups", as a result of a forecast reduction in flying-hour receipts.

GE Aviation recorded "net unfavourable changes of $1.1 billion to the estimated profitability in its long-term service agreements", it explained in its 2020 annual reporting.

But as flying returns, the engine OEMs remain confident they can make up the lost ground.

"The services backlog in 2020 was resilient, despite the impact of Covid. As travel recovers and utilisation accelerates, we expect to capture much of that delayed spending," GE Aviation chief executive John Slattery said during an investor update in March.

There will, however, be dislocations. In its report, Covid-19: Fleet outlook and impact on lessors and MROs, global consultancy ICF says: "Airlines will challenge the flight-hour contract concept in the short- to medium-term. They will want to stay away from minimum-flight-hour guarantees in contracts, given the significant uncertainty around demand."

One market feature that is thought not to have changed is the annual OEM replacement parts price escalation – a yearly ritual that airlines naturally dislike but have little control over. The pandemic has not given airlines any relief, according to industry sources, with price rises of 6-7% last year as the manufacturers sought to plug their revenue shortfalls.

The priority is for aviation to restart – but when? "The industry has been in a kind of stasis, with enough money to survive but with restricted ability to 'build back better'," says Stewart.

Restart activity is intense, and Christopher Whiteside, chief executive at global parts and repair specialist AJW, sums up the frustration for many. "I have 200 deals in play at present, from Peru to Pakistan, but airlines say, 'we are not flying yet', so the inking of the contract has not really happened."

Niklas Prescher/Shutterstock

MRO revenues nosedived in 2020 as many aircraft went into storage

So, what next? And what are the recovery scenarios and strategic moves likely to be seen in the sector? The most obvious impact is that for an industry that has stalled, there will be surplus capacity and some MRO players will either fail or downsize.

"Airlines may face some challenges in terms of disruption of supply as the supplier base in certain markets or geographies comes under strain," believes Stewart.

AJW, which carries a hefty parts inventory worth $500 million, has dipped to 65% of its pre-pandemic revenue base, but has restructured and lent heavily on its diversified portfolio in addition to airline clients to weather the storm. "There will be a culling of people in our business that don't have contracted services, military or cargo business," says Whiteside.

Those that survive will be keener than ever to do whatever it takes to win. "We have been even more engaged with our customer base as a partner through the crisis – it's all about avoiding unnecessary spending," says Martin Friis-Petersen, senior vice-president MRO programmes at MTU Aero Engines.

35%

Pandemic-driven fall in revenue recorded at global parts and repair specialist AJW

Strong, credit-worthy airlines have found suppliers willing to entertain flexible payment terms, discounts on shop visits and help to use so-called "green time" engines – powerplants with life left on the clock. Higher-risk carriers will not always be offered such flexible terms.

Airlines have been outsourcing their MRO services for years, and this trend may accelerate again. The goal is to move from high fixed costs, such as in-house MRO entities, to a more variable cost base. "Boardrooms will once again be asking the question: why do we want the infrastructure?", says Stewart.

It may be attractive for some to look at partial disposals of their MRO assets as a mechanism to raise capital. A sale of a 30-40% stake in an airline MRO would be an attractive prospect for private equity, a sovereign wealth fund or pension fund seeking a secure income stream, while the airline retains operational control.

For Airbus and Boeing, there may be a requirement to temper aftermarket ambitions as they digest bigger issues for now.

"There is a need to refocus on the core business and return to a steady state. And there is the fact that the services business is even more competitive than ever because everyone is fighting for survival," says Yann Cambier, aviation principal at ICF.

While the desire to capture more aftermarket business will remain, the trend could be away from capital-intensive services and to higher-margin activities such as data services, around predictive maintenance, or via acquisitions of specialist service providers.

Alternative spares

The expected increase in retirements, aircraft part-outs and availability of green engines for some years ahead has ramifications for supply and demand across the whole services ecosystem. Manufacturers of non-OEM spare parts, which airlines can favour as they are cheaper than those bought from the original manufacturer, should be well placed, as well as companies specialising in parts repair.

