The A330neo, A350 family, 787-10, and 777-8X/-9X family provide international capacities between 246 and 414 seats. An initial assessment of the aircraft's main specifications and features, operating and & fuel burn performance, maintenance programmes, and operating range are examined.

New widebody programmes: initial assessment of the A330neo, A350 family, 787-10 & 777-X

A new generation of widebodies will provide standard two-class intercontinental cabin configurations of 246-414 seats: the A330-800, A330-900, A350-900, A350-1000, 787-10, 777-8X and 777-9X. The A350-900, A350-1000 and 787-10 have entered service while the other types are due to enter service from 2018 to 2022. These aircraft are clearly set to replace current types such as the A340-300, A330-200 and -300, 777-200 and -300 series, and remaining 747-400s. An assessment of the new generation types is made here.

Seat capacities

The standard intercontinental configuration, two-class seat capacities provided by Airbus and Boeing are summarised *(see tables, pages 6 & 10)*. The split between business- and economy-class seat numbers is also given, because many long-haul airlines have ditched first-class cabins in favour of business-class cabins with lie-flat seats.

The original equipment manufacturer's (OEM's) standard two-class configuration does not necessarily provide an equal comparison of the two, because many variables affect the number of seats that can be fitted in a given area, particularly in business-class cabins. These include seat size and configuration, especially width and seat pitch. Lie-flat seats, for example, use a large floor area per seat. Airlines have attempted to increase the utilisation of cabin floor space in business-class cabins by arranging seats in a herringbone style.

Boeing has changed the arrangement of the economy-class cabins of the 787 and 777 families from the initial eight- and nine-abreast seating arrangements to nine- and 10-abreast. The 787 was marketed with an eight-abreast cabin in the years before its service entry, but many airlines subsequently adopted a nine-abreast arrangement.

The 777-200 and -300 series were initially operated with nine-abreast economy-class cabins. Many operators, however, have reconfigured their aircraft with 10-abreast economy-class cabins since 2013 and 2014. The resulting boost in seat numbers has partly offset the reduction in seat numbers caused by the introduction of business-class cabins with lie-flat and other styles of seats with generous seat pitch.

Nevertheless, many A330 and A350 operators have kept the aircraft in the standard eight- and nine-abreast layouts.

The two-class cabin configuration makes it harder to compare these aircraft on a seat capacity basis with older generation aircraft, because many were operated with a tri-class cabin.

The OEMs' standard, two-class, intercontinental configuration of each type are therefore also used here to illustrate its seat capacity *(see tables, pages 6 & 10)*.

A330-800/-900

The A330-800 and -900 are the two smallest aircraft of the six main types, and are also referred to as the A330 new engine option (neo) variants. The A330-800 and -900 are direct replacements for the A330-200 and -300, referred to as the current engine option (ceo) variants. That is, the -800 uses the same fuselage and systems as the -200, and the -900 uses the same fuselage and systems as the -300. The -800 and -900 also use the same wing and empennage as the -200 and -300. The A330neo has also, however, adopted the sharklets used on the A350 on its wingtips.

The main difference between the two sub-groups is that the -800 and -900 are equipped with a new engine: the Rolls-Royce (RR) Trent 7000. The A330-800 and -900 are virtually identical to the A330-200 and -300 series in all other respects.

The A330neo was primarily launched to provide smaller aircraft than the A350, in close competition with the 787-8 and -9.

The A330-200 and -300 have attracted about 1,490 firm orders to date. The A330-300 was launched nine years before the smaller -200.

The A330-300 had some close competition from the 777-200, but in many respects the A330-300 was in a class of its own. It has proved particularly popular with Asia Pacific carriers for flying high-density, regional routes that have mission lengths equivalent to medium- and long-haul sectors. The A330-300 has also proved to be a popular medium- and long-haul aircraft with airlines in other parts of the world. Standard tri-class capacity is 285 seats, but the average two-class configuration is 292 seats *(see table, page 6)*. The type provided a twin-engined replacement for the previous generation L-1011 and DC-10 trijets. The A330-300 has won almost 790 firm orders since 1986.

