The CS300 has been in operation since mid-2016. The aircraft is an all-new, lightweight and new generation aircraft with latest generation PW1500G ultra high bypass engines. Charles Williams examines its operating performance across a range of short-haul routes.

CS300 fuel burn and operating performance

The Bombardier CS300 is an all-new design, and typically has a seat capacity of 145. It entered service in late 2016, and its introduction provided airlines with their first alternative to the smaller and mid-sized variants of the 737 and A320 families that have been available since production of the MD-80 and 737-400 ceased in the mid-1990s.

The CS300 is lighter than its nearest sized Airbus and Boeing alternatives, and is also equipped with a new-generation ultra-high bypass Pratt & Whitney (PW) PW1500G engine. The CS300 also has an all-new maintenance programme, which should give it airframe-related maintenance cost advantages over older types. The CS300 therefore has the potential to offer airlines a fuel and maintenance cost per seat-mile advantage over its rivals. The CS300's fuel burn and operating performance are analysed here on six European routes with tracked distances of 227-1,821nm, and equivalent still air distances (ESADs) of 240-2,057nm.

The CS300 is in operation with Air Baltic and Swiss in Europe. Both airlines have configured the aircraft with 145 seats, in a two-class configuration. This makes the CS300 very close in seat numbers to the 737-400 and MD-81/2/3/8, which are no longer being operated by any first-tier passenger operators.

CS300 alternatives

The closest-sized alternatives to the CS300 are the A319, 737-700, 737 MAX 7, A320, 737-800, and 737 MAX 8.

The A319 is operated in a variety of configurations, and these average 128 seats in two classes *(see table, page 28)*. The 737-700 is configured with an average of 129 seats; and the 737 MAX 7, which has an equal fuselage length to the 737-700, will therefore have the same number. The average of two-class A320 configurations is 153 seats; while the 737-800 and the 737 MAX 8 are 18 inches longer and have an average of 158 seats *(see table, page 28)*. The A320 new engine option (neo), which entered service in January 2016, has a re-configured passenger cabin, in particular in the placing of the toilets and galleys. This allows at least an additional row of economy-class seats. Average capacity is 161 seats *(see table, page 28)*.

In terms of seat numbers, the CS300 therefore sits about halfway between the A319/737-700 and the A320/737-800. Moreover, there are no other commercial aircraft with a seat capacity equal to the CS300, giving it a unique place in the narrowbody market.

To illustrate the relative efficiency of the aircraft's operating performance and fuel burn, the CS300 can be compared with the A320 and 737 family variants that are closest to it in terms of size and relative seat numbers. The A320neo was analysed this way, and compared against the A320, and 737-800 *(see A320neo fuel burn & operating performance, Aircraft Commerce, December 2016/January 2017, page 18)*.

The CS300 and other aircraft are analysed on the same five routes as in the A320neo analysis. The CS300's relative fuel burn efficiency can be quantified either on an absolute fuel burn basis, or on a fuel burn per seat and per available seat-mile (ASM) basis. Moreover, in each case the aircraft should also be compared with several levels of passenger payload. The first of these is with all types carrying the same number of passengers, which limits the number to the seat capacity of the smallest type. This will illustrate the relative fuel burn per seat for the same payload, while also examining the incremental fuel burn and related cost of the remaining types relative to the most efficient aircraft.

The second analysis has each type carrying a payload in proportion to its seat capacity, either at 100% load factor, or a smaller load factor typical of scheduled operations, such as 80-85%. This allows the fuel burn per seat efficiency of each type, which provides different levels of seat capacity according to route network demand, to be examined.

Aircraft types

The CS300 is relatively light for its seat capacity, with a maximum take-off weight (MTOW) of 149,000lbs, which is up to 19,653lbs less than the heaviest variant of the smaller A319, even though the CS300 has a 17-seat advantage. The CS300's gross weight per seat is 1,028lbs, while the A319 is 140lbs heavier at 1,300lbs per seat *(see table, page 28)*. The CS300 also has a lighter MTOW weight option at 132,000lbs, making it even more efficient than the A319 in terms of weight per seat.