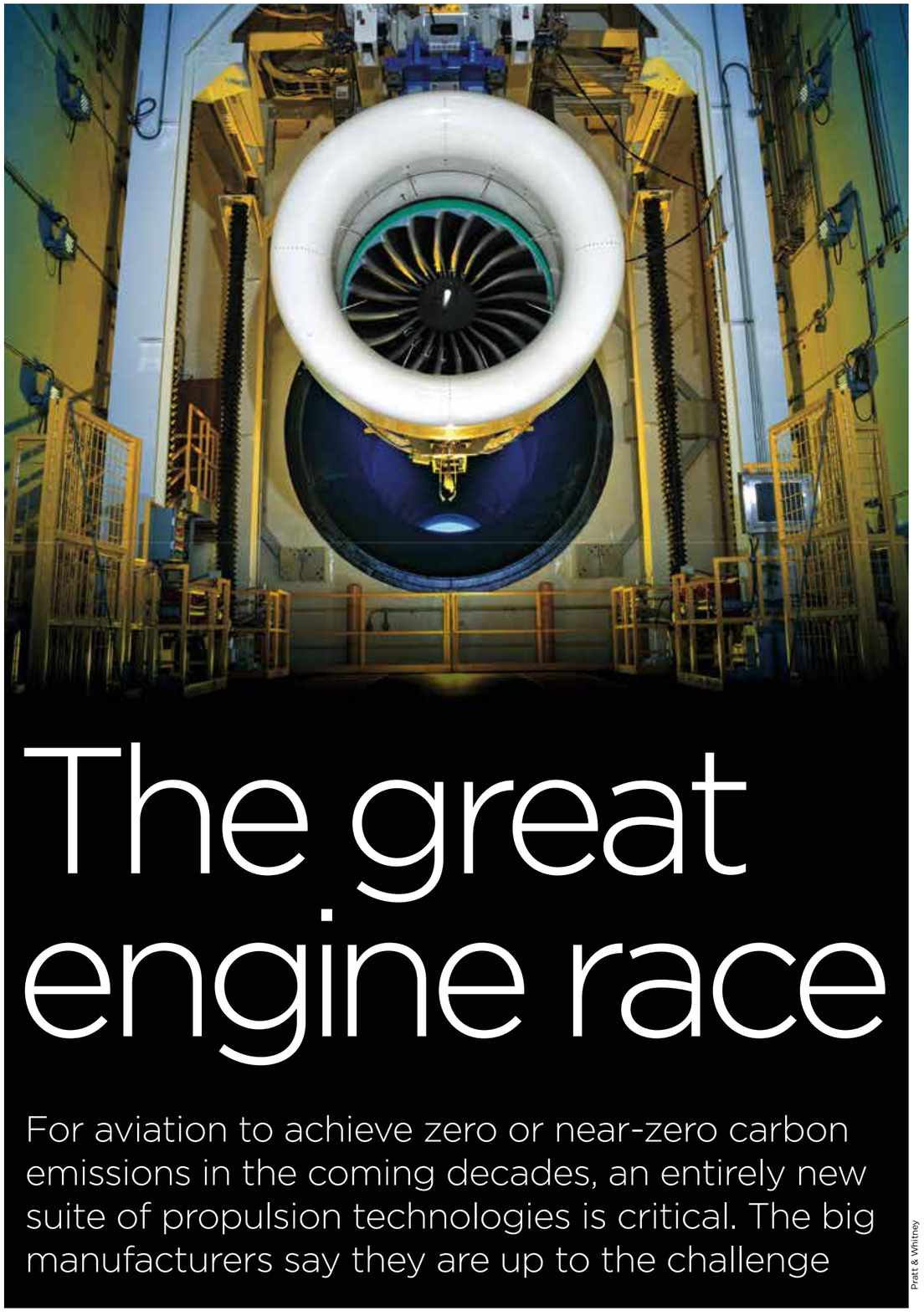
MTU works in some of these areas, in addition to offering used serviceable material (USM) and green-time engines, and in-house parts repair. "The wave of retirements expected from mid-2020 has not materialised, but it will come," says Friis-Petersen. "We will be an active player where we see value."

A disrupted industry brings opportunities, and the environment is ripe for mergers, acquisitions and consolidation. Cambier says that with excess MRO supply "ICF expects that investors may buy some suppliers with weak cash positions".

Stewart agrees: "There are private equity investors that are looking for a good deal in a market that has long-term growth prospects." There is plenty of interest, he says, particularly in players that deal in end-of-life services, asset management and USM.

How the aftermarket develops in the coming years is entirely dependent on the pace and shape of the traffic recovery. A snap back to previous growth patterns could see the aftermarket arena emerge battered and bruised but fundamentally unaltered.

