The 787-8 is pitched as a replacement for the 767-300ER and A330-200, and also for its ability to operate long- and ultra-long-haul routes that are beyond the range of mid-sized widebodies. The fuel burn and operating performance of the 787-8 is examined against the 767-300ER and A330-200 on routes of 2,200-6,700nm.

Fuel burn & operating performance of the 787-8, 767-300ER, & A330-200

The entry into service of the 787 in October 2011 signalled the beginning of the next generation of long-haul aircraft. With a range of more than 8,000 nautical miles (nm), the 787 will be able to connect almost any two airports in the world, with few operating and performance restrictions. This ultra-long-haul capability offers operators of the aircraft significant and valuable flexibility in planning their route network and schedules.

The 787 is a mid-sized aircraft, seating 220-280 passengers, depending on configuration. Various design characteristics provide it with the range performance to operate long-distance point-to-point services. The aircraft also has features and characteristics that should provide it with seat-mile costs similar to larger types such as the 777 and 747-400. This is intended to provide airlines with an aircraft that makes long-distance routes, with low demand, economically viable. Airlines will no longer be limited to operating with larger types, such as the A340 or 777, at limited service frequencies.

To achieve an acceptable cost per seat-mile performance, one of the 787's key features is lower fuel burn per seat than the aircraft it is intended to replace, mainly the 767 and A330. On a simple level, this is due to the 787's more advanced technology, lighter materials used in production, and brand new, high-bypass ratio engines.

This article aims to analyse the 787's fuel burn and operating performance on a variety of routes that have been announced by current and prospective 787 operators. The 787-8 will be compared to aircraft of similar size: the 767-300ER and A330-200. This analysis will give details of each aircraft's take-off weight and required fuel burn, in order to show their permitted payload on each route, across different operating conditions.

767-300ER, 787-8, & A330-200 SPECIFICATIONS

	767-300ER	787-8	A330-200
Engine type	CF6-80C2B6F	GEnx-1B70	CF6-80E1A3
Thrust (lbs)	60,800	69,800	68,530
MTOW (lbs)	412,000	502,500	513,765
MLW (lbs)	320,000	380,000	401,300
MZFW (lbs)	295,000	355,000	374,850
OEW (lbs)	198,440	229,501	266,830
Max payload (lbs)	96,560	125,498	108,020
Fuel capacity (USG)	24,140	33,528	36,744
Seats (3-class airline average)	220	224	231

Aircraft specifications

To make a fair comparison between these three types, the same engine manufacturer will be used, all at the highest thrust rating. The 787-8 analysed here has the General Electric (GE) GEnx-1B70, with a thrust rating of 69,800lbs *(see table, this page)*. The 767-300ER and A330-200 both use variants of the older GE CF6 engine. The 767-300ER is powered by the CF6-80C2B6F, rated at 60,800lbs of thrust, while the A330-200 uses the CF6-80E1A3, rated at 68,530lbs of thrust *(see table, this page)*.

The 787-8, 767-300ER, and A330-200 carry, on average, similar numbers of passengers. Due to the long- and ultra-long-haul nature of some of these routes, a three-class layout was chosen for each aircraft. The three-class airline average number of seats for the A330-200 is 231 passengers, making it the largest aircraft in this analysis. The average for the 767-300ER is 220 seats, while for the 787-8, 224 seats will be used *(see table, this page)*. Currently, the 787-8 is only in service with two carriers, All Nippon Airways and Japan Airlines (JAL), with Qatar Airways soon to follow, all in two-class configuration. To compare on a fair basis with the 767-300ER and A330-200 in three-class configurations, an estimate of 224 seats will be used for the 787-8.

The A330-200 is the largest aircraft analysed here, in terms of weight specifications. The maximum take-off weight (MTOW) of the A330-200 is 513,765lbs, with a maximum landing weight (MLW) of 401,300lbs *(see table, this page)*. The maximum zero fuel weight (MZFW) is 374,850lbs and the operating empty weight (OEW) is

The GEnx-powered 787-8 burns 20.5% less per seat-mile than a CF6-80C2-powered 767-300ER, and 28% less per seat-mile than a CF6-80E1-powered A330-200.

266,830lbs. The A330-200 also has the largest fuel capacity of any aircraft here, at 36,744 US gallons (USG). This gives the A330-200 a maximum payload of 108,020lbs *(see table, page 36)*.