The heavier CS300 variant is also more efficient than the A319 on the basis of dry operating empty weight (DOW). Depending on the engine type installed, the CS300's DOW is 85,700lbs, compared to 89,763/89,023lbs for the A319. The CS300 therefore has an empty weight of 591lbs per seat, while the A319 is heavier at 701/695lbs per seat *(see*

AIRCRAFT SPECIFICATIONS & WEIGHTS

Aircraft type	CS300	A319	A319	737-700	A320	A320	737-800	A320neo	A320neo
Engine	PW1521G	CFM56-5B7	V2524-A5	CFM56-7B24	CFM56-5B4/P	V2527-A5	CFM56-7B26	CFM LEAP-1A26	PW1127G
Engine bypass ratio	12.0:1	5.7:1	4.9:1	5.3:1	5.7:1	4.8:1	5.1:1	11.0:1	12.5:1
MTXW - lbs	150,000	167,331	167,331	154,998	170,638	170,638	175,267	175,047	175,047
MTOW - lbs	149,000	166,449	166,449	154,500	169,756	169,756	174,200	174,165	174,165
MLW - lbs	129,500	137,789	137,789	127,998	145,505	145,505	146,300	148,592	148,592
MZFW - lbs	123,000	128,970	128,970	120,500	137,789	137,789	138,300	141,757	141,757
OEW/DOW - lbs	85,700	89,763	89,023	86,642	93,256	93,256	97,663	95,901	95,901
Max payload - lbs	37,300	39,207	39,947	33,858	44,533	44,533	40,637	45,856	45,856
Fuel capacity - USG	5,901	6,303	6,303	7,007	6,506	6,506	6,875	6,303	6,303
Dual-class seat	145	128	128	129	153	153	158	161	161
Passenger payload - lbs	33,495	29,568	29,568	29,799	35,343	35,343	36,498	37,191	37,191
Remaining cargo payload - lbs	3,805	9,639	10,379	4,059	9,190	9,190	4,1396	8,665	8,665
Range with full passenger payload - nm	2,350	2,850	2,900	2,500	2,800	2,900	2,500	3,300	3,300
MTOW/seat - lbs	1,028	1,300	1,300	1,197	1,110	1,110	1,102	1,082	1,082
OEW/DOW/seat - lbs	591	701	695	672	610	610	618	596596	595

table, page 28). The A319 is therefore about 18% heavier per seat on a DOW or operating empty weight (OEW) per seat basis than the CS300.

The CS300 is powered by two variants of the PW1100G: the PW1521G, rated at 21,000lbs thrust; and the PW1524G/PW1525G, both rated at 23,300lbs. The CS300 variant analysed here, with the higher MTOW of 149,000lbs, is powered by the PW1521G *(see table, this page).*

The PW1100G family has a geared turbofan configuration, which gives it a very high bypass ratio. There are six sub-families of the Pratt & Whitney (PW) PW1000G, with the PW1500G powering the Bombardier C Series. The PW1000G family has bypass ratios ranging from 9.0:1 to 12.5:1, and these are higher than any of the CFM56-5B, CFM56-7B and V2500 engines powering the A319/20ceo and 737NG variants. These are in the range of 4.8-5.7:1 *(see table, this page).*

The PW1500G variants have a bypass ratio of 12.0:1, which is one of the highest of all PW1000G variants *(see table, this page).* PW has used a high bypass ratio for the PW1000G family to achieve the highest possible level of propulsive efficiency and so a lower fuel burn than previous generation engines.

The CS300 has a fuel capacity of 5,901 US Gallons (USG). This gives the aircraft a range of about 2,350nm with a full passenger payload under standard operating conditions *(see table this page).*

The variants and specifications of the A319, 737-700, A320neo, and 737-800 used in this analysis are summarised *(see table, this page).* The weight variant of the A319 used is one of 14 options. The variant used has the second highest MTOW of 166,449lbs; the heaviest being 168,653lbs. A lighter variant of the A319, with an MTOW of 149,500lbs was also examined. This can carry a full passenger load on four of the five routes with an ESAD of up to 1,180nm, but has a payload restriction on the longest route. A higher gross weight variant was therefore examined.

The weight variants of the A319 used are therefore about 8,000lbs heavier than to the CS300, despite the A319 having 17 fewer seats. The 737-700 variant used has 16 fewer seats, but has almost the same MTOW as the CS300.

The A319 has been analysed with both main engine types available for the current engine option (ceo): the CFM56-5B7 rated at 27,000lbs thrust; and the V2524-A5, rated at 24,480lbs thrust. The CFM56-5B7 has a bypass ratio of 5.7:1, while the V2524-A5 has a bypass ratio of 4.9:1 *(see table, this page).* The A319 aircraft has a fuel capacity of 6,303USG, and a maximum range of 2,850/2,900nm with a full passenger payload.