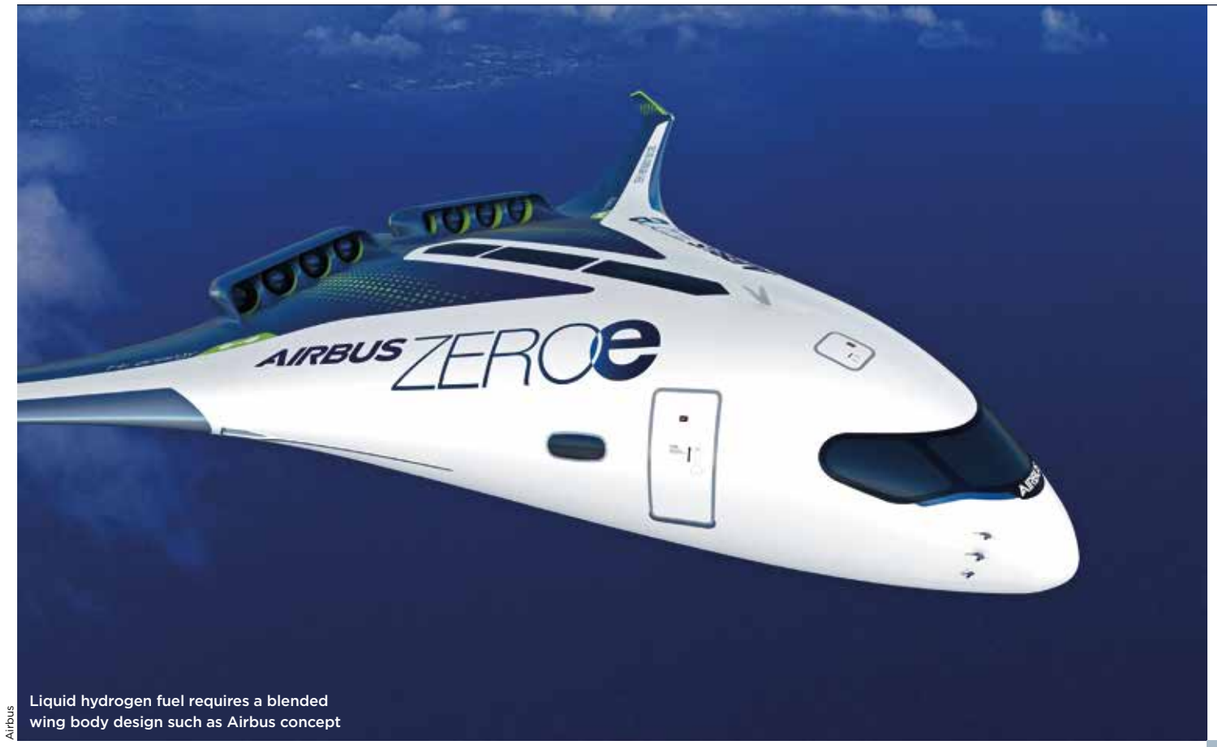
Analysts are cautious about predicting wholesale changes just yet, but the underlying feeling is that some business models have changed for good.



The great engine race

For aviation to achieve zero or near-zero carbon emissions in the coming decades, an entirely new suite of propulsion technologies is critical. The big manufacturers say they are up to the challenge

Pratt & Whitney



Airbus

Liquid hydrogen fuel requires a blended wing body design such as Airbus concept

Mark Pilling London

The cocktail of possible engine technologies and fuels that are going to propel an industry desperate to prove it can decarbonise becomes more extraordinary by the day.

The ingredients in this cocktail are bewildering, encompassing next-generation turbines, sustainable and hydrogen aviation fuels, hybrid, electric, fuel cells, and an intoxicating mixture of all of them.

For the engine makers researching a raft of technical solutions, a discipline that constantly absorbs millions of dollars, this is their day job. However, the task of developing the next generation of engines has arrived at the worst moment financially, with balance sheets swamped by the pandemic-induced crisis.

Nobody, however, has been tempted to take a hatchet to research and development budgets. Andy Geer, chief engineer, UltraFan at Rolls-Royce, acknowledges the challenge: "Our R&D strategy is very much unchanged by the events of the last 12 months; the only thing that has changed is the need for it to be delivered in perhaps the most cost-constrained environment that can be imagined."

Perversely, the crisis could offer industry more clarity on its priorities. Government bailouts and stimulus packages are inexorably connected with accelerating environmental progress: what some dub the "green recovery".

The manufacturers are aligning themselves accordingly. "Essentially the engine game has not changed, but it is the speed with which these technologies are going to be adopted because the industry has really changed," believes Arjan Hegeman, general manager of advanced technologies at GE Aviation.

"In the past 12 months, our strategy has not changed, but rather has been confirmed by the ongoing public discussions, which are driving us to continue to intensively pursue our goals," says Stefan Weber, senior vice-president, engineering and technology for MTU Aero Engines.

Central to these goals is the all-consuming and unaltered drive for better performance. In the old days, the target was obvious: a better turbofan than the previous generation, bringing double-digit fuel burn efficiency gains for airliners to bring lower costs.

And they are good at it. For example, CFM International brought in a 20% improvement with the CFM56, while its successor, the Leap, has delivered another 15%, explains Jerome Bonini, vice-president research and technologies at Safran Aircraft Engines.

But when will the next step-change be required? Guillaume Faury, Airbus chief executive, offered clarity in March during a Eurocontrol webinar, saying that a 2035 entry-into-service date for a next-generation aircraft "makes sense". A formal launch would take place in 2027-2028, giving industry a lead time of five to seven years to mature the technology, he said.

Faury has also been enthusiastic that a future jet will feature hydrogen fuel in some form. Airbus is pushing hydrogen because it offers the most significant impact on carbon emissions reduction.

Rolls-Royce

R-R's UltraFan should be in service around 2030

So, what will the next-generation engine be? Hydrogen is firmly in the sights of all manufacturers; but whether the fuel is Jet A-1, sustainable aviation fuel (SAF) or hydrogen, the turbine engine is the starting point in each case.

"What is obvious is that, for the foreseeable future, there will be no alternative to the aero gas-turbine – in further optimised form – as a propulsion system for large commercial aircraft," says Weber.

"We have spent $10 billion on a technology that was moving in a direction we knew we had to go," says Geoff Hunt, senior vice-president engineering and technology at Pratt & Whitney, describing the US manufacturer's bet on its geared turbofan (GTF). "We have established what I think is a benchmark architecture that provides the flexibility to adjust as the industry looks towards climate change alignment."

