The A321neo entered service with expectations of a 16-17% lower fuel burn over its older generation counterpart the A321ceo. The A321neo's performance is analysed on five routes of 227nm to 1,821nm.

A321neo fuel burn & operating performance

The A321neo, which entered service with Virgin America in April 2017, should deliver the lowest unit cost per available seat-mile (ASM) of any narrowbody. The new engine option (neo) variants of the A320 family were launched in 2010 to replace current engine option (ceo) variants of the A319, A320 and A321. The main feature of the neo variants is an option of two new ultra-high bypass engine types that will provide a 16-17% reduction in fuel burn over the ceo variants. The fuel burn performance of an initial variant of the A321neo is examined here, and compared with other types that include the A321ceo.

The neo variants also feature improvements to the passenger cabin, which allow increases in seat numbers, without apparently affecting comfort levels. The aircraft cabin flex (ACF) system for the passenger cabin includes changes such as new door positions, which allow higher seat numbers. The neo variants are, therefore, expected to have a fuel cost per ASM lower than the ceo models.

The A321neo has the same fuselage and wing as the A321ceo. The A321ceo was the second most popular member of the A320ceo family. More than 9,355 have been ordered, of which the A320ceo accounts for about 6,100. Firm orders for the A321ceo have reached about 1,800 units, about 19% of all ceo members.

The A321neo is more successful in comparison, and has attracted about 1,650 firm orders, accounting for 29% of all firm orders for neo models. The A321neo has two engine options: the CFM LEAP-1A and the Pratt & Whitney (PW) geared turbofan (GTF) PW1000G. The LEAP-1A variants for the A321neo are the -1A30, -1A32, -1A33 and -1A35 which are rated at 32,160lbs.

There are several series of the PW1000G for the A320neo, the Bombardier C Series, and the Mitsubishi regional jet (MRJ). The PW1000G series for the A320neo family is the PW1100G, with the PW1133G rated at 33,000lbs thrust for the A321neo.

The ultra-high bypass ratios of these engines is the main factor contributing to the aircraft's lower absolute fuel burn compared to earlier generation A320ceo family types. The neo variants of the A320 and A321 have a large number of specification variants for airlines to choose from. The highest gross weight neo models are heavier, however, than their heaviest ceo counterparts. The neo variants also have higher fuel capacity. The combination of more fuel-efficient engines, higher gross weight and higher fuel volume provides the neo variants with longer range than the ceo variants.

A321oneo alternatives

As well as being an evolution from the A321ceo, the A321neo has been introduced to the market partly as a potential replacement for the 757-200. The A321neo has a standard two-class seat capacity of 192 seats, eight more than the A321ceo, which takes the A321neo, with a ACF cabin, close to the capacity of a 757-200.

The A321neo can also absorb growth on routes operated by smaller types. The A321neo is close in size to the 737-900, which has a standard OEM two-class capacity of 177 seats. Like the A321ceo, 737-900 and 757-200, the A321neo can serve most US domestic and trans-continental North American routes, as well as a large number of trans-European, Chinese domestic and intra-Asia Pacific routes.

In addition to the closest-sized A321ceo, 737-900 and 757-200, the A321neo's operating performance and fuel burn should be compared to those of smaller family members, including the A320ceo, A320neo and 737-800. The performance of these three types has already been analysed on routes with tracked distances of 227nm to 1,821nm *(see A320neo fuel burn & operating performance, Aircraft Commerce, December 2016/January 2017, page 18; and CS300 fuel burn and operating performance, Aircraft Commerce, October/November 2017, page 27).*

Aircraft types

The A321neo's fuel burn and operating performance have been compared with those of six other main types, three of which have two alternative engine variants. These three types are the A320ceo, the A320neo and the A321ceo. A high gross weight variant of each has been analysed here.

The types included with a single engine type are the 737-800 with winglets, the 737-900ER with winglets, and the 757-200 with winglets. All three types have winglets fitted as an option by Aviation Partners Boeing.

There are several gross or maximum take-off weight (MTOW) variants of the 737-800, 737-900ER and 757-200. The

When compared to the A321ceo, the A321neo has an absolute fuel burn that is 15-17% lower. On initial analysis, the A321neo seems to meet its initial expectations at product launch. This percentage difference between the two is enhanced in the A321neo's favour due to its higher seat count because of its ACF interior.

highest MTOW variants of the 737-800 and 737-900ER and a high gross weight variant of the 757-200 have been analysed here.

There are, therefore, 10 different aircraft types and variants included in this analysis. Weight, engine variant, fuel capacity and passenger payloads are summarised *(see table, page 16)*.

All aircraft have been examined with two-class seat numbers that reflect typical mainline configurations. All 10 types have a standard six-abreast economy class configuration.

There has been wider variance in narrowbody dual-class cabin configurations in recent years, however, as airlines seek to differentiate product offerings. Variations include: four-abreast seating in the premium cabin to provide wider seats; closing off centre seats in a six-abreast arrangement to provide four window and aisle seats that are wider than economy-class seats; and reducing the economy-class seat pitch from 31 inches to 29 inches to accommodate more seat rows or a more generous seat pitch in business class.