The 737-700 variant analysed is a higher gross weight model, with an MTOW of 154,500lbs. This variant is fitted with winglets, and powered by the CFM56-7B24. It is rated at 24,200lbs thrust and has a bypass ratio of 5.3:1 *(see table, this page).* It also has a fuel capacity of 7,007 USG, and a range of 2,500nm with a full passenger payload of 129.

The weight variant used for the A320ceo has an MTOW of 169,756lbs. This is one of the higher gross weight options. There are 20 different weight specifications to choose from, with MTOWs ranging from 145,505lbs to 171,961lbs. The engine variants used are the CFM56-5B4/P and the V2527-A5 rated at 27,000lbs and 24,800lbs. These engines have bypass ratios of 5.7:1 and 4.8:1 *(see table, this page).* These are the same A320ceo variants featured in the analysis for the A320neo *(see A320neo fuel burn & operating performance, Aircraft Commerce, December 2016/January 2017, page 18).*

The A320ceo has a fuel capacity of 6,506USG, which gives it a range of 2,800-2,900nm with a full passenger payload of 153.

The A320neo has 11 MTOW options at 154,324-174,165lbs. The mid-weight A320neo variant at 174,165lbs is therefore similar to the mid-weight A320ceo. The A320neo, however, has an empty weight about 2,650lbs heavier than the A320ceo, and also other higher structural weights.

The A320neo variants used in this analysis are powered by the PW1127G and CFM LEAP-1A26. These are rated at 27,000lbs and 26,000lbs thrust. These have bypass ratios of 12.5:1 and 11.0:1, so will have similar levels of propulsive efficiency and fuel burn characteristics to the C Series. These two A320neo variants are the same used in the A320neo's fuel burn and operating performance analysis *(see A320neo fuel burn & operating performance, Aircraft Commerce, December 2016/January 2017, page 18).*

The CS300 has a fuel burn that is up to 14% lower than the A319ceo and 737-700, despite them having 12-13% fewer seats. The CS300 also has 21 and 23%% lower fuel burn per ASM than the 737-800 and A320ceo on typical short-haul routes, despite their larger size and seat numbers.

The A320neo does, however, have a slightly smaller fuel capacity than the A320ceo, of 6,303USG. This provides the A320neo with a range of 3,300nm with an eight-passenger greater payload. This longer-range performance indicates the A320neo's fuel efficiency over the ceo variants.

The 737-800 variant analysed has the highest MTOW of 174,200lbs. It is equipped with winglets, and is powered by the CFM56-7B26 rated. This is rated at 26,300lbs thrust, and has a bypass ratio of 5.1:1. It is the same 737-800 variant used in the analysis of the A320neo's fuel burn and operating performance *(see A320neo fuel burn & operating performance, Aircraft Commerce, December 2016, January 2017, page 18)*.

The relative gross weight and empty weights per seat of all aircraft types provide an indication of the CS300's efficiency compared to the eight alternative aircraft types examined *(see table, page 28)*. While larger types generally benefit from economies of scale, the A320, 737-800 and A320neo all have higher MTOWs and OEWs/DOWs per seat than the CS300. The only exception to this is the 737-800's OEW/DOW per seat, which is the same as that of the CS300.

Basis of comparison

A large number of variable factors can affect an aircraft's operating performance on a route. The CS300 and eight other aircraft variants have been analysed on five routes originating from Amsterdam (AMS) to five main European airports. These are the same five routes used to analyse the A320neo's operating and fuel burn performance *(see A320neo fuel burn & operating performance, Aircraft Commerce, December 2016/January 2017, page 18)*.

The performance of the nine aircraft variants has been analysed using simulated flight plan data from Lufthansa Systems' Lido/Flight solution. The results from these simulations are based on only a single set of operating conditions, but provide an indication of the relative operating efficiencies of the types.

Operating assumptions

Assumptions have to be made for several main operational, aircraft configuration and specification, and payload parameters, including: the flight rules; the rules relating to what fuel reserves are carried; the assumptions relating to the track taken, the altitude or flight level (FL) used or available; the cruise speed and the flight profile; the winds and temperatures; the number of engines used during taxi and the related fuel burn; the taxi-in and taxi-out times; and the payload carried.