As a matter of course, P&W expects to be able to continue the trend of annual fuel efficiency improvements of 1% on average as programmes mature. "Continuing to improve on the GTF architecture is very much the near-term drive and that is consistent with the long-term strategy if you are going into SAF or hydrogen fuel or hybrid-electric," says Hunt. The introduction of these fuels and technologies "will all base off that architecture", he adds.

"The first pillar of our strategy is to define and build an ultra-efficient engine architecture," says Bonini. Safran is working on different architectures – for example, the work it has conducted into open rotor design, in preparation for the aircraft configuration the airframers will chose.

Like P&W with the GTF, CFM joint venture partners GE and Safran have a modern-generation engine, in their case the Leap, as a baseline propulsive system architecture.

Alongside this work there is heavy investment in lightweight, high-performance materials as well as sophisticated cooling technologies, as the trend towards higher engine pressures and temperatures continues. "All these new technologies will work their way into the engine," says Hegeman.

MTU Aero Engines

Focus at MTU is still on performance, says Weber

The conviction that a next-generation turbine is an essential pillar for "decarbonising aviation" is the reason R-R remains committed to its UltraFan programme, says Geer. "We plan to have that engine available around the turn of the decade and as it is a scaleable technology, it is suitable for both narrowbody and widebody new aircraft programmes," he adds.

For its part, "MTU is currently concentrating on the WET [Water-Enhanced Turbofan] engine," says Weber. This employs a heat exchanger to use the energy from the engine's exhaust gas stream to generate additional power.

Eric Drouin/Safran

One of Safran's projects is an open rotor design

> "What is obvious is that, for the foreseeable future, there will be no alternative to the aero gas-turbine"
>
> **Stefan Weber Senior vice-president, engineering and technology, MTU Aero Engines**

Efficiency drive

Whatever mix of architecture, materials or fuel is in the cocktail, the engine technologists interviewed by FlightGlobal all agree the target in efficiency terms for the next-generation engine is 20% and more.

"This generation needs to provide a major step change in efficiency to, firstly, reduce emissions by simply burning less fuel and, secondly, to enable alternative fuels spanning from SAF to electric to hydrogen by providing longer range through its increased efficiency and, as such, overcoming some of the disadvantages of alternative fuels in supply constraints and/or associated weight increases [batteries] or airframe drag increases from large storage needs [hydrogen]," Hegeman says.

The use of liquid hydrogen fuel, for example, will require an aircraft shape and size like the Airbus ZEROe blended wing body design, because hydrogen takes up about four times the volume of jet fuel.

Another clear strategic pillar to achieve decarbonisation is to develop engines that run 100% on low-carbon fuels, such as SAF and synthetic fuels, or liquid hydrogen, which would be zero-carbon, says Bonini.

Boeing agrees. It has set a target of 2030 for all its commercial aircraft to be certified to fly on 100% SAF. Today, the maximum is a 50:50 Jet A-1/SAF mix. There is work on fuel standards and the technical

changes needed to run turbines at 100% SAF, but it is not a tough nut to crack and 2030 or probably earlier is achievable.

The prospect of burning liquid hydrogen in aero engines is more captivating. The first thing the engine makers point out is that hydrogen is not new to them. P&W ran a hydrogen engine in the 1950s, while GE ran one in the 1960s. Russian scientists flew a modified Tupolev Tu-154 using hydrogen fuel in the late 1980s.

"We understand the challenges and the opportunities of hydrogen. From an engine manufacturer's perspective, we do not see we are the long pole in the tent to get into a hydrogen solution at the aircraft level," says Hunt.

"Burning hydrogen inside an engine is not the issue; getting the hydrogen into the right conditions to be used is the challenge," explains Bonini. In February, Safran announced the Hyperion study, where it will work with space launch vehicle maker Ariane Group and Airbus on turbines that burn liquid hydrogen.

Yes, the combustor will be different, as is the control system – but the biggest challenge is not how the fuel is burnt, it is upstream and integrating it into the aircraft design, says Hegeman.

Questions on storing the bulky hydrogen in the airframe and the infrastructure needed to deliver it to an aircraft are harder to answer. "The bigger challenge, similar to SAF, is the need to scale it up. And the need will be for green hydrogen," explains Hegeman, referring to hydrogen produced using renewable power generation.

The view is that liquid hydrogen will be an attractive longer-term option, with advances in current turbine technology and the use of SAF both providing near-term benefits.

"An ultra-efficient engine is still the key to the future – whatever fuel you burn," says Bonini. Embedding electrical systems in such engines to create a hybrid configuration will deliver further levels of efficiency and represents the third strategic pillar of decarbonisation.

The target is to make hybrid variants of current models, such as P&W's GTF family and CFM's Leap, where electrical power is generated to help provide or save energy in the engine. The aim of this work, says Weber, is "the most complete electrification of the drive train possible in order to be as emission-free as possible in flight".

> "Burning hydrogen inside an engine is not the issue; getting the hydrogen into the right conditions to be used is the challenge"
>
> **Jerome Bonini Vice-president research and technologies, Safran Aircraft Engines**

Many believe the concerted hybrid research efforts in play will yield benefits in the short- to mid-term. "A hybrid-electric variant of GTF is certainly something that we are studying," says Hunt. Although P&W did last year slow Project 804, an effort to develop a hybrid-electric engine for a regional aircraft, starting with a De Havilland Canada Dash 8-100, this work has a "lot of merit" and is ongoing, he says. However, a flight demonstration planned for 2022 will slip.