Some airlines also have simplified cabin service, resulting in fewer galleys that free up space to allow for more economy cabin seats.

The A320ceo is the smallest type examined here. As with the CS300 fuel burn and operating performance analysis *(see CS300 fuel burn and operating performance, Aircraft Commerce, October/November 2017, page 27)*, the seat numbers used for the A320ceo are 153 *(see table, page 16)*.

The A320neo has a re-configured cabin, and uses the cabin flex system, so it has a dual-class seat capacity of 161; eight more than the A320ceo *(see table, page 16)*.

The 737-800 has a two-class capacity of 158 seats, while the larger 737-900ER has a two-class capacity of 179.

The A321 is about 13 feet longer than the 737-900ER. The A321 also has four sets of main cabin doors, while the 737-900ER has smaller overwing exits. The A321ceo has a two-class seat capacity of 184 in this analysis.

The largest 757-200 was traditionally operated by mainline US carriers that included American Airlines, America West, Continental, Delta, Northwest, United and USAirways. Other mainline operators were British Airways, Icelandair, China Southern, China Southwest, Shanghai Airlines and Xiamen Airlines.

The average two-class seat capacity for these airlines is 192, based in most cases on a 31-inch seat pitch in economy class. Many of these seat configurations are older layouts that were used up to 15 years ago. Since then some operators have retired their 757 fleets, while others have reconfigured their aircraft with spacious three-class cabins. This is especially the case with US airlines that have adopted their 757-200s for medium- and long-range operations.

Aircraft specifications

The A321neo has the same fuselage length and wing as the A321ceo, but the A321neo has adopted the new ACF cabin. To date, Airbus has released weight specification for seven different A321neo variants that have MTOWs ranging from 196,211lbs to 213,848lbs. The highest gross weight and highest maximum landing weight (MLW) A321neo variant has been included in this analysis *(see table, page 16)*.

There are several fuel capacity options for the A321neo. The standard specification is a usable fuel volume of 6,205US gallons (USG). There is the option to fit up to two auxiliary fuel tanks (ACTs), each with a capacity of 790USG. The aircraft with three auxiliary fuel tanks is referred to as the A321LR.

Since its introduction into service in April 2017, the A321neo is in operation with several carriers, including: Alaska Airlines, Avianca, Lufthansa and SriLankan for the LEAP-powered aircraft, and All Nippon Airways, China Southern, Hawaiian Airlines and Volair for the PW1100G-powered aircraft.

The A321neo variant analysed here has been examined and assessed with the CFM LEAP-1A32 engine. The -1A family has an intake fan diameter of 78 inches, and a bypass ratio of 11.0:1, which is the highest for all engine types powering the 10 aircraft variants analysed here. In comparison, the -1B family that powers the 737 MAX family, has a fan diameter of 69.4 inches and a bypass ratio of 9.0:1. The -1A32 has a take-off thrust rating of 32,160lbs.

The gross weights of the A321neo family overlap the A321-200ceo; the lowest gross weight for the A321neo is less than the highest gross weight of the A321-200ceo at 206,132lbs. The fuel capacities of the A321ceo and A321neo, however, are similar. The neos' higher gross weight and 16-17% lower fuel burn combine to provide it with a longer range

AIRCRAFT SPECIFICATIONS & WEIGHTS

Aircraft type	A32ceo	A320ceo	A320neo	A320neo	737-800	737-900ER	A321ceo	A321ceo	A321neo	757-200
Engine	V2527-A5	CFM56-5B4/P	PW1127G	LEAP-1A26	CFM56-7B26	CFM56-7B27/B3	V2533-A5	V2533-A5	LEAP-1A32	RB211-535E4
Engine bypass ratio	4.8:1	5.7:1	12.5:1	11.0:1	5.1:1	5.1:1	4.5:1	4.5:1	11.0:1	4.3:1
MTXW - lbs	170,638	170,638	175,047	175,047	175,267	188,200	197,093	207,014	215,833	250,996
MTOW - lbs	169,756	169,756	174,165	174,165	174,200	187,700	196,211	206,132	213,848	250,004
MLW - lbs	145,505	145,505	148,592	148,592	146,300	157,300	166,449	171,520	174,606	209,990
MZFW - lbs	137,789	137,789	141,757	141,757	138,300	149,300	157,631	162,701	166,669	184,086
OEW/DOW - lbs	93,256	93,256	95,901	95,901	97,663	97,003	114,640	108,027	119,711	137,789
Max payload - lbs	44,533	44,533	45,856	45,856	40,637	52,297	42,991	54,674	46,958	46,297
Fuel capacity - USG	6,506	6,506	6,303	6,303	6,875	7,007	7,037	7,028	10,366	11,492
Dual-class seat	153	153	161	161	158	179	184	184	192	192
Passenger payload - lbs	35,343	35,343	37,191	37,191	36,498	41,349	42,504	42,504	44,352	44,352
Remaining cargo payload - lbs	9,190	9,190	8,665	8,665	4,139	10,948	487	12,170	2,606	1,945
Range with full passenger payload - nm	2,800-2,900	2,800-2,900	3,300	3,300	2,500	2,750	2,050	2,050	3,400	3,300
MTOW/seat - lbs	1,110	1,110	1,082	1,082	1,103	1,049	1,066	1,120	1,114	1,302
OEW/DOW/seat - lbs	610	610	596	596	618	542	623	587	623	718

of up to 3,400nm.