The flight rules used are international flight rules, relating to the semi-circular rules for cruising altitudes depending on direction of travel, and vertical separation between cruising altitudes of 4,000 feet in the same direction and 2,000 feet in the opposite direction.

The diversion and contingency rules used are based on European Aviation Safety Agency (EASA) standards. The reserve fuel carried is the sum of contingency fuel, alternate fuel, and final reserve fuel. A 5% allowance of planned trip fuel is carried for contingency, and alternate fuel is the trip fuel from alternate to destination that includes fuel for a missed approach. Final reserve is fuel for a 30-minute hold at 1,500 feet at the alternate.

The route tracks, FLs and cruise speeds have been optimised by Lido/Flight solution to achieve the lowest total cost for fuel burn, time-related costs, and all navigation and air traffic control (ATC) charges. This last category is high in Europe, so optimisation in other parts in world may result in different cruise speeds and altitudes. The FL on the AMS-LR is not optimised, however, and a cruise altitude of FL260 has therefore been used for all types to reflect real airline conditions.

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

The weather assumptions include average temperatures and winds for the month of June, with 85% reliability winds on each route.

The block fuel used *(see table, page 31)* is the sum of trip, taxi fuel and fuel used for the auxiliary power unit prior to engine start. The assumption used by Lido is that both engines are used during taxi-in and taxi-out by all aircraft. The taxi-in times at each of the five destinations and taxi-out time at AMS are from the Lido/Flight solution database. This adds 590-850lbs of fuel per trip, depending on aircraft type and taxi time.

Fuel density used is 6.55lbs per US Gallon (USG), and this is used to convert the aircraft fuel capacity and consumption figures to USG *(see table, pages 31)*.

Two levels of payload were used to analyse the performance of the aircraft in two ways.

The first analysis used a payload of 125 passengers for all nine aircraft types, which is just three fewer than the A319's capacity of 128. The average weight per passenger used was 231lbs, which provides an allowance for large carry-on or checked-in baggage. The passenger payload is therefore 28,875lbs *(see table, page 31)*. No additional belly freight is carried.

BLOCK FUEL BURN PERFORMANCE OF CS300, A319CEO, 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	CS300	PW1521G	145	33,495	241	32,915	77	626	0.0190
	A319ceo	CFM56-5B6	128	29,568	240	29,056	76	732	0.0252
	A319ceo	V2524-A5	128	29,568	240	29,056	75	748	0.0258
	737-700	CFM56-7B24	129	39,799	240	29,283	77	713	0.0243
	A320ceo	CFM56-5B4/P	153	35,343	240	34,731	76	760	0.0219
	A320ceo	V2527-A5	153	35,343	239	34,731	77	730	0.0210
	737-800	CFM56-7B26	158	36,498	241	35,866	78	805	0.0224
	A320neo	CFM LEAP-1A26	161	37,191	240	36,547	76	664	0.0182
	A320neo	PW1127G	161	37,191	240	36,547	76	677	0.0185
AMS-DUB	CS300	PW1521G	145	33,495	465	63,365	97	927	0.0146
	A319ceo	CFM56-5B6	128	29,568	462	55,936	96	1,062	0.0190
	A319ceo	V2524-A5	128	29,568	462	55,936	95	1,062	0.0190
	737-700	CFM56-7B24	129	39,799	462	56,373	96	1,039	0.0184
	A320ceo	CFM56-5B4/P	153	35,343	462	66,861	96	1,102	0.0165
	A320ceo	V2527-A5	153	35,343	463	66,861	96	1,069	0.0160
	737-800	CFM56-7B26	158	36,498	465	69,056	97	1,193	0.0173
	A320neo	CFM LEAP-1A26	161	37,191	462	70,357	95	967	0.0138
	A320neo	PW1127G	161	37,191	462	70,357	95	956	0.0136
AMS-FCO	CS300	PW1521G	145	33,495	726	106,285	143	1,314	0.0124
	A319ceo	CFM56-5B6	128	29,568	726	93,824	141	1,500	0. 0160
	A319ceo	V2524-A5	128	29,568	726	93,824	140	1,497	0.0160
	737-700	CFM56-7B24	129	39,799	726	94,557	141	1,471	0.0156
	A320ceo	CFM56-5B4/P	153	35,343	726	112,149	141	1,559	0.0139
	A320ceo	V2527-A5	153	35,343	726	112,149	141	1,510	0.0135
	737-800	CFM56-7B26	158	36,498	726	115,814	142	1,683	0.0145
	A320neo	CFM LEAP-1A26	161	37,191	726	118,013	140	1,362	0.0115
	A320neo	PW1127G	161	37,191	726	118,013	140	1,349	0.0114
AMS-FAO	CS300	PW1521G	145	33,495	1,181	163,995	195	1,995	0.0122
	A319ceo	CFM56-5B6	128	29,568	1,175	144,768	193	2,261	0.0156
	A319ceo	V2524-A5	128	29,568	1,180	144,768	192	2,242	0.0155
	737-700	CFM56-7B24	129	39,799	1,174	145,899	192	2,204	0.0151
	A320ceo	CFM56-5B4/P	153	35,343	1,182	173,043	194	2,349	0.0136
	A320ceo	V2527-A5	153	35,343	1,180	173,043	194	2,272	0.0131
	737-800	CFM56-7B26	158	36,498	1,180	178,698	194	2,543	0.0142
	A320neo	CFM LEAP-1A26	161	37,191	1,174	182,091	192	2,033	0.0112
	A320neo	PW1127G	161	37,191	1,174	182,091	193	2,014	0.0111
AMS-TFS	CS300	PW1521G	145	33,495	2,057	287,535	309	3,350	0.0116
	A319ceo	CFM56-5B6	128	29,568	2,048	252,800	306	3,784	0.0150
	A319ceo	V2524-A5	128	29,568	2,048	252,800	305	3,728	0.0147
	737-700	CFM56-7B24	129	39,799	2,049	254,904	305	3,677	0.0144
	A320ceo	CFM56-5B4/P	153	35,343	2,050	302,481	306	3,921	0.0130
	A320ceo	V2527-A5	153	35,343	2,050	302,481	307	3,788	0.0125
	737-800	CFM56-7B26	158	36,498	2,056	313,314	308	4,271	0.0136
	A320neo	CFM LEAP-1A26	161	37,191	2,057	319,424	307	3,386	0.0106
	A320neo	PW1127G	161	37,191	2,057	319,263	308	3,354	0.0105