At P&W, there is a benefit having sister Raytheon Technologies company Collins Aerospace in the family. "We work extremely closely with Collins, which has very strong capability in the electrical systems area," says Hunt.

GE has been working on a basket of hybrid research efforts for more than a decade, including a project in 2016 where 1MW of electrical power was siphoned off from a military F110 engine while also generating thrust. This much electrical energy could power a small, six- to 10-seat aircraft.

The years of foundational work spent on such research gives GE confidence it will have the answers. "We are running all of these systems towards a flight of a full hybrid propulsion system," says Hegeman. "We are very far along that journey, with a ground demonstration of a fully built-up engine and flight demonstration of a twin aircraft planned within a couple of years."

GE Aviation

GE has invested heavily in future powerplant research

Safran

Low-carbon engines represent years of research, says Bonini

The hybrid technologies under development will have applications in turbines powering jetliners in the 100-plus seat class, and there are dozens of smaller aircraft being touted for cargo, regional airline, and urban air mobility opportunities. Further down the size class there are many working on all-electric engine applications.

Another technology with promise, which MTU advocates for the longer term, is the conversion of hydrogen into electricity with the help of fuel cells. It is studying this technology with the DLR German Aerospace Center. "These technologies could go into series production even before 2040," believes Weber.

Ultimately, all the engine makers say they will respond with a powerplant when asked. "There isn't any user knocking on our door today. When they do, we are going to have a product," says Hegeman.

Today, the product opportunities appear to centre on a new narrowbody to succeed the Airbus A320 and Boeing 737 Max families, while Boeing chief executive David Calhoun has hinted that it might still develop an aircraft with around 270 seats.

Airbus has been the most progressive and aggressive, clearly signalling a desire to speed up moves to low or zero-emissions aircraft, while Boeing has committed to its 2030 target for using 100% SAF on all its commercial aircraft.

With their existing positions on the A320 and 737, CFM and P&W appear well placed, while R-R is relying on its UltraFan to force its way into the reckoning. "This is a new generation of gas turbine, with the capability to grow and adapt to become an entire engine family, designed for service around the turn of the decade, offering a 25% efficiency improvement compared with our first generation of Trent engine," says Geer.

Multiple technologies

As Bonini explains, a new class of low-carbon engine will bring millions of dollars and years of research to fruition: "This is a great challenge, a huge effort, which is why we need the construction of other technologies, including SAF, hydrogen and hybridisation, to achieve the decarbonisation goals we have."

Hegeman agrees. "I don't think there is one single solution that is going to work. All these different technologies are going to be necessary across the whole spectrum of commercial aircraft," he says.

With its open rotor technology, Safran claims it has already demonstrated a 15% fuel efficiency gain compared with the Leap. Moving away from a nacelle, as an open rotor does, is one of the options airframers will be considering as they deliberate aircraft configurations.

Perhaps an open rotor design is one of the answers. Perhaps not. Today, it is impossible to judge which technologies, in which order, or in what blend, will flourish. The manufacturers are obliged to spend big across a variety of bets, uncertain as ever if their strategy will be the one that ultimately succeeds.

The flag has truly dropped on this urgent technology race to discover a new low- or zero-carbon aviation engine nirvana. Without doubt, it is a contest the engine manufacturers are relishing. Their tradition says they almost always come up with the answer. They are convinced they will this time too.

Why Honeywell is an eager disruptor

To help describe where it plays in the hybrid engine space, Honeywell has a nifty slide with nine boxes on it that explains the thrust source (turbine, electric, or both) and power source (fuel, battery, or both).

The important part for the US aerospace manufacturing giant is that it can tailor a solution in seven of the nine hybrid architectures to address product opportunities in civil and defence markets, from commercial airliner auxiliary power units (APUs) to helicopter engines and in unmanned air vehicles (UAVs).

"It's our view we need to be prepared for conventional and disruptive solutions," says David Marinick, president of engine and power systems at Honeywell. "We are working on improvements to conventional architecture, such as greater efficiency and better fuel burn for our APUs, including the ability of our turbomachinery to run on sustainable aviation fuels [SAFs]."

But with every passing quarter, "more of our investment is moving toward the disruptive side", says Marinick. A growing element of this disruption is the development of electric, hybrid-electric and hydrogen propulsion technology.

This is familiar territory for Honeywell, says Marinick, for "integrating gas turbines with generators and gearboxes is something we have been doing for decades. We feel we are in our core here."

The next step on its roadmap is a recently announced plan to mate a 1MW Honeywell generator with its HGT1700 APU, which is found on Airbus A350s, to create a turbogenerator. A demonstration unit will run this year with a view to a product that could power air taxis, cargo UAVs and small hybrid-electric aircraft.

"We feel like in many ways we are uniquely suited in this space, because we have so much domain expertise," says Marinick. Part of its DNA is being a partner with the engine OEMs on a host of airframes, and the "opportunity for [further] partnerships is strong", he believes.