The 787-8 has slightly lower weight specifications than the A330-200, yet offers a higher maximum payload of 125,498lbs *(see table, page 36)*. The MTOW is 502,500lbs, MLW is 380,000lbs, MZFW is 355,000lbs, and the OEW is 229,501lbs. The 787-8 has a slightly lower fuel capacity than the A330-200, with 33,528USG *(see table, page 36)*.

The 767-300ER is the smallest aircraft analysed here, with a MTOW of 412,000lbs, MLW of 320,000lbs, MZFW of 295,000lbs, and OEW of 198,440lbs *(see table, page 36)*. The 767-300ER has a significantly lower fuel capacity than the A330-200 and 787-8, with 24,140USG. The 767-300ER has a maximum payload of 96,560lbs *(see table, page 36)*.

Flight profiles

Routes have been chosen to be both representative of those routes announced by current and prospective 787-8 operators, as well as a variety of route lengths and operating conditions. Route lengths increase and vary from a great circle distance of 2,186nm up to 6,416nm.

The tracked distance, or the distance the aircraft will actually fly, is always longer than the great circle distance due to Air Traffic Control (ATC), airways, and extended-range twin-engine operations (ETOPs) requirements; as well as the effects of curved departure and arrival routeings.

When mission length increases, aircraft move towards the edge of their payload-range performance profiles, and may have to operate with restricted payloads so that they can complete the mission non-stop.

Important factors to consider in these routes include wind speed and weather. Wind speed is important in calculating the equivalent still air distance (ESAD). The ESAD takes into account the effect of tailwinds or headwinds on the tracked route distance. Against a strong headwind, an aircraft will have a lower ground speed compared to its airspeed, and so has to fly a longer ESAD than the tracked distance. This therefore increases fuel burn. The reverse is true for tailwinds, when the ESAD is shorter than the tracked distance.

Average weather for the month of June has been used, with 85% reliability winds and 50% reliability temperatures, with flight plans produced by Navtech.

The flight plans in each case are based on International Flight Rules. This includes standard assumptions on fuel reserves, diversion fuel, and contingency fuel. The actual fuel burn figures use only the fuel used for the flight and taxiing fuel. Optimum routes and levels have been used for every flight, except in those cases where it is necessary to restrict levels due to airspace or airway restrictions.

A taxi time of 30 minutes has been added into the fuel burns and added to the flight time to give the block time. Although these aircraft can fly at a number of different speeds, long-range cruise (LRC) has been chosen for all routes due to their length, and to enable equal comparison between routes. LRC enables an aircraft to use less fuel per nautical mile, meaning longer block times, but this is the economical and operational compromise between fuel consumption and flight times.

A standard weight of 220lbs for each passenger and their luggage is assumed. In a tri-class layout, this means the maximum passenger payload for the 767-300ER is 48,400lbs, 49,280lbs for the 787-8, and 50,820lbs for the A330-200 *(see table, page 38)*.

The passenger payload, taken away from the available payload for any particular flight, gives the potential cargo weight that can be carried in the belly of the aircraft, representing additional revenue that can be earned.

Route analysis

Routes chosen for this analysis, therefore, are based on 787-8 routes announced by current and prospective operators of the type.

The shortest route chosen is from Addis Ababa (ADD) to Johannesburg (JNB), a route that Ethiopian Airlines has announced will be operated by the 787-8. This route has a great circle distance of 2,186nm, with a tracked distance of 2,256nm *(see table, page 38)*. This route also has a slight headwind of between one and three knots. This slightly increases the ESAD distance for all three aircraft to 2,260–2,270nm. ADD provides a performance challenge to the three aircraft, since the airfield has an elevation of 7,600 feet. It also experiences high ambient temperatures, and so will test the three types in 'hot-and-high' conditions.

Block times for this route are 5 hours 13 minutes (05:13) for the 787-8, 05:23 for the 767-300ER and 05:24 for the A330-200 *(see table, page 38)*.

The second route is between Tokyo Narita (NRT) and Delhi (DEL), which JAL has announced will be operated by the 787.

The great circle distance is 3,196nm, and a tracked distance of 3,479nm. There are strong headwinds on this route due to its westerly direction. Winds are 32-37 knots. This increases the ESAD to 3,730–3,760nm, and gives block times of 08:09 for the 787-8, 08:20 for the 767-300ER and 08:27 for the A330-200 *(see table, page 38)*.