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.

This weight is higher than probable average passenger weights, given that the mix of passengers will include some infants and passengers with light or no checked baggage. The weight used, however, allows a conservative comparison to be made.

This first analysis of an equal load for all nine types, allows the relative differences in block fuel used by each type carrying the same payload to be used. It therefore allows the incremental fuel burn and cost for the larger and less efficient types to be compared to the most efficient type *(see table, this page)*.

The second analysis examines each aircraft variant with a 100% load of passengers: 128 for the A319, 129 for the 737-700, 145 for the CS300, 153 for the A320ceo, 158 for the 737-800, and 161 for the A320neo. This results in payloads of 29,568lbs for the A319, 29,799lbs for the 737-700, 33,495lbs for the CS300, 35,343lbs for the A320ceo, 36,498lbs for the 737-800, and 37,191lbs for the A320neo *(see table, this page)*.

This allows the fuel burn per seat to be examined for each type on the basis of the aircraft type being used matching different levels of demand. In addition, it illustrates the performance of each type at its maximum passenger load, and so also allows the relative differences in efficiency

The A319ceo is the least efficient of older generation types examined here compared to the CS300. The A319neo is expected to have about 13-15% lower fuel burn than the A319ceo. This would put the A319neo's absolute fuel burn on a par with the CS300, but the CS300 still has a 17-seat higher capacity.

due to required aircraft size between the types to be examined.

Aircraft variants

The weight and specification characteristics of the nine types used in the analysis are detailed *(see table, this page)*. The weight and engine specifications of the CS300 variant used in this analysis have been described. The aircraft has a fuel capacity of 5,901USG and maximum payload of 37,300lbs *(see table, page 31)*. This allows it to carry 3,800lbs additional belly freight over a full passenger load, where average weight per passenger is 231lbs.

The weights, fuel capacities, and engine variants of the eight other aircraft types and variants used in the analysis are listed *(see table, page 31)*.

The assumed seat numbers for these eight variants is on the basis of average configurations used by most scheduled and full-service airlines that operate each type. The high-density configurations of low-cost carriers (LCCs) and European inclusive-tour airlines have not been included to calculate the average. This is because the aircraft have been examined on the basis of typical full-service operations.