The smaller A330-200 was launched in 1995. It has won more than 700 firm orders to date, including 662 passenger variants. At its launch, the A330-200 had no direct competitors. The 767-400ER was launched shortly after as a stretch of the highly successful 767-300ER, but the -400ER did not achieve mainstream success.

The A330-200 offered a standard tri-class capacity of 256 seats, but the average

The A330-900 is a direct replacement for the A330-300. The A330-900 will, however, have 10 more seats than the -300. The A330-900 is also expected to have about 13.5% lower trip fuel burn than the A330-300.

two-class capacity is 259 seats *(see table, page 6)*.

Like the larger -300, the A330-200 was a unique type in the market. Despite the 767-300ER winning large orders, the A330-200 provided a unique combination of 240-260 seats and long-range performance of about 6,400nm. It was effectively a direct replacement for the DC-10-30/-40, but with 1,000nm longer range.

The A330-200 also provided more seat and belly freight capacity and range performance over the older and smaller A310-300 and A300-600R. It also offered a step in seat capacity over the 767-200ER and -300ER if required, so it provided a long-haul aircraft for airlines that found the A330-300 and 777-200 were too big.

The A330-200 therefore provided the right combination for a large number of airlines to operate on medium- and long-haul networks. The A330-200 matched the requirements of many airlines, so it has sold well. The main issue is that the A330-200 was able to offer competitive costs per available seat-mile (ASM). Smaller aircraft types have an inherent disadvantage of having higher ASM unit costs than larger types. The A330-300 therefore had an inherent advantage, since its higher seat capacity gave it economies of scale over the smaller -200. The A330-200 nevertheless had the right configuration to provide the right mix of capacity, range, unit cost per ASM and trip costs for many airlines.

Since the launch of the A330-200, the 787 family followed with similar capacity and range characteristics. The 787-8 has a standard dual-class seat capacity of 242, while the 787-9 has a standard dual-class capacity of 290; both have ultra-long-range performance *(see table page 6)*. Actual airline average two-class seat capacities are 220 and 266. That is, 22 and 28 fewer seats than the OEM's standard layout.

In addition to having similar characteristics to the A330-200, the 787-8 also has several advantages that combine to give it a competitive unit cost per ASM performance. These include high bypass ratio engines that translate to 11-19% lower fuel burn than the A330-200, and a maintenance-efficient design that has several attributes to reduce both the aircraft's maintenance requirements and the rate of increase in maintenance costs.

The A330-800 and -900 were therefore challenged to provide an alternative to the 787-8 and -9, and to some degree the larger 787-10. With cabin optimisation, the A330-800 will be able to accommodate six more economy-class seats than the A330-200, and the A330-900 will be able to carry 10 more seats than the A330-300.

The A330-800 and -900 have standard dual-class seat capacities of 246 and 300, while the larger A350-900 and -1000 have standard dual-class seat numbers of 315 and 369 *(see table, page 6)*. The 787-8, -9 and -10 in contrast have dual-class seat counts of 242, 290 and 330.

The actual two-class seat capacities of the A330-200 and -300 are likely to be 265 and 302 seats. This compares to average airline two-class configurations of 251 and 308 for the 787-8 and 787-9. This indicates that the 787-8 and A330-800 are close competitors; as are the 787-9 and A330-900.

The A330neo variants therefore have a challenge to provide an alternative to the 787-8 and -9 with similar or competitive units costs per ASM.

The main aircraft operating cost categories are financing, fuel, maintenance and crew. The first three can influence an economic difference between the A330neo and 787-8 and -9, but fuel burn performance and the aircraft's relative maintenance requirements are the only two main areas where a difference in cash operating cost can be realised. The A330-800 will have a 16-seat advantage over the 787-8, but the 787-9 will have a six-seat advantage over the A330-900.