There will undoubtedly be new players to this market that will take on the established order, but Marinick is unfazed. "The combination of both might ultimately win the day with the best of both worlds," he says.

"We maintain a very strong interest in hydrogen, both as a fuel cell and as a fuel source," he adds.

Honeywell brought some "compelling technology" into the company last October, with the acquisition of US hydrogen fuel cell system firm Ballard Unmanned Systems, which manufactures engines for UAV applications.

Honeywell

Honeywell is designing powerplants for air taxis, cargo UAVs and hybrid-electric aircraft

While Covid-19 meant it was anything but business as usual for aircraft orders from airlines, a number of powerplant decisions, contracts and aftermarket developments were still finalised over the past year

Engine tracking

Sun Express

Greek start-up opted for Leap engines for its planned fleet of six A320neos

Editor's Note: The below is a selection of the powerplant decisions, support agreements and engine aftermarket developments across the past 12 months covered by FlightGlobal, with additional reporting from Cirium

October 2020

Sky Express picks Leap for its Neos

Greek carrier Sky Express selected CFM International Leap-1A engines to power the four Airbus A320neos it began taking delivery of in November.

CFM valued the engine order at $130 million at list prices.

The airline will also lease two additional Leap-powered A320neos.

SkyExpress owner Ioannis Grylos says: "We chose the Leap engine based on CFM's long-standing experience in powering single-aisle aircraft. The reliability of CFM engines, combined with the Leap fuel efficiency and environmental performance, will be key assets to supporting the sustainable growth of our company."

January 2021

Frontier diversifies with P&W engines

US carrier Frontier Airlines has selected Pratt & Whitney PW1100Gs to power 134 incoming Airbus A320neo-family jets, a move that will diversify its fleet away from complete reliance on CFM International powerplants.

The Denver-based ultra-discount airline, owned by private equity company Indigo Partners, currently operates jets powered only by CFM's Leap-1A and CFM56 engines.

Airbus offers A320neo-family jets with a choice of Leap-1As or P&W's PW1100G geared turbofan.

"The airline is a first-time Pratt & Whitney customer and will operate their GTF-powered A320neo-family aircraft on domestic and international routes in North America," P&W said on 25 January.

The 134 jets that will receive PW1100Gs include 49 A320neos, 67 A321neos and 18 A321XLRs, P&W says. The first of those aircraft is due for delivery to Frontier in 2022. P&W will also maintain those engines through a long-term service contract, the Connecticut-based engine maker adds. Frontier has a total of 156 A320neo-family jets on order. It has not disclosed which engines will power the other 22 jets, according to Cirium fleets data.

Other aircraft in the fleet of all-Airbus operator Frontier include 14 first-generation A320ceos and 17 A321ceos, all powered by CFM56s.

February 2021

SAS keeps with Leap on A320neo

Scandinavian operator SAS has stayed with CFM International for a further batch of engines for its Airbus A320neo-family fleet.

SAS has directly ordered a total of 65 A320neos of which 30 have been delivered so far. It also operates another 15 on lease, including a single A321LR, all of them fitted with the CFM Leap-1A powerplant.

CFM says SAS has again selected the manufacturer for the additional 35 aircraft it ordered in April 2018, topping up its original agreement for 30 placed in June 2011.

The deal covers 78 engines – 70 for the 35 twinjets plus eight spares. It also features a per-hour maintenance agreement bringing the overall list-price value of the order to $2.9 billion.

"We take SAS's trust as a great responsibility to keep supporting their operations with the high-level CFM standards in terms of reliability and utilisation," says CFM chief Gael Meheust.

SAS says the maintenance pact includes spares and also covers the 15 Leap-powered aircraft it has on lease. "This new agreement is part of SAS's fleet upgrade programme that aims to improve efficiency and sustainability performances," it adds.

Volaris adds to P&W commitment

Mexican discount airline Volaris has agreed to power another 80 incoming Airbus A320neo-family jets with Pratt & Whitney PW1100G geared turbofans.

The Hartford-based engine maker confirmed on 11 February that it had signed an agreement with the airline to supply the engines.

P&W competes for A320neo engine sales with CFM International, which offers its Leap 1-A as a power option for the jet.

Volaris has long stuck with engines made by P&W and its affiliate International Aero Engines.

The airline's 84 in-service jets include 54 first-generation A320s powered by IAE V2500s, and 30 PW1100G-powered A320neo-family jets, Cirium fleets data shows.

US low-cost carrier has concluded a long-term service agreement covering 230 International Aero Engines V2500s on its A320ceos

Airbus

Volaris has 43 A321neo aircraft and 56 A320neos on order with Airbus.

With the latest deal, Volaris has committed to receiving a total 124 PW1100G-powered Airbus narrowbodies.

Volaris has also signed a long-term agreement under which P&W will maintain the powerplants.

Air France finalises GTF deal on A220s

Air France-KLM Group in February finalised an order for more than 120 Pratt & Whitney GTF engines to power 60 Airbus A220-300s.