The A320ceo analysed here has an MTOW of 169,756lbs, a MLW of 145,505lbs and a fuel capacity of 6,506USG *(see table, this page)*. This weight variant is one of more than 20 different available weight specifications. The lowest MTOW for the A320ceo is 145,505lbs, and the highest certified MTOW is 171,961lbs.

The two engine variants used are the International Aero Engines V2527-A5, rated at 24,800lbs, and the CFM International CFM56-5B4/P, rated at 27,000lbs. The V2725-A5 has a bypass ratio of 4.8:1, while the CFM56-5B4/P has a bypass ratio of 5.7:1.

The fuel capacity of 6,506USG gives the A320-200ceo a range of 2,800-2,900nm with a full payload of 153 passengers. This is an average passenger weight of 231lbs, including a baggage allowance.

The A320neo included in this analysis has an MTOW of 174,165lbs. There are 11 weight specification options that have so far been certified. The weight variant used in the analysis has the highest MTOW of 174,165lbs, and the highest MLW of 148,592lbs *(see table, this page)*. The aircraft also have the standard fuel capacity of 6,303USG, 202USG less than the A320-200ceo variants used in the analysis.

The A320neo's empty weight is about 2,650lbs heavier than the A320ceo, and the A320neo also has other higher structural weights.

The A320neo variants used in this analysis are equipped with two engine options: the Pratt & Whitney PW1127G, rated at 27,000lbs thrust, and the CFM LEAP-1A26, rated at 26,000lbs thrust. The two engines have bypass ratios of 12.5:1 and 11.0:1. The PW1127G has an intake fan diameter of 81 inches, versus the LEAP-1A's fan diameter of 78 inches. Both engines have wide fan diameters, and, therefore, high propulsive efficiency. This allows the A320neo to have 13.0-17.0% lower fuel burns than the A320ceo counterparts *(see A320neo fuel burn & operating performance, Aircraft Commerce, December 2016/January 2017, page 18)*.

The A320neo's fuel capacity, high gross weight and fuel-efficient engines give these variants a range of 3,300nm with a full payload of 161 passengers.

The 737-800 variant included in this analysis is fitted with optional winglets, and is the highest of three MTOW specification variants, at 174,200lbs. The aircraft has an MLW of 146,300lbs, a fuel capacity of 6,875USG, and is equipped with CFM56-7B26 engines rated at 26,300lbs *(see table, this page)*. These have a bypass ratio of 5.1:1, which is the lowest of all engines for the 10 aircraft types analysed here.
The 737-800 is examined with a two-class layout of 158 seats. In this configuration, the aircraft has a range of about 2,500nm with a full passenger load *(see table, page 16)*.

The 737-900ER is the largest narrowbody type currently manufactured by Boeing, and so it is the nearest competitor to the A321. The 737-900ER's average two-class seat capacity of 179 puts it close to the A321ceo, which is just five seats larger. The 737-900 and -900ER are operated by carriers that include Alaska Airlines, Continental Airlines, Delta Air Lines, United Airlines, El Al, Jet Airways, Korean Air, Lion Air and Turkish Airlines.

The 737-900ER included in this analysis is one of two variants with the highest MTOW available of 187,700lbs. It also has an MLW of 157,300lbs and fuel capacity of 7,007USG *(see table, page 16)*.

The 737-900ER is powered by the CFM56-7B27/B3, which is rated at 27,300lbs of thrust and has a bypass ratio of 5.1:1. As with the CFM56-7B26 powering the 737-800, the -7B27/B3 has the lowest bypass ratio of all engines powering the 10 aircraft variants included in this analysis.

The 737-900ER has a range of about 2,750nm with a full payload of 179 passengers.

Of the two A321-200ceo variants in this analysis, one has a medium-level gross weight, and the other the highest possible gross weight. Both variants are powered by the V2533-A5 engine, rated at 33,000lbs of thrust. This has a fan diameter of 6.35 inches, and a bypass ratio of 4.5:1, the lowest of all engine types for aircraft included in the analysis.

There are 12 A321-200ceo weight specification variants, with MTOWs ranging from 171,961lbs to 206,132lbs *(see table, page 16)*. The two variants used are listed by Airbus as WV000 and WV011. The higher gross weight aircraft, WV011, is also equipped with winglets.

Both variants have usable fuel volumes of 7,051USG. This is the standard volume of 6,261USG for a V2500-powered A321ceo, plus an additional 790USG provided by a single ACT auxiliary fuel tank. Fuel capacity is, however, 3,315USG less than the A321neo included in this analysis. In this configuration, the A321ceo variants have a non-stop range of about 2,400nm with a full load of 184 passengers.