Previous analysis of the 787-8 versus the A330-200 shows that the 787-8 has an 11.0-19.0% lower trip fuel burn *(see Fuel burn & operating performance of the 787-8, 787-9 and A350-900, Aircraft Commerce, October/November 2016, page 16)*. The actual difference depends on the aircraft configuration, including engine type and operating conditions. The difference between the two main types is higher at 16-19% on shorter routes of about 3,600nm, and gradually reduces as mission length increases up to 5,500nm.

Similarly, previous analysis shows that the 787-9 has a 1.4-12.2% lower trip fuel burn than the A330-300. The difference between the two is higher at 10.0-12.5% on shorter routes of 3,600-4,200nm, but falls to 1.4-8.1% on longer routes of up to 5,300nm.

The A330neo variants are exclusively powered by the RR Trent 7000. The Trent 7000 is based on the architecture of the Trent 1000 TEN, used to power the 787-10; and the Trent XWB, used to power the A350-900/-1000.

The Trent 7000 has several thrust ratings from 68,000lbs to 72,834lbs. It has a 112-inch diameter fan, which delivers a bypass ratio of 10:1. This compares to the PW4000-112 which powers the 777-200/-200ER. It is rated at up to 99,000lbs, has an equal fan diameter of 112 inches, and a bypass ratio of up to 6.4:1.

The Trent 7000 compares to the RR Trent 700, one of three engine choices powering the A330ceo. This has thrust ratings 67,500-72,000lbs, a fan diameter 97.4 inches, and a bypass ratio of 5.0:1.

These two examples illustrate the increase of bypass ratios relative to thrust rating of modern engine types.

The Trent 7000's main benefit over the Trent 700 is its wider fan, and resulting higher bypass ratio. The Trent 7000 is heavier than the 700, and the 7000's wider intake and higher weight increases drag.

AIRBUS A330 & A350 FAMILY FEATURES & SPECIFICATIONS

Aircraft type	A330-800	A330-900	A350-900	A350-900ULR	A350-1000
Date Certified			Sep-14	Sep-14	Nov-17
EIS Date			Jan-15	Jan-15	Dec-17
Firm Orders	8	224	714	714	173
Standard dual-class seats					
Business class	36	36	48	48	54
Economy class	210	264	267	267	315
Total seats	246	300	315	315	369
Average airline two-class seats	N/A	310	318	161	327
Fuselage length - feet	189	206	214	214	237
Model Number	WV804/820	WV904/922	WV017/010	WV013	WV007/ 002
MTOW - lbs	507,063/553,360	507,063/544,542	462,971/617,295	617,295	573,202/696,661
MZFW - lbs	388,000	399,000	431,445	423,288	491,631
OEW - lbs	291,000	302,000	314,000	314,000	350,000
Max. Struct Payload - lbs	97,000	97,000	117,445	109,288	141,631
Usable Fuel - USG	36,744	25,765/36,744	36,456	43,589	41,212
Old generation aircraft	A330-200	A330-300	A340-500	A340-500	A340-600
Fuselage length	191	209	217	217	241
Airline Seats: Two-Class	259	292	238	238	332

RR says that the Trent 7000 is nevertheless overall about 11% more efficient than the Trent 700. The A330neo, however, has adopted the A350's use of sharklets, so Airbus says the A330neo variants will have 14% lower fuel burn per seat than their A330ceo counterpart variants.

Given that the A330-800 and -900 are expected to have 2.3% and 3.4% more seats than their predecessors, their trip fuel burns should be about 13.5% lower than the A330ceo variants. The implications are therefore that the A330neo models' trip fuel burn performance is on a par with that of the 787-8 and 787-9.

The A330neo variants are derivatives of the A330ceo. One of the main implications of this is that the A330neo's older design will affect its maintenance costs. For example, the aircraft will have a maintenance programme with similar base check intervals, but with a larger number of tasks compared to the 787.