Singapore (SIN) to Auckland (AKL) is the next route analysed. It has a great circle distance of 4,540nm and a tracked distance of 4,637–4,692nm.

OPERATING & FUEL BURN PERFORMANCE OF THE 787-8, 767-300ER & A330-200

Aircraft type	Tracked distance (nm)	ESAD (nm)	Wind (kts)	Block time (hr:min)	MTOW (lbs)	Actual TOW (lbs)	Max payload (lbs)	Available payload (lbs)	No. seats	Pax payload (lbs)	Possible cargo (lbs)	Payload %	Block fuel (USG)	Fuel burn USG per ton-mile	Fuel burn USG per seat-mile
Route: ADD - JNB															
767-300ER	2,256	2,270	-3	05:23	412,000	362,178	96,560	96,560	220	48,400	48,160	100%	8,845	0.0904	0.0177
787-8	2,256	2,260	-1	05:13	502,500	416,615	125,498	125,498	224	49,280	76,218	100%	8,020	0.0633	0.0158
A330-200	2,256	2,261	-1	05:24	513,765	449,229	108,020	108,020	231	50,820	57,200	100%	9,683	0.0888	0.0185
Route: NRT - DEL															
767-300ER	3,479	3,730	-32	08:20	412,000	409,700	96,560	94,192	220	48,400	45,792	98%	15,040	0.0959	0.0183
787-8	3,479	3,760	-37	08:09	502,500	461,125	125,498	125,498	224	49,280	76,218	100%	13,491	0.0640	0.0160
A330-200	3,479	3,758	-35	08:27	513,765	505,762	108,020	108,020	231	50,820	57,200	100%	16,643	0.0918	0.0192
Route: SIN - AKL															
767-300ER	4,692	4,318	40	09:51	412,000	409,700	96,560	79,650	220	48,400	31,250	82%	17,120	0.1115	0.0180
787-8	4,637	4,296	38	09:32	502,500	475,364	125,498	125,498	224	49,280	76,218	100%	15,397	0.0640	0.0160
A330-200	4,692	4,291	43	09:50	513,765	513,265	108,020	98,387	231	50,820	47,567	91%	19,044	0.1010	0.0192
Route: PVG - SFO															
767-300ER	5,690	5,617	6	12:40	412,000	409,698	96,560	57,579	220	48,400	9,179	60%	20,965	0.1452	0.0170
787-8	5,690	5,609	7	12:03	502,500	495,880	125,498	118,626	224	49,280	69,346	95%	19,923	0.0671	0.0159
A330-200	5,690	5,605	7	12:36	513,765	501,492	108,020	64,970	231	50,820	14,150	60%	22,999	0.1415	0.0178
Route: NRT - BOS															
767-300ER	6,125	5,871	20	13:13	412,000	400,678	96,560	44,913	204	44,913	0	47%	21,354	0.1814	0.0178
787-8	6,125	5,870	21	12:43	502,500	496,050	125,498	110,819	224	49,280	61,539	88%	20,696	0.0713	0.0157
A330-200	6,125	5,862	21	13:03	513,765	484,341	108,020	47,774	207	47,774	0	44%	22,966	0.1837	0.0189
Route: PVG - EWR															
767-300ER	6,724	6,511	15	14:42	412,000	369,699	96,560	13,939	63	13,939	0	14%	21,630	0.5339	0.0524
787-8	6,724	6,523	15	13:57	502,500	496,023	125,498	101,064	224	49,280	51,784	81%	22,655	0.0770	0.0155
A330-200	6,724	6,509	15	14:52	513,765	440,521	108,020	3,948	17	3,948	0	4%	23,422	2.0416	0.2105

Source: Navtech

Jetstar announced this as a 787 route. Significant tailwinds are in place here, however, at 38–43 knots. This reduces the ESAD to 4,291–4,318nm. The 787-8 has a block time of 09:32, the slower 767-300ER is 09:51, and the A330-200 is 09:50 *(see table, this page)*.

Increasing distance still further is the route between Shanghai Pudong (PVG) and San Francisco (SFO), announced by Hainan Airlines as a 787 route.