The gross weight variants used for each type are those required to complete all five routes without performance or payload limitations. The exception is the A320neo, where the heaviest variant available has been used.

The MZFW and OEW vary slightly with each gross weight variant. The maximum structural payloads of the aircraft types are also listed *(see table, page 31)*. With maximum passenger payload deducted, using a weight of 231lbs per passenger, this leaves an available capacity for belly freight of 3,805-10,379lbs for the nine types *(see table, page 31)*.

The A320neo variant used has a gross weight that is about 5,000lbs heavier than the A320ceo's. The A320neo, however, has an actual take-off weight that is only up to 3,000lbs heavier than the A320ceo on shorter routes, and almost equal to the A320ceo on the longer routes.

Routes

As described, the performance of the nine types is analysed on five routes originating from AMS. The aircraft are examined on a uni-directional, outbound basis. The five destinations are: London Heathrow (LHR), United Kingdom; Dublin (DUB), Ireland; Rome Fiumicino (FCO), Italy; Faro (FAO), Portugal; and Tenerife (TFS), Canary Islands.

These five airport-pairs have been chosen to provide an examination of aircraft performance on routes with tracked distances of 227-1,821nm. ESADs are 240-2,057nm *(see table, page 31)*.

The five routes operate in a westerly, south-westerly or southerly direction from AMS. The aircraft therefore experience headwinds or a headwind component on four of the five routes. A small tailwind is experienced on AMS-FCO. The ESAD the aircraft flies is therefore increased by a headwind component, so the distances flown are longer than the tracked distances on four of the routes. The five routes have flight times ranging from 41 minutes, to 4 hours and 43 minutes *(see table, page 31))*.

AMS-LHR is the shortest route, with a tracked airway distance of 227nm (*see table, page 31)*. The aircraft encounter a headwind of 19 knots. This increases the ESAD to 239-241nm depending on type and their flight profile. There are small differences between types for the ESAD because of issues such as steep climbs, and different climb and descent profiles.

The total of taxi-out and taxi-in times is 35 minutes, with AMS and LHR being relatively busy and congested compared to other airports used in the analysis. The resulting block times are therefore 75-78 minutes, depending on type.

The alternate airport used for LHR is London Gatwick (LGW), which is 78nm from LHR.

The AMS-DUB route is the second longest, with a tracked airway distance of 437nm. The aircraft experience an average headwind of 21 knots on the length of the route taking ESAD up to 462nm *(see table, page 31)*.

The total taxi-out and taxi-in time on this sector is 25 minutes, 10 minutes shorter than AMS-LHR. The flight time for all aircraft is 70 minutes, taking the block time to 95 minutes *(see table, page 31)*.

The alternate airport used in the analysis is Belfast (BFS), Northern Ireland; and is 101nm from DUB.

AMS-FCO is the third longest route, with a tracked airway distance of 733nm. The aircraft types have a flight time varying from 1 hour and 45 minutes to 1 hour and 48 minutes *(see table, page 31)*. On average this is typically 15-20 minutes longer than the average flight time of European short-haul operations for most airlines.

The aircraft encounter an average tailwind on the route of 4kts, and so an ESAD of 726nm *(see table, page 31)*.

The total taxi-out and taxi-in time on this sector is 35 minutes, the same as AMS-LHR; the longer time reflecting the larger size of Rome FCO and London LHR airports compared to Dublin (DUB). The block time for the nine types therefore varies from 2 hours and 20 minutes to 2 hours and 23 minutes *(see table, page 31)*.

The alternate airport used for FCO is Rome Ciampino airport (CIA), which is just 43nm from FCO, so relatively small

The 737-800 has a 17-18% higher burn per ASM than the CS300. The 737-800 also has a 7-9% higher burn per ASM than the A320ceo.

amounts of alternate fuel are required for this route.

The fourth longest route is AMS-FAO, with an airway tracked distance of 1,131nm *(see table, page 31)*. The aircraft experience an average headwind component of 17kts on this route, increasing the ESAD to 1,180nm.

The total taxi-out and taxi-in time for this sector is 27 minutes, and the short time reflects the small size of FAO airport. Flight time ranges from 2 hours and 45 minutes to 2 hours and 48 minutes, depending on aircraft type *(see table, page 31)*. The total block time therefore varies from 3 hours and 12 minutes to 3 hours and 15 minutes *(see table, page 31)*.