The A330ceo's base maintenance programme is a system of six checks. These have an interval of 24 months (MO). The third and sixth checks include a large number and portion of structural and heavy access inspections. They have intervals of six years (YE) and 12YE. The base check cycle is thus completed every six checks and 12YE.

These two heavier checks have a high portion of structural tasks. There are also, however, high threshold structures tasks. The initial interval for these are 24YE (second 12YE check), and there are an extra 263 tasks in the 24YE check compared to the 12YE check.

The A330neo variants were launched in 2014. They have had contrasting sales success.

The A330-800 has only managed to attract eight firm orders to date, from Kuwait Airways. This contrasts to the A330-200, which has sold at a faster rate than the larger A330-300 which preceded it by nine years.

The A330-800 will have an average of 265 seats, so 43 less than the -900. The A330-800 and -900 are likely to have close trip costs, so the -800 will clearly have higher unit costs per ASM.

In contrast to the A330-800, the 787-8 has won 443 firm orders since 2004. The relatively large number of orders for the 787-8 may explain the A330-800's low sales volume to date. A large number of A330-200s are relatively young, so there is still scope for further orders. Like the A330-200, the -800 provides the right combination of seat capacity and range performance for a portion of medium- and long-haul routes for a number of carriers.

The A330-900 has won 234 firm orders, close to one-third of the A330-300's sales volume. The 787-9 has attracted 784 firm orders since 2004. The A330-900 has therefore gained appreciable success. The largest orders for the -900 are for Air AsiaX (68), Delta Airlines (25), Garuda (14), Iran Air (28), TAP Air Portugal (18), Avolon (19) and Air Lease Corporation (20).

A350-900/-1000

The A350-900 and -1000 are primarily pitched as alternatives and replacements for the 777-200 and -300 series, the 150 passenger-configured 747-400s still in operation, the A340-600, and potentially the A330-300.

The A350 is an all-new aircraft, and so has several advantages, including new systems, and weight-saving materials. These make it a more maintenance-efficient aircraft than its predecessors.

A350-900

The A350-900 comes in two main variants. Standard OEM two-class seat capacity is 315, while the actual average of four airline configurations is 318 seats. This is a split between 32 business-class seats at a long pitch of 60 inches, plus 287 economy-class seats in a standard nine-abreast layout at a pitch of 32 inches.

This seat capacity compares with the two-class configuration averages of 332 for the A340-600, 337 for the 787-10 (Singapore Airlines) and 304 for the 777-200ER. Some airline configurations have more generous pitch and overall room for business-class seats on the 777-200ER, so this may distort the aircraft's seat capacity when compared to the other types.

The 777-300ER has a two-class airline average of 382 seats, and is clearly larger than the A350-900. The A350-900 therefore clearly competes most closely with the 787-10. The A350-900's main market is as a replacement for the A340-600, 777-200ER and the smaller number of A340-300s still in service.

The A350-900 has 18 different weight specification variants. The lowest maximum take-off weight (MTOW) is 210 tonnes or 462,976lbs, and the aircraft has a standard fuel capacity of 36,456USG. The highest MTOW variant is 280 tonnes, or 617,295lbs, and provides the aircraft with a range of up to 8,100nm.

This range is being used by some airlines for ultra-long-distance routes.

The A350-1000 is close in size to the 777-300ER. Indications are that the A350-1000 will have a smaller seat count in an intercontinental service two-class cabin. The 777-300ER has the advantage of being able to be configured with a 10-abreast economy class.

Philippine Airlines, for example, is using the high MTOW version of the A350-900 to operate non-stop between Manila and New York, which is a 7,400nm sector, with no payload limitations in either direction.

This performance compares with the 787-10's range of about 6,450nm with 337 passengers, and the 777-200ER's range of up to 7,100nm with 304 passengers. The 787-10 has the highest MTOW of 560,000lbs and a range of 6,450nm.

The A350-900's main challenge against the 777-200ER will be its relative fuel burn and maintenance costs.