The A321ceo is used widely by major airlines around the world, including: Aeroflot, Air China, Vietnam Airlines, Cathay Pacific/Dragonair, China Eastern, Air Canada, jetBlue Airways, American Airlines, Air France, Alitalia, Finnair and Lufthansa. As with other types, seating and cabin configurations vary. Two-class seat numbers vary from 169 to 200. Average two-class capacity is 184 seats; eight fewer than the A321neo.

The 757-200 variant included is equipped with RB211-535E4 engines, and has the highest gross weight variant of 255,000lbs and a fuel capacity of 11,492USG. The aircraft has been analysed here with an average seat count of 192 for a two-class configuration that was used by US, European and Chinese airlines for intra-regional operations. This is the same seat count used for the A321neo which has the use of a SCF interior to provide more seats than the A321ceo. In this configuration the aircraft has a range of about 3,300nm *(see table, page 16)*.

An interesting characteristic of relative fuel burn performance between types is weight in relation to seat numbers. The two specifications of MTOW and operating empty weight (OEW) or dry operating empty weight (DOW) are the most relevant in terms of indicating how weight-efficient each aircraft type is compared to seat capacity.

The A320neo variants have slightly lower gross weight per seat than the A320ceo variants. This is because, despite the A320neo's higher gross weight, the ACF allows for increased seat numbers. The same applies to the OEW/DOW per seat for the A320neo compared to the A320ceo.

The 737-800 is closest in seat numbers to the A320neo, with just a three-seat difference between them. The 737-800 has always had a seat capacity advantage over the A320ceo, so the A320neo provides a closer match. The highest gross weight 737-800 variant also has a similar MTOW and OEW/DOW weight per seat to the A320neo.

The 737-900ER has a similar gross weight and lower OEW/DOW weight per seat than the two A320ceo variants examined here. This should give the 737-900ER an advantage over the A321ceo.

As with the A320ceo and A320neo, the A321neo has similar weights per seat to the A321ceo, despite the neo's higher weight specifications. The A321neo's higher seat numbers, thanks to the ACF, compensate for higher weights.