The GTF engine is the sole powerplant option available on the A220, an order for which Air France-KLM first unveiled in the summer of 2019.

Deliveries of the aircraft, which will be operated by Air France, are due to commence in September.

The engines will be supported by Pratt & Whitney through a long-term comprehensive service agreement, with engine maintenance planned to be carried out by AFI KLM Engineering & Maintenance.

Southwest, the biggest Max customer, placed a follow-on order for 100 Max 7 aircraft on 29 March

March 2021

Southwest Max order boosts CFM

Southwest Airlines signed a contract with CFM International for Leap-1B engines to power another 100 Boeing 737 Max aircraft after its follow-up commitment for the type announced at the end of March.

The US carrier was launch customer for the engine, the sole powerplant option available on the Boeing Max aircraft. Southwest, the biggest Max customer, placed a follow-on order for 100 Max 7 aircraft on 29 March.

May 2021

IndiGo picks CFM to power new jets

Indian budget carrier IndiGo has chosen the CFM International Leap-1A for another 310 Airbus A320neo-family aircraft.

It operates A320neos and A321neos with the Leap-1A and rival Pratt & Whitney PW1100G powerplant. But the selection of 620 new engines – plus spares – cements CFM as the primary supplier to airline's re-engined fleet. The Leap-1A will be used on aircraft including IndiGo's new long-range A321XLRs.

Aftermarket news

June 2020

P&W adds Maine MRO capabilities

Pratt & Whitney will be expanding its North Berwick, Maine, facility to include MRO capabilities for the PW1100G geared turbofan.

The expansion is part of a $12.5 million investment the engine maker is pumping into the plant. P&W adds that the investment "bolsters" its global PW1100G MRO network and "accelerates growth by utilising the facility's existing expertise".

The North Berwick plant, which employs more than 2,000 people, manufactures components and parts for commercial and military engines.

While P&W has not gone into detail over what the expansion will entail, it says: "The transformation will consist of upgrades to the current space, increasing efficiencies to help minimise disruption to the current flow of operations and allowing for a seamless transition as the facility takes on a new role."

July 2020

JetBlue inks deal to support V2500

JetBlue Airways signed a 13-year fixed-price support agreement with International Aero Engines covering 230 V2500 engines that power the airline's A320ceo family fleet.

Chief financial officer at the US carrier, Steve Priest, says: "The V2500 engine has been the workhorse of the JetBlue fleet since the airline's inception.

"This agreement provides predictable maintenance and supports efficient operations needed to serve our customers for many years to come."

September 2020

LHT to open up Dublin repair shop

Lufthansa Technik (LHT) will open an engine repair station in Dublin in early October to meet increased demand for limited repairs that keep engines flying.

The new facility is part of the MRO provider's mobile engine services network, and will be used to conduct repairs on site or at customer facilities.

"These solutions extend an engine's time-on-wing and... enable airlines to postpone or even avoid cash-intensive major overhaul shop visits," the company says.

Dublin will be the fifth engine repair station in the network. Existing facilities are located in Frankfurt, Montreal in Canada, Tulsa in the USA, and the Chinese city of Shenzhen.

The new site in the Irish capital – close to the aircraft leasing community, LHT notes – has five repair bays and will employ more than 20 mechanics. It will initially support CFM International CFM56-5B and -7B engines, which power Airbus A320ceos and Boeing 737NGs, respectively.

Ameco in China first for PW1100G

Pratt & Whitney has opened its first PW1100G geared turbofan MRO centre in China, by adding Beijing-based Ameco to its global network of MRO providers.

Ameco will also be Asia's fourth PW1100G MRO centre, after Eagle Services Asia in Singapore, as well as IHI and Mitsubishi Heavy Industries Aero Engines in Japan.

P&W adds that by the end of the year, there will be 10 active PW1100G MRO centres in the world, including Ameco.

Chinese Operators of the type include Ameco parent company Air China, as well as China Southern Airlines and Sichuan Airlines.

November 2020

CFM wins Chinese carrier MRO work

CFM International has inked long-term contracts with China Eastern Airlines and Zhejiang Loong Air for the maintenance of Leap-1A engines on their Airbus A320neo aircraft.

The engine maker signed a 12-year, rate-per-flight-hour agreement with both carriers, which will see it base maintenance costs on a per-engine flight-hour basis. Both carriers also placed orders for spare Leap-1A engines, one of the two powerplant options for the A320neo family.

With China Eastern, the contract covers 36 A320neo aircraft, which are operated by the China Eastern Group of carriers. China Eastern also ordered six spare Leap-1As.

CFM also says the contract adds to a 2017 agreement signed between both parties, when China Eastern picked CFM to power its A320neo fleet.

As for Loong Air, CFM will provide maintenance for Leap engines on its leased fleet of A320neo family aircraft.

OGMA takes on PW1100G support

Embraer's Portuguese maintenance affiliate, OGMA, has become an authorised Pratt & Whitney PW1100G maintainer, a move Embraer says reflects its push towards revenue diversification.

OGMA is now part of P&W's "authorised maintenance centre network", giving P&W its first MRO presence in Portugal, says Embraer.