The A350's fuel burn will be largely influenced by its engine configuration. The A350 family is powered by the RR Trent XWB. This has five thrust ratings ranging from 74,200lbs to 97,000lbs. The engine's main attributes are a fan diameter of 118 inches and a bypass ratio of 9.6:1. This compares to a bypass ratio of 10:1 for the Trent 7000 powering the A330neo, and a bypass ratio of 10:1 for the Trent 1000 powering the 787-10.

The A350-900's fuel burn has already been analysed and compared with the 777-200ER *(see Fuel burn & operating performance of the 787-8, 787-9 and A350-900, Aircraft Commerce, October/November 2016, page 16).*

The aircraft were analysed on long-haul routes ranging from 3,600nm to 5,300nm, and the highest gross weight version of the 777-200ER was compared with a version of the A350-900 with an MTOW of 268 tonnes, 12 tonnes less than the highest MTOW version of the A350-900.

The A350-900 had a 16.0-16.4% lower fuel burn on these route lengths. With the A350-900's 14-seat advantage, its fuel burn per ASM is therefore likely to be about 16.7% lower than the 777-200ER's. The A350-900's fuel burn advantage may not have been so large, however, with a higher gross weight version of the aircraft.

A350-900ULR

The A350-900ULR is an ultra-long-range version. In addition to the standard highest MTOW variant of 280 tonnes or 617,295lbs, it has a fuel capacity of 43,589USG. This extends its range to an ultra-long-range performance of 9,700nm.

Singapore Airlines (SIA) is the only airline to specify the -900ULR. It has seven aircraft in this configuration out of a firm order for 67. SIA has configured its aircraft with an ultra-spacious interior for ultra-long-range missions. The aircraft will have 67 business-class and 94 economy-class seats. The business class is configured with four lie-flat seats abreast, with a 78-inch pitch. The four-abreast arrangement and seat pitch is the same as SIA's business-class configuration on its standard A350-900s.

Business class takes about three-quarters of the length of the cabin. The economy class on the -900ULR is configured in an eight-abreast layout, one fewer seat than on the standard A350-900. This allows 19.5 inch wide seats on the -900LR. Seat pitch is 38 inches, six inches more than on its the standard A350-900. The cabin has 94 seats. The A350-900ULR in SIA's configuration therefore has 161 seats.

The airline is using the aircraft to re-launch its service between Singapore and New York Newark. The route has a still air, great circle distance of almost 8,300nm and a tracked distance of about 8,950nm. SIA has reinstated the route with the A350-900ULR in 2017, having originally operated it with the A340-500 configured with 64 business- and 117 economy-class seats from 2004 to 2013.

The 777 variant that serves as an alternative to the A350-900ULR is the 777-200LR. The 777-200LR has the same fuselage as the -200ER, but the -200LR has an MTOW of 766,800lbs, which is 110,000lbs heavier than the -200ER. The 777-200LR also has high fuel capacity. Two options are 47,890USG and 53,440USG, compared to 45,220USG for the 777-200ER.

The 777-200LR is operated by eight airlines, and Qatar Airways and Pakistan International configure their aircraft in a two-class configuration of 259 and 310 seats. Most of the other six operators configure the aircraft with 239-291 seats. The aircraft has a still air range of about 9,600nm with a full load of 260 passengers. If configured with a more spacious layout similar to SIA's A350-900ULR, the 777-200LR might have room for 80-100 economy seats in addition to 65-70 business-class seats.

A350-1000

The A350-1000 is the larger A350 variant, with a 23-feet longer fuselage than the -900. The aircraft has a standard two-class capacity of 369 seats. There are several weight variants, the highest MTOW being 696,661lbs or 316 tonnes. It also has a fuel capacity of 41,22USG, which is about 2,400USG less than the highest option for the A350-900. This fuel capacity gives the A350-1000 a range of about 7,900nm with a full load of 369 passengers.

The A350-1000 has won 17 firm orders from eight airlines and one major lessor. The largest orders are for British Airways (18), Cathay Pacific (20), Etihad Airways (22), Iran Air (16) and Qatar Airways (42).