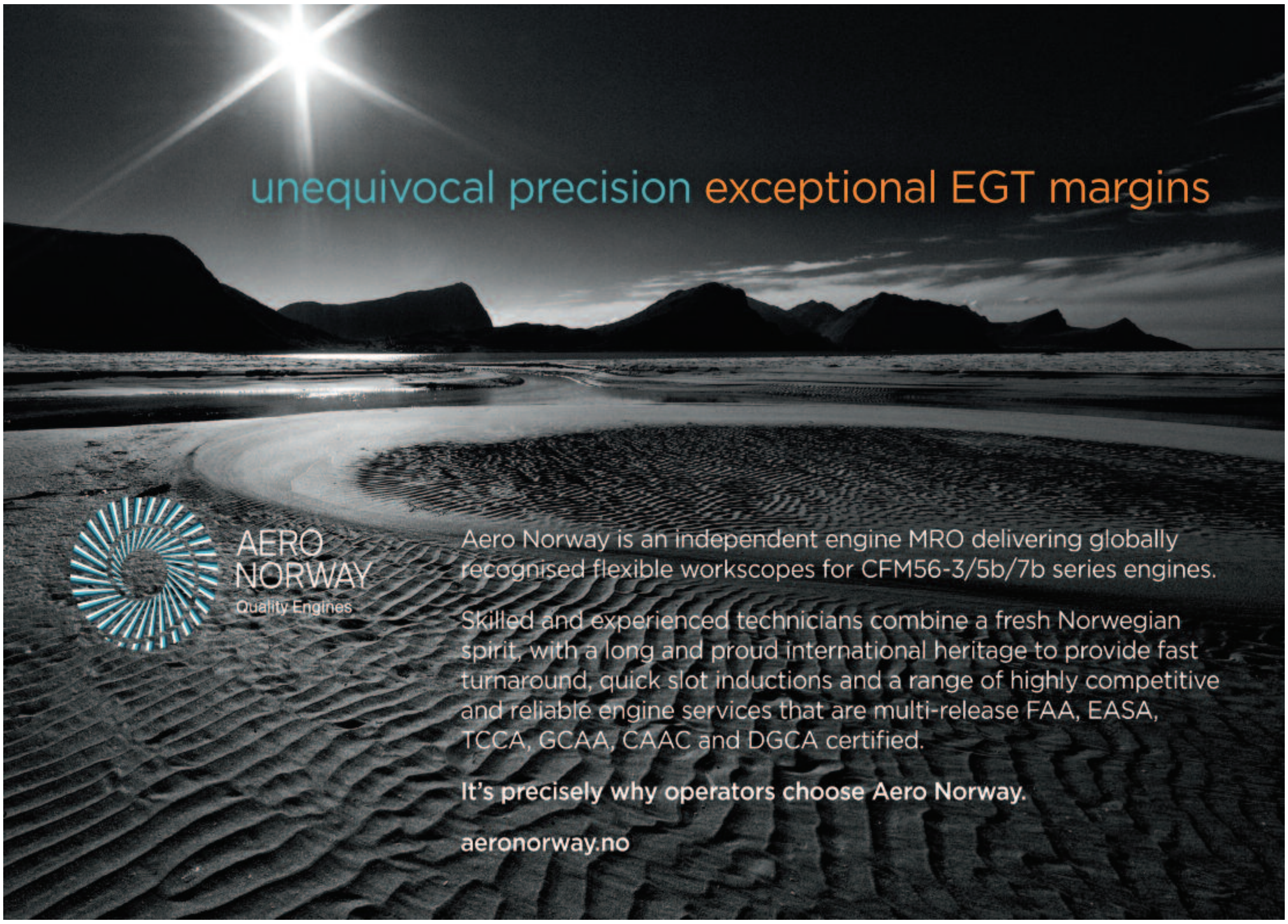
Basis of comparison

The basis of comparing the fuel burn and operating performance of the single A321neo variant with the nine other aircraft types is to analyse the aircraft on five routes. These are the same routes used to analyse fuel burn and operating performance of the A320neo and CS300, and several other similar-sized types *(see A320neo fuel burn & operating performance, Aircraft Commerce, December 2016/January 2017, page 18; and CS300 fuel burn and operating performance, Aircraft Commerce, October/November 2017, page 27)*.

The five routes are European sectors that aircraft of this size may typically operate. All originate from Amsterdam, and go to London Heathrow (LHR), United Kingdom; Dublin (DUB), Ireland; Rome Fiumicino (FCO), Italy; Faro (FAO), Portugal; and Tenerife (TFS), in the Spanish Canary Islands.

These routes have tracked airway distances of 421nm to 2,057nm *(see table, page 18)*.

Performance of the aircraft has been examined on the basis of operating a typical two-class, full-service operation.



ROUTE CHARACTERISTICS

Route	AMS-LHR	AMS-DUB	AMS-FCO	AMS-FAO	AMS-TFS
Flight time - mins	41-46	72-77	109-112	171-173	271-274
Taxi out time - mins	15	15	15	15	15
Taxi in time - mins	20	10	20	12	10
Block time - mins	76-81	97-102	144-147	198-201	296-299
Tracked distance - nm	227	437	733	1,131	1,821
Wind component - kts	-19	-21	4	-17	-16
ESAD - nm	240	449	726	1,180	2,055
Alternate airport & distance - nm	LGW/80	BFS/101	CIA/43	LIS/160	LPA/85

The aircraft are assumed to carry a full payload of passengers, with an allowance of 231lbs per passenger to include baggage. This results in a relatively high payload for each type, and is higher than most scheduled airline operations are likely to experience. The aircraft are still compared, however, on an equal basis. Seat numbers used are: 192 for the A321neo; 153 for the A320ceo; 161 for the A320neo; 158 for the 737-800; 179 for the 737-900ER; 184 for the A321ceo; and 192 for the 757-200.

Performance of the 10 aircraft variants has been analysed with simulated flight plans using the Lufthansa Systems' LIDO/Flight solution. There are a large number of variables that will clearly affect flight and block times and fuel burned for each aircraft to operate each route. These include: payload carried; various operating procedures, such as the number of engines operating during taxi; taxi times; many parameters of the flight profile; weather conditions; speed; and altitude.

There are, therefore, thousands of permutations for operating parameters that can be used to analyse an aircraft on a route. One set has been used here, and these have been applied to all aircraft types for a comparison on an equal basis.

Operating assumptions

There are 10 or 11 main sets of parameters that have to be decided to simulate the operation of the 10 aircraft variants. The first set comprises the aircraft seating configuration and weight specification and engine variants, and is as described *(see table, page 16)*. The second set is the payload carried; this is listed for each of the 10 aircraft variants *(see table, page 16)*.

The other main operating parameters are:

- The flight rules used
- The assumptions in relation to the track taken and altitude or flight level (FL) used assuming availability
- The cruise speed and flight profile used
- The winds and temperatures encountered
- The rules relating to the fuel reserves that are carried
- The number of engines used during taxi
- The taxi and taxi-out times and the related taxi fuel burn
- Time spent holding or delays encountered

International flight rules are used, and these relate to the semi-circular rules on cruising altitudes and FLs. These depend on direction of travel, and require a vertical separation of 4,000 feet for the same direction of travel, and a separation of 2,000 feet for travel or flightpaths in opposite directions.

The route tracks, FLs and cruise altitudes have been optimised by the Lido/Flight solution to achieve lowest total cost for fuel burn, time-related costs, and all navigation and air traffic control (ATC) charges.

The FLs have been optimised in the case of routes from AMS to DUB, FCO, FAO and TFS. The FLs are, therefore, not necessarily the same for all 10 aircraft variants on each route.

The FL on the shortest route, AMS-LHR, is not optimised because the aircraft would be flown ballistically, and so it would not achieve a cruising altitude over the short tracked distance of 240nm. This does not reflect usual operating conditions. Thanks to ATC restrictions and congested airspace, the vast majority of flights reached an FL between FL200 and FL280. In this analysis, FL260 is used for all 10 aircraft variants.

The cruise speed used by Lido is Mach 0.78 on all routes for all aircraft types and variants. Mach 0.78 is the default cruise speed used by the Lido system.