The alternate airport used for FAO is Lisbon (LIS), which is 160nm from FAO. This route has the highest requirement for diversion and holding fuel of the five routes analysed.

The fifth longest route is AMS-TFS, which has a tracked airway distance of 1,977nm or 1,983nm, depending on the aircraft type and the FL used *(see table, page 31)*. The aircraft experience an average headwind of 16kts over the length of the route, which increases the ESAD from 2,050nm to 2,057nm, depending on aircraft type. The flight time varies from 4 hours and 41 minutes to 4 hours and 44 minutes.

The total taxi-out and taxi-in time for this sector is only 25 minutes, as TFS is a small airport. The block time therefore ranges from 5 hours and 6 minutes to 5 hours and 9 minutes *(see table, page 31)*.

The alternate airport used for TFS is Las Palmas (LPA), the other airport on the Canary Islands. This is 85nm from TFS, resulting in a relatively low alternate fuel requirement.

Performance

As described, the nine aircraft have been analysed with two different levels of payload. The first is with a consistent payload of 125 passengers for every type, equal to 28,875lbs. The second is with a full payload for each aircraft.

The flight plans generated have been used to analyse the fuel burn and operating performance of the aircraft in terms of any performance and payload limitations on any of the aircraft on all routes, to examine flight and block times, and to provide block fuel consumption. The fuel used is then analysed in terms of absolute fuel consumption, and consumption per seat and per available seat mile (ASM). The per ASM analysis takes into account the effects of the higher seat numbers of larger types and longer mission length on improving efficiency.

The number of ASMs has been calculated by multiplying the tracked airway distance by the number of available seats. The number of ASMs in the second analysis varies from 29,056 for the A319 on the shortest route to 319,424 for the A320neo on the longest route *(see table, page 31)*.

Equal passenger payload

In this scenario where all nine aircraft are tested with an equal passenger payload of 125, equal to 28,875lbs, the differences between the most fuel-efficient aircraft and other types will be more exaggerated than in an analysis where each aircraft operates with a payload that is proportionate to its seat numbers.

The CS300 is the most fuel efficient, and burns 415USG on the shortest AMS-LHR route. The aircraft with the closest burns to these are the new-generation A320neo variants. The LEAP-powered aircraft with 161 seats, burns 586USG, and the PW1127G-powered aircraft burns 575USG. These are 38.8% and 41.5% more than the CS300.

In the case of the older generation types, the closest to the CS300 is the 737-700 at 652USG on the AMS-LHR route; a 57% higher burn. The A3219ceo and A320ceo variants, and the 737-800 burn 59-75% more than the CS300.

The differences between the CS300 and its alternatives are not significant on the longest AMS-TFS route. The two A320neo variants burn 34.9% and 36.2% more fuel than the CS300, while having only 11% more seats.

The three older and smaller types burn 55-61% more fuel, and the three larger types burn 55-73% more fuel, despite only having 5-6% more seats.

Full passenger payload

As described, the five routes have ESADs of 240nm to 2,057nm. The shorter routes will not limit the performance of the aircraft under the weather and temperature conditions used. The longest route of AMS-TFS has an airway tracked distance of 1,977-1,984nm, depending on the aircraft type.

The fuel burns can be analysed in absolute terms. The first and clear issue is that the CS300 burns the least fuel of all nine aircraft types on the five routes. Its fuel efficiency in absolute USG burned is high compared to the other eight aircraft variants in most cases. This is not surprising since the CS300 is an all-new design, is efficient in terms of weight per seat, and has a high bypass ratio engine.

The aircraft variants with older generation engines burn 9.8-29.0% more block fuel than the CS300 across the five mission lengths. That is, the CFM56-powered A319 burns up to 17% more fuel, while the V2500-powered A319 burns up to 19.6% more fuel, despite having 17 fewer seats than the CS300. This also illustrates the difference between the two engine options on the A319ceo on this short mission length.

The A320neo variants with CFM LEAP-1A26 and PW1127G engines have 1-8% higher absolute fuel burns, depending on mission length, than the 16-seat smaller CS300. The A320neo therefore has a superior fuel burn per ASM to the CS300.

The CFM56-powered version of the A319 burns more fuel than the V2500-equipped model.

The differences between the two A319ceo variants and the CS300 reduces with increased mission length, as may be expected because of the effects of a longer cruise segment in the operation. The CFM56-powered and V2527-powered A319ceo variants burn 13% and 11.3% more fuel than the CS300. At the current spot fuel price of about $1.80 per USG, this is equal to a $190-226 higher cost for the A310ceo variants on the shortest route, and $680-780 higher for them on the longest route.