The aircraft entered service in February 2018, and to date Qatar Airways and Cathay Pacific are the only two airlines operating it. These have two- and three-class seat capacities of 327 and 334. Both these airlines, however, have generous spacing for their premium cabins, with four-abreast seating at 75- or 103-inch pitch.

The 777-300ER is the closest aircraft in seat capacity to the A350-1000. The average airline two-class configuration for the 777-300ER is 343 seats, just 12 more

BOEING 787-10 GE, 777-8X & 777-9X FAMILY FEATURES & SPECIFICATIONS

Aircraft	787-10 GE	777-8X	777-9X
Date Certified	Jan 2018		
EIS Date	Mar 2018	2022	2020
Firm Orders	171	53	263
Standard dual-class seats			
Business class	32		42
Economy class	298		372
Total seats	330	365	414
Average Airline Seats	337	N/A	N/A
Fuselage Length - Feet	221	223	246
Weight Specs			
MTOW - lbs	560,000	775,000	775,000
MZFW - lbs	425,000	N/A	562,000
OEW - lbs	298,700	N/A	N/A
Max. struct payload - lbs	126,300	N/A	N/A
Usable Fuel - USG	33,399	N/A	52,300
Old generation aircraft	777-200ER	777-200LR	777-300ER
Fuselage length	206	206	239
Airline seats: two-Class	304	260-290	382

than the A350-1000. Many 777-300ER operators, however, have a similar number of business-class seats in six-abreast arrangements and narrower seats than either Qatar Airways or Cathay do in their four-abreast business-class seats on the A350-1000. If configured similarly, therefore, the A350-1000 would have fewer seats than the standard OEM layout of 369, and therefore a greater differential with the 777-300ER. Moreover, the A350-1000's average airline two-class seat capacity is only 13 more seats than the A350-900's, despite the -1000's 23-feet longer fuselage, which can allow eight more rows of economy-class seats than the -900's, assuming the two aircraft have equal-sized business class cabins.

In addition to the 777-300ER, the A350-1000 is also a direct replacement candidate for the A340-600. The A340-600 has average two-class seat capacities of 332, almost equal to the A350-1000. Like many 777-300ER airline layouts, the A340-600's seat capacity has a six-abreast business-class configuration. This again implies the A350-1000 would have a higher seat capacity if configured on an equal basis.

There have been several maintenance planning document revisions released since the A350 entered service. The A350-900 and -1000 have a different number of maintenance inspection tasks. The overall objective was for the A350 to have 25% fewer tasks and a 40% lower labour man-hour requirement than the A330ceo.

The A350's generally groups a large number of tasks into multiples of a 1,200FH interval. These can be regarded as 'A' checks. There are other large groups of tasks that have intervals which are multiples of 36MO. These groups can be arranged into block checks that can be regarded as 'C' or base checks. There are groups of structural and deep access tasks with 6YE and 12YE intervals. These can be grouped into checks to form the two heavier checks that are similar to the third and sixth checks in the A330ceo's maintenance programme. The base check cycle therefore has four checks, with the cycle having a full interval of 12YE.

Unlike older aircraft, there are no corrosion or fatigue sampling programmes in the A350's MPD. There are also no supplemental structural inspection document (SSID) tasks in the structures section of the MPD. The A350 therefore does not have a lot of the deep access and heavy inspection tasks that the A330ceo has. Airbus also aims to eliminate the airworthiness limitation item (ALI) Tasks from the MPD by 2019.

A350 operators expect that it will consume 15-20% fewer MH for the 6YE and 12YE heavy base checks, and 15-20% fewer MH over the whole base check cycle compared to the A330ceo.

787-10

The 787-10 is the largest of three 787 family variants. It has a fuselage of 221 feet, seven feet longer than the A350-900 and 16 feet shorter than the A350-1000. These differences broadly indicate how the three types compare in relative seat numbers because they all have nine-abreast seating as standard in the economy cabin.