Notably, OGMA will service PW1100Gs – the geared turbofan that powers Airbus A320neo-family aircraft. Embraer services and support chief executive Johann Bordais tells FlightGlobal the work will help Embraer's service business increase revenue by being more "agnostic".

"It is very big milestone in our strategy to remain one of the centres of excellence in engine maintenance in the world," he adds.

Bordais expects that OGMA will expand in future years to maintain other GTF variants, such as the PW1700Gs and PW1900Gs that power E-Jets E2s.

2,200

Number of shop visits overseen by SR Technics covering the CFM International Leap-1B engine

Air Serbia selects MTU for V2500s

MTU Aero Engines has won a contract to maintain International Aero Engines V2500s powering Air Serbia's Airbus A320-family fleet.

The exclusive, six-year deal spans MRO services, trend monitoring and spare engines, MTU says.

Air Serbia's fleet comprises 21 aircraft. The airline's website indicates that the fleet includes 11 A319s and one A320. These are operated alongside an A330 and ATR 72 turboprops at the mainline, and Boeing 737 Classics at charter subsidiary Aviolet.

Air Arabia signs CFM support deal

UAE carrier Air Arabia has signed a nine-year agreement with CFM International under which it will support the airline's fleet of six Leap-1A-powered A321neo aircraft.

The agreement builds on a relationship with CFM that includes a fleet of 52 CFM56-powered A320ceo aircraft and six A321neo-LRs.

Air Arabia, which signed for 120 A320neo aircraft at the Dubai air show in November 2019, is the first Leap-powered A321neo operator in the Middle East.

Uganda Airlines took delivery of its first A330neo, powered by the Rolls-Royce Trent 7000, in December 2020

Airbus

December 2020

P&W grows GTF network in Asia

Pratt & Whitney in December expanded its PW1100G geared turbofan MRO centre in Asia, adding new providers in China and Taiwan.

On 3 December the company announced that MTU Maintenance Zhuhai – a joint venture between China Southern Airlines and German engine specialist MTU Aero Engines – would join the network of MRO providers. It becomes the second PW1100G MRO centre in mainland China alongside Ameco.

P&W then in mid-December announced that China Airlines, through its MRO division, would provide engine MRO for the P1100G at its facility in Taiwan.

January 2021

MTU adds P&W shop in Zhuhai

MTU Aero Engines is building a second overhaul facility near its MRO joint venture with China Southern Airlines' parent in Zhuhai, which will be dedicated to servicing Pratt & Whitney PW1000G engines.

Scheduled to become operational in 2024, the new site – to be named MTU Maintenance Zhuhai Jinwan branch – will have an "initial" capacity to handle 250 engines per year and employ around 600 staff "according to current estimates", MTU says.

It will have its own test cell and "focus on Pratt & Whitney narrowbody engines", the Munich-headquartered company says, without disclosing precise models.

February 2021

Uganda Airlines seals Neo support

Uganda Airlines has signed a TotalCare agreement with Rolls-Royce covering its two new Trent 7000-powered Airbus A330neos.

The Ugandan carrier took delivery of its first A330neo, which is exclusively powered by the R-R engine, in December 2020 and the second in January 2021.

Uganda Airlines chief executive Cornwell Muleya says: "We are proud to include our new Rolls-Royce powered Airbus A330neos into our fleet and this agreement will ensure that our Trent 7000 engines will be maintained to world-leading levels of service."

April 2021

Rolls-Royce seals DHL Trent pact

DHL Express has concluded an aftermarket service agreement with Rolls-Royce for Airbus A330-powering Trent 700 engines.

R-R says the hour-based contract covers eight Trent-powered A330 freighters currently in operation at DHL and any Trent 700 engines that will be added to the operator's fleet in future.

DHL operates purpose-built A330-200Fs and converted A330 freighters, the engine maker notes.

In 2017, DHL became the first A330 passenger-to-freighter (P2F) operator, with an A330-300 converted at Elbe Flugzeugwerke in Germany. But that aircraft is powered by Pratt & Whitney PW4000 engines.

May 2021

SR Technics adds Leap-1B service

Maintenance firm SR Technics is to extend its servicing portfolio to cover the CFM Leap-1B engine for the Boeing 737 Max.

The company says it is aiming to achieve certification approval for work on the powerplant at its Zurich facility by the first quarter of next year.

SR Technics already carries out maintenance on the CFM56, which powers earlier 737 variants as well as the Airbus A320 family.

It states that it has overseen more than 2,200 shop visits with this powerplant.

As a result of an agreement with the engine manufacturer – a venture between Safran and GE Aviation – at the end of 2020, it is to broaden its remit to the Leap-1B.

"[We are] confident [we] can establish initial capabilities on the Leap-1B in less than a year," states SR Technics.

Vice-president of new engines Florent Leforestier says the measure is a "natural and essentially necessary move forward" for the company.

SR Technics already provides line maintenance for the 737 Max. CFM International chief Gael Meheust says the extension will continue the manufacturer's "long-standing relationship" with the servicing firm.

Engine options by commercial aircraft

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

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

Commercial aircraft by engine type

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

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

SUSTAINABILITY
A CLEAR AMBITION

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

cfmaeroengines.com

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

cfm