These absolute differences are then expressed in terms of fuel burn per ASM, and the relative differences between the variants. The difference in burn per ASM is highest between the V2524-A5-powered A319ceo and the CS300 on the shortest route, at 35.5% more for the A319ceo, and 32.6% higher for the CFM56-5B6-powered A319ceo.

These differences reduce to 13% higher burn per ASM for the CFM56-powered A319ceo, and 11.3% higher burn per ASM for the V2524-powered A319ceo than the CS300 on the longest AMS-TFS route.

The 737-700 burns 14% more fuel than the CS300 on the shortest AMS-LHR trip, and this reduces to 9.8% more for the 737-700 on AMS-TFS at an ESAD of 2,057nm. The relative difference in fuel per ASM is higher because of the 737-700's 16 smaller seat count. On the shortest route the 737-700 burns 28% more fuel per ASM, and still has a 23.8% higher burn per ASM on the longest AMS-TFS route.

The CFM56-powered A320ceo burns 21.5% more fuel than the CS300, while the V2527-powered A320ceo burns 16.7% more fuel on the shortest mission of AMS-LHR. This is in contrast to the A320ceo, which has eight more seats, or 5.5% more than the CS300. This difference is equal to $240 and $187 for the two A320ceo variants.

The differences between the A320neo variants and the CS300 reduce as sector length increases. These reduce down to almost zero on the longest AMS-TFS route, which is almost 2,000nm tracked distance and a flight time of more than 4 hours and 20 minutes. The two A320neo variants have a fuel cost that is just $69 and $92 higher than the CS300 on the shortest route, and actually smaller on the longest route.

The difference in burn per ASM is less pronounced between the V2527-powered A320ceo and the CS300 on the shortest route at 10.6%, and is 15.1% higher for the CFM56-powered A320ceo.

These differences reduce to 11.3% higher burn per ASM for the CFM56-powered A320ceo, and 7.5% higher burn per ASM for the V2527-powered A320ceo on the longest AMS-TFS route.

The 737-800 burns less fuel than either A320ceo variant, and burns 28.7% and 27.5% more than the CS300 on the shortest and longest routes. The 737-800's burn per ASM is still 18.1% higher that the CS300 on the shortest route, and 17.0% higher on the longest route.

The differences between the two A320neo variants and the CS300 are large on the short AMS-LHR route, at 8.2% higher for the PW1127G-powered A320neo, and 6.2% higher for the LEAP-1A26-powered A320neo.

These differences quickly reduce as mission and route length increase, however. They are 4.4% and 3.2% for the 437nm AMS-DUB route, and are just 1.1% and 0.1% for AMS-TFS, which has a tracked distance of 1,983nm and flight time of more than 280 minutes.

These small differences in absolute fuel burn between the CS300 and two A320neo variants translate into lower burns per ASM for the A320neo on all five routes over ESADs of 240-2,057nm.

The two A320neo variants have virtually equal fuel burns, with the PW1127G-powered variant having about a 1% advantage over the LEAP-equipped variant.

The burn per ASM advantage held by the A320neo variants on the longer routes is expected, given the effects of the extended cruise segment combined with higher seat numbers.

The analysis illustrates overall the CS300's fuel efficiency in terms of absolute block fuel and fuel consumption per ASM. The CS300 has the lowest absolute fuel burn compared to all A319ceo, A320ceo, 737-700 and 737-800 variants on the five routes. Moreover, because the A319 and 737-700 have 17 and 16 fewer seats than the CS300, the A319 and 737-700 have higher burns per ASM.

These are 28.5-32.6% higher for the CFM-powered A319ceo, 26.6-35.5% higher for the V2500-powered A310ceo, and 23.8-28.1% higher for the 737-700.

The larger A320ceo and 737-800 have 7.5-18.1% higher burns per ASM than the CS300, despite their eight- and 13-seat advantages over the CS300.

The analysis clearly demonstrates the CS300's superior fuel burn performance over larger and smaller older generation aircraft types. The CS300 is only inferior in terms of burn per ASM to the A320neo. This is not surprising, given the A320neo's larger size coupled with having the same generation of engine technology. The A319neo's and 737 MAX 7 performance will be interesting to compare with the CS300. AC