The aircraft's performance is most affected by temperature, particularly at take-off, and winds along the entire route. Average winds and temperatures for the month of June, with 85% reliability are used.

Fuel reserves are a significant issue, and are governed by European Aviation Safety Agency (EASA) standards, which specify fuel needed for diversion to a suitable alternative airport and for contingency. Reserve fuel carried is the sum of en-route contingency fuel, fuel required to fly to the designated alternate airport from the approach position of the arrival airport, and final reserve fuel. A 5% allowance of trip fuel is provided for contingency. Final reserve is fuel for a 30-minute hold at 1,500 feet at the alternate airport.

Flight plans have been calculated on the basis of both engines being used for taxi-out and taxi-in. The taxi-out and taxi times at the five destinations are taken from the Lido database. Taxi-out time at AMS is 15 minutes, while taxi-in times are 10 minutes for DUB and TFS, 12 minutes for FAO, and 20 minutes for LHR and FCO *(see table, this page)*.

The total taxi-out and -in times for the five routes are 25 minutes for AMS-DUB and -TFS, and up to 35 minutes for AMS-LHR and AMS-FCO. Taxi fuel burns add 1,000-2,220lbs and 150-340USG of fuel per trip.

Fuel density is taken as 6.55lbs per USG. The Lido planning system provides fuel burns in lbs, and this conversion factor is used to derive fuel consumption in USG.

As described, the aircraft types were analysed with full passenger payloads, and an allowance of 231lbs per passenger, including luggage. This resulted in the aircraft types carrying the following payloads:

- A320ceo: 35,343lbs
- A320neo: 37,191lbs
- 737-800: 36,498lbs
- 737-900ER: 41,349lbs
- A321ceo: 42,504lbs
- A321neo: 44,352lbs
- 757-200: 44,252lbs

Examining the 10 variants with a full passenger payload allows analysis of fuel burn per seat across a range of passenger demands on each route. It also permits an analysis of each type's fuel burn and operating performance close to maximum payload. Each type has a small amount of remaining cargo payload available.

Routes

Performance of the 10 aircraft variants is examined on the five routes originating from AMS on a uni-directional basis. The five routes have tracked distances ranging from 227nm to 1,821nm. With the effect of en-route headwinds on four of the routes, the equivalent still air distances (ESADs) of these five routes are increased to 240-2,057nm. A tailwind is experienced on AMS-FCO, reducing its ESAD to less than the tracked distance.

Main operational factors and characteristics of the five routes are summarised *(see table, page 18)*. The main factors are the taxi-out and taxi-in times, the tracked distance, the en-route wind component, the ESAD, and the alternate airport and distance to it.

The routes operate in a westerly or south-westerly direction from AMS. The aircraft, therefore, experience a headwind or headwind component of 16 to 21 knots on four of the five routes. AMS-FCO has a small tailwind of four knots, and so marginally shortens the ESAD compared to the tracked distance by seven nm. Flight times on the five routes are 42-274 minutes *(see table, page 18)*.

On each route there are small differences between types in the resulting ESAD because of issues relating to flight profiles. Different types have different climb and descent profiles.

Aircraft performance

The flight plans generated for the 10 aircraft variants on the five routes are for full passenger payloads, as described. The resulting performance of the ASMs, block times and absolute fuel burn for each aircraft on each of the five routes is summarised *(see table, page 20)*. Fuel consumption per ASM is then calculated and included in the table.

The number of ASMs is the product of available passenger seat numbers and tracked distance. The number of ASMs on AMS-LHR varies from 34,731 for the A320ceo, to 43,584 for the A321neo and 757-200 on AMS-LHR. This increases to 302,175 for the A320ceo and up to 380,736 for the A321neo and 757-200 on AMS-TFS.

The ESADs for each aircraft variant on each of the five routes are listed *(see table, page 20)*. While the tracked distance is the same for each variant on the same route, there is a small difference in the ESAD between aircraft variants. This is because flight profiles differ between types, so the wind component has different overall effects over the length of the route.

The ESAD on AMS-LHR, for example, varies from 249nm to 253nm. The spread of ESADs on AMS-TFS is 1,991-2001nm *(see table, page 20)*.

Fuel burns are listed in absolute terms in USG, and also in burn per ASM *(see table, page 20)*. Given that the aircraft have been analysed with full passenger payloads, the more important comparison is relative difference in burn per ASM between the most fuel-efficient type and the nine other aircraft.

The A321neo variant analysed has the highest gross weight and MTOW of all variants currently available. The aircraft has the lowest fuel burn per ASM on all five routes of all types and variants with the exception of the two A321neo variants *(see table, page 20)*.