Great circle distance is 5,344nm, with a tracked distance of 5,690nm. Small tailwinds of 6–7 knots decrease the ESAD to 5,605–5,617nm. The 787-8 has the shortest block time for this route of 12:03, the 767-300ER has a block time of 12:40, and the A330-200 has a block time of 12:36 *(see table, this page)*.

JAL recently began operating the route between NRT and Boston (BOS), which has a great circle distance of 5,823nm. Tracked distance is 6,125nm, with an ESAD of 5,862–5,871nm due to tailwinds of 20–21 knots. Block times are 12:43 for the 787-8, 13:03 for the A330-200, and 13:13 for the 767-300ER *(see table, this page)*.

The longest route analysed is between PVG and Newark (EWR), with a great circle distance of 6,416nm, which is at the edge of the payload-range envelope for both the 767-300ER and A330-200. Tracked distance is 6,724nm, although a tailwind of 15 knots reduces the ESAD to 6,509–6,523nm. Block time for the 787-8 is almost 14 hours at 13:57, while the 767-300ER has a block time of 14:42, and the A330-200 has a block time of 14:52 *(see table, this page)*.

Performance analysis

The total fuel burn (block fuel), fuel burn per ton-mile and fuel burn per seat-mile are shown *(see table, this page)*.

In all measures, and on all routes, the 787-8 outperforms both the 767-300ER and A330-200 by a significant margin. In total terms, the 787-8 burns an average of 795USG less fuel per route than the smaller 767-300ER across all six routes, and 2,429USG less fuel per route than the five-seat larger A330-200 across all six routes *(see table, this page)*. The 787-8's burn is 4.5% lower than the 767-300ER's, and 12.7% less than the A330-200's.

The largest differences were seen on the SIN–AKL route, where the 787-8 burns 1,723USG less (10% less) than the 767-300ER and 3,647USG less (19.2% less) than the A330-200.

To gain a clearer comparison of fuel burn, however, two measures have been utilised. The fuel burn per ton-mile, is the fuel burned (in USG) to transport one ton of revenue-generating payload (both passengers and cargo) each mile. The fuel burn per seat-mile is included, since it shows how much fuel (in USG) was required to transport each passenger seat each mile.

Again, the 787-8 outperforms the 767-300ER and A330-200 in both measures on all routes. The 787-8 averaged 0.0077 USG per seat-mile less (20.5%) than the 767-300ER across the six routes, and 0.0349USG per ton-mile less (28%) than the A330-200 *(see table, this page)*.

This is because the payload-range envelope for the 787-8 is higher than both the 767-300ER and A330-200. This allows the 787-8 to maintain higher payloads on long- and ultra-long-haul routes, than the 767-300ER and A330-200. This is demonstrated by the available payload percentage. This shows the restrictions that are put in place on payload in order to compensate for fuel to complete the route non-stop.

The only route where all aircraft operate unrestricted in terms of available payload is ADD–JNB, which is not surprising, given that this is the shortest route analysed. The fuel burn per ton-mile on this route was least for the 787-8, which burned 0.0633USG per ton-mile, compared with 0.0904USG per ton-mile for the 767-300ER and 0.0888 per ton-mile for the A330-200 *(see table, this page)*.

Fuel burn per seat-mile on this route was also the least for the 787-8 at 0.0158USG per seat-mile, compared with 0.0177USG per seat-mile for the 767-300ER and 0.0185USG per seat-mile for the A330-200 *(see table, this page)*. In terms of burn per seat-mile, the 787-8's burn is 10.5% lower than the 767-300ER's and 14.5% lower than the A330-200's.

The 767-300ER suffers a small

Besides a difference in fuel burn per seat between the 787-8 and older generation types, the 787-8 has longer range and superior operating performance. This is illustrated by the 787-8's ability to carry a full load of passengers on a 6,500nm mission, while the 767-300ER and A330-200 carry a small fraction of their capacity.

payload restriction on the NRT–DEL route, carrying 98% of available payload, while the 787-8 and A330-200 maintain 100% payload *(see table, page 38)*.

As you would expect, as distance increases, fuel burn increases. The fuel burn differences between the three aircraft remain consistent, however. Fuel burn is lowest for the 787-8 at 0.0640USG per ton-mile and 0.0160USG per seat-mile for this route. This compares with 0.0959USG per ton-mile and 0.0183USG per seat-mile for the 767-300ER, and 0.0918USG per ton-mile and 0.0192USG per seat-mile for the A330-200 *(see table, page 38)*. For the burn per seat-mile comparison, the 787-8 has a 12.6% lower burn than the 767-300ER and 16.5% lower than the A330-200.