Clearly, the fuel burn per ASM and the relative differences of burn per ASM between types depend on actual seat numbers. The A321neo here has eight more seats than the A321ceo, taking into consideration the effects of cabin flex on seat capacity. The A321neo's capacity of 192 seats is also equal to the 757-200. It is possible, however, that the A321neo could have an even higher seat count because of the cabin flex interior. This would give the aircraft a higher capacity than both used in this analysis, and

BLOCK FUEL BURN PERFORMANCE OF 737-800, A320CEO, A320NEO, 737-700 & 737-800 WITH FULL PAX PAYLOAD

City-pair	Aircraft variant	Engine variant	Seats	Payload carried lbs	ESAD nm	ASMs	Block time min	Block fuel USG	Fuel /ASM
AMS-LHR	737-800	CFM56-7B26	158	36498	252	35,866	79	895	0.0250
	A320ceo	CFM56-5B4/P	153	35,343	251	34,731	77	884	0.0254
	A320ceo	V2527-A5	153	35,343	250	34,731	78	854	0.0246
	A320neo	CFM LEAP-1A26	161	37,191	251	36,547	76	796	0.0218
	A320neo	PW1127G	161	37,191	251	36,547	76	783	0.0214
	737-900	CFM56-7B27	179	41,349	252	40,633	79	920	0.0226
	A321ceo	V2533-A5	184	42,504	249	41,768	77	1,005	0.0241
	A321ceo winglets	V2533-A5	184	42,504	251	41,768	77	976	0.0234
	A321neo	CFM LEAP-1A32	192	44,352	251	43,584	77	895	0.0205
	757-200	RB211-535E4	192	44,352	253	43,584	81	1,275	0.0292
AMS-DUB	737-800	CFM56-7B26	158	36498	487	69,046	100	1,247	0.1810
	A320ceo	CFM56-5B4/P	153	35,343	486	66,861	98	1,230	0.0184
	A320ceo	V2527-A5	153	35,343	486	66,861	99	1,161	0.0174
	A320neo	CFM LEAP-1A26	161	37,191	485	70,357	97	1,051	0.0149
	A320neo	PW1127G	161	37,191	485	70,357	97	1,038	0.0148
	737-900	CFM56-7B27	179	41,349	489	78,223	100	1,303	0.0167
	A321ceo	V2533-A5	184	42,504	488	80,408	98	1,427	0.0177
	A321ceo winglets	V2533-A5	184	42,504	485	80,408	98	1,350	0.0168
	A321neo	CFM LEAP-1A32	192	44,352	488	83,904	98	1,237	0.0147
	757-200	RB211-535E4	192	44,352	488	83,904	102	1,688	0.0201
AMS-FCO	737-800	CFM56-7B26	158	36498	757	115,814	146	1,778	0.0153
	A320ceo	CFM56-5B4/P	153	35,343	757	112,149	144	1,765	0.0157
	A320ceo	V2527-A5	153	35,343	753	112,149	145	1,658	0.0148
	A320neo	CFM LEAP-1A26	161	37,191	756	118,013	144	1,497	0.0127
	A320neo	PW1127G	161	37,191	756	118,013	144	1,481	0.0126
	737-900	CFM56-7B27	179	41,349	767	131,207	146	1,863	0.0142
	A321ceo	V2533-A5	184	42,504	760	134,872	144	2,053	0.0152
	A321ceo winglets	V2533-A5	184	42,504	756	134,872	144	1,924	0.0143
	A321neo	CFM LEAP-1A32	192	44,352	756	140,736	144	1,787	0.0127
	757-200	RB211-535E4	192	44,352	753	140,736	147	2,407	0.0171
AMS-FAO	737-800	CFM56-7B26	158	36498	1,232	178,698	200	2,623	0.0147
	A320ceo	CFM56-5B4/P	153	35,343	1,231	173,043	199	2,621	0.0151
	A320ceo	V2527-A5	153	35,343	1,225	173,043	199	2,424	0.0140
	A320neo	CFM LEAP-1A26	161	37,191	1,224	182,091	198	2,166	0.0119
	A320neo	PW1127G	161	37,191	1,227	182,091	198	2,148	0.0118
	737-900	CFM56-7B27	179	41,349	1,232	202,449	201	2,763	0.0136
	A321ceo	V2533-A5	184	42,504	1,236	208,104	199	3,067	0.0147
	A321ceo winglets	V2533-A5	184	42,504	1,230	208,104	198	2,837	0.0136
	A321neo	CFM LEAP-1A32	192	44,352	1,236	217,152	199	2,630	0.0121
	757-200	RB211-535E4	192	44,352	1,226	217,152	200	3,499	0.0161
AMS-TFS	737-800	CFM56-7B26	158	36498	2,001	313,314	300	4,075	0.0130
	A320ceo	CFM56-5B4/P	153	35,343	2,000	302,175	298	4,095	0.0136
	A320ceo	V2527-A5	153	35,343	1,991	302,175	299	3,754	0.0124
	A320neo	CFM LEAP-1A26	161	37,191	1,991	318,136	298	3,338	0.0105
	A320neo	PW1127G	161	37,191	1,991	318,136	298	3,121	0.0098
	737-900	CFM56-7B27	179	41,349	2,001	353,883	299	4,300	0.0122
	A321ceo	V2533-A5	184	42,504	1,999	364,872	296	4,788	0.0131
	A321ceo winglets	V2533-A5	184	42,504	2,000	365,056	298	4,402	0.0121
	A321neo	CFM LEAP-1A32	192	44,352	1,999	380,736	297	4,079	0.0107
	757-200	RB211-535E4	192	44,352	1,990	380,736	296	5,406	0.0142

Source: Lufthansa Systems' Lido/Flight

Notes:
1). Lufthansa Systems provided block fuel figures in lbs. These have been converted to USG using 1 USG = 6.55lbs.

Like the A321neo, the A320neo has a 15-17% lower fuel burn compared to its older generation counterpart the A320ceo. This is in the case of CFM-powered aircraft. The difference is smaller at about 11-12% between V2500- and PW1127G-powered A320ceos and A3220neos.

compared to the 757-200.

The other main issue affecting performance of the A321neo variant analysed is the engine type and model with which the aircraft is equipped. The PW1127G-powered A320neo persistently has a lower fuel burn than the CFM LEAP-1A26-powered A320neo on all five routes *(see table, page 20)*. This is not surprising given the PW1127G's higher bypass ratio over the LEAP engine. The A321neo analysed here is, therefore, likely to have a higher absolute burn and burn per ASM than the same variant powered with a PW1133G engine.

Relative fuel burn

The A321neo's burn per ASM is superior to both A320neo variants on the two shorter routes. The A321neo and two A320neo variants are almost on a par in terms of burn per ASM on AMS-FCO, which has an ESAD of 753-760nm.

The A321neo in fact has a small burn per ASM disadvantage over the A320neo in the order of 2% on the two longer routes that are more than 1,200nm *(see table, page 20)*.

Not surprisingly, the two A321ceo variants have the second smallest difference in burn per ASM with the A321neo. The A321ceo equipped with winglets consistently has a lower burn per ASM than the aircraft without winglets; both are powered by the V2533-A5 engine. The aircraft equipped with winglets burns about 3% less fuel than the same standard variant, but this advantage increases to about 8% on the longest route. This clearly illustrates that the winglets provide the main advantage while the aircraft is in the cruise.

The A321ceo variant without winglets has an absolute burn that is about 12.2% higher than the A321neo on the shortest routes, and about 17.4% higher on the longest route. These relative differences are increased when considering the burn per ASM because of the A321neo's eight-seat higher capacity. The A321ceo variant without winglets has a burn per ASM that is 17.1-22.5% higher over the five routes.

The A321ceo equipped with winglets has a smaller difference in absolute burn and fuel consumption burn ASM compared to the A321neo. The A321ceo with winglets, nevertheless, has a 7.7-9.2% higher fuel burn, and a 12.3-13.8% higher burn per ASM than the A321neo.

The difference between absolute fuel burns of the A321neo and the A321ceo variant without winglets indicates that the A321neo's fuel burn is 16-17% lower as claimed. The A321ceo with winglets has its performance enhanced to reduce the A321neo's advantage by about one quarter on shorter routes, but by up to half on longer routes that have a higher portion of the flight in cruise phase.

The older technology and relative inefficiency of the 757-200 are clearly illustrated here. First, the 757-200 has an 8-21.6% higher burn per ASM than the standard A321ceo without winglets, and a 17.8-25.1% higher burn per seat than the A321ceo with winglets, but the 757-200 also has a 32.5-42.4% higher burn per seat and per ASM than the A321neo. This is despite the A321neo and 757-200 being configured with equal seat numbers.

Another illustration of the A321neo's fuel efficiency is that it has almost exactly the same absolute fuel burn on all five routes as the 737-800, despite the A321neo having 34 more seats (equivalent to 21.5% more). The 737-800, therefore, has a burn per ASM that is 20.9-22.5% higher per ASM than the A321neo.

Similarly, the larger 737-900 has a 2.7-5.4% higher absolute burn than the A321neo, and the 737-900 has a 10-13.4% higher burn per ASM than the A321neo.

Relative fuel cost

Fuel prices have risen 50% or more over the past year to about 220 cents per USG. This exacerbates the relative differences between the aircraft types. The A321neo's fuel cost per ASM is 2.36-32.24 cents per ASM on the four longer route of 486-2,001nm. Not surprisingly, it is higher at 6.42 cents per ASM on the short AMS-LHR route which has a short cruise phase at medium altitude.

The difference with the 757-200 is equal to 0.74-1.2 cents per ASM, in the A321neo's favour.

The 737-800 has a 0.62-0.73 cents per ASM higher fuel cost, and the 737-900's is 0.31-0.43 cents per ASM higher than the A321neo.

The A320ceo variants' fuel cost is 0.62-0.78 cents per ASM higher. These differences in fuel cost per ASM are $5-6 per seat for trips of 750-800nm.

Only the A320neo has a fuel cost per ASMs that is comparable to the A321neo. The differences between the three variants are 0.05-0.10 cents.

The initial analysis of the A321neo clearly illustrates its superior fuel efficiency and related economic performance. This is particularly in comparison with the 757-200, but also to a lesser extent the 737 variants the A320ceo, and A321ceo. The A320neo and A321neo series have clear economic advantage. It will be interesting to see how the 737 MAX family performs in comparison. -CW AC

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