When distance further increases, higher payload restrictions can be seen. On the next longest route, SIN–AKL, the 787-8 remains unrestricted, while the 767-300ER can only carry 82% of maximum payload, and the A330-200 is restricted to 91% of payload *(see table, page 38)*. This clearly demonstrates the 787's superior payload-range performance.

This pushes the fuel burn per ton-mile higher for the 767-300ER (0.1115USG per ton-mile) and A330-200 (0.1010USG per ton-mile), compared with the 787-8, which remained at the same rate as on the NRT–DEL route at 0.0640USG per ton-mile *(see table, page 38)*. Fuel burn per seat-mile stayed similar for all three aircraft on the SIN–AKL route, compared to the previous two routes *(see table, page 38)*.

On the PVG-SFO route, all three aircraft suffer a payload restriction, with both the 767-300ER and A330-200 only being able to carry 60% of their maximum payload. The 787-8 suffers a small payload restriction of 5%, carrying 95% of its maximum payload *(see table, page 38)*.

These restrictions cause fuel burn per ton-mile to increase for all three aircraft, although this is higher for the 767-300ER and A330-200 because the restrictions are higher. Fuel burn per ton-mile for the 787-8 rises to 0.0671USG per ton-mile, compared with 0.1452USG per ton-mile for the 767-300ER and 0.1415USG per ton-mile for the A330-200 *(see table, page 38)*. Despite this, a full complement of passengers can still be carried (we assume belly freight is restricted before passenger numbers), but due to increasing distance, fuel burn per seat-mile reduces slightly for all three aircraft. The 787-8 remains the best performer in this respect, with fuel burn per seat-mile of 0.0159USG. The 767-300ER and A330-200 are higher at 0.0170 and 0.0178USG per seat-mile respectively *(see table, page 38)*. The 787-8's burn is 6.5% lower than the 767-300ER's and 10.7% lower than the A330-200's.

Even higher payload restrictions can be seen when distance further increases. Between NRT and BOS, the 787-8 is restricted to 88% of its full payload, while the 767-300ER and A330-200 are restricted to just 47% and 44% respectively *(see table, page 38)*.

Fuel burn per ton-mile, therefore, continues to increase for all three aircraft, although it rises at a higher rate for the older generation 767-300ER and A330-200 as payload restrictions increase. These two older aircraft also suffer a slight restriction on passenger numbers, which reduce to 204 for the 767-300ER (compared with maximum of 220), and 207 for the A330-200 (compared with 231 maximum).

This increases fuel burn per seat-mile for these two aircraft to 0.0178USG and 0.0189USG respectively. The 787-8 fuel burn per seat-mile on this route actually reduces slightly from previous routes to 0.0157USG *(see table, page 38)*.

On the longest route, between PVG and EWR, the 767-300ER and A330-200 are on the edge of their payload-range envelopes. This is shown by payload restrictions of just 14% for the 767-300ER and only 4% for the A330-200.

The 787-8 still performs strongly, carrying 81% of available payload on this route *(see table, page 38)*. This illustrates how much larger the 787-8's payload-range envelope is compared to the two older types.

In terms of fuel burn per seat-mile, the 787-8 shows its lowest figures on the longest route, burning 0.0155USG per seat-mile *(see table, page 38)*. Since the older two aircraft suffer high seat number restrictions, their fuel burn per seat-mile figures are skewed and are higher in comparison with shorter routes.

Summary

As expected, the 787-8 has lower fuel burn than older aircraft in the same size class, the 767-300ER and A330-200. On the routes analysed, the 787-8 shows that its payload-range envelope is larger than that of similar, mid-sized widebody aircraft.

On the longest route, PVG–EWR, the 787-8 still operates with most of its payload, while the 767-300ER and A330-200 suffer significant payload restrictions. This means that the 787-8 is ideal for operators that want to operate lower-demand point-to-point routes in excess of 6,000nm.

On shorter routes where payload restrictions are not an issue, the 787-8 offers lower fuel burn per ton-mile and per seat-mile on all sectors than older aircraft in a similar size class. In terms of fuel burn and operating performance, therefore, the 787-8 outperforms two of the aircraft that it is pitched to replace: the 767-300ER and A330-200. AC