The 787-10 has a standard OEM two-class seat capacity of 330. This compares with 315 for the A350-900. The 787-10, however, has a standard six-abreast, 85-inch pitch arrangement in its business class.

The A350-900, however, has a six-abreast configuration but with a shorter 60-inch seat pitch. This suggests that the 787-10 should have more than a 15-seat differential over the A350-900.

The 787-10 has won 171 firm orders, and the first few aircraft are in service with SIA. The airline has a two-class seat capacity of 337 seats, including a generously spaced four-abreast business-class cabin, and also a nine-abreast economy-class cabin.

Some airlines operating the 787-9 in a two-class cabin have six-abreast business-class cabins. The 787-9 has an average airline two-class seat count of 308.

This suggests the difference between the average two-class seat capacity of the 787-9 and -10 would be more than 29 seats if the two variants were configured on an equal basis.

In addition to being an alternative to the A350-900, the 787-10 is also a replacement candidate for the 777-200 and -200ER, and the A340-600. The average two-class 777-200ER configuration is 33 business-class seats in a six or seven abreast arrangement, and a smaller economy class than the 777-300ER at 272 seats in a 32-inch pitch in a nine-abreast arrangement.

The A340-600 has a similar seat count to the standard and SIA's layout of passenger accommodation (LOPA) for the 787-10; the A340-600 averaging 332 seats, 44 in business class and 288 in economy, totalling 332 seats.

The 787-10 has the highest MTOW of 560,000lbs, and a fuel capacity of 33,384USG. It is powered by the RR Trent 1000 TEN, or the General Electric GEnx-1B. Both are rated at 76,000lbs.

The RR Trent 1000 TEN has a fan diameter of 112 inches, and has thrust ratings of up to 81,000lbs. It has a bypass ratio of 10.0:1.

The configuration gives the 787-10 a range of about 6,500nm with a full load of 330-337 passengers.

While the 787-10 has similar seat capacity to the A350-900 and 777-200ER, the 787-10 is a lower weight alternative.

That is, the 787's configuration is optimised for the 787-9, which has an ultra-long range of about 7,600nm, depending on passenger load and seat count. The 787-10 is light, has a small wing, and small fuel capacity compared to the A350-900 and the 777-200ER *(see table, this page)*. The 787-10's highest MTOW is 560,000lbs, it has a fuel capacity of 33,3984USG, and a wing area of 4,060 square feet.

The A350-900, as described, has two high MTOW specifications of 617,295lbs and 628,495lbs (280 and 285 tonnes), fuel capacities of 36,456USG and 43,589USG, and a wing area of 4,760 square feet. This

The 787-10 has a similar or larger seat capacity than the 777-200ER. The 787-10 is, however, lighter and has a smaller wing and fuel capacity. It can operate up to 6,500nm, about 1,400nm less than the 777-200ER's maximum range.

gives it longer-range performance of 8,100nm and 9,700nm *(see table page 10)*.

The older generation 777-200ER has the highest MTOWs of up to 656,000lbs, a fuel capacity of 45,220USG, and a wing area of 4,605 square feet. This gives the aircraft a range of up to 7,900nm. The 787-10 is thus a lightweight replacement option for the 777-200ER, and can carry a similar number of people on most routes but has about a 1,400nm shorter range.

Like the A350, the 787 has a base maintenance programme of four base checks. These each have a basic interval of 36MO, and so the cycle of four base checks is completed every 12YE. Actual MH inputs for the first two checks in the cycle are 1,200-1,800MH, depending on customer tasks; and 4,000-5,000MH in the 6YE check which has some deep inspection and heavy tasks *(see 787 base check maintenance analysis, Aircraft Commerce, June/July 2018, page 35)*.

777-8X/-9X

The 777-8X and -9X are straight replacements for the 777-200 and 777-300 series. The 777-8X and -9X are, however, larger in all main respects than the 777-200 and -300 series.

The -8X has a 17-feet longer fuselage and a higher seat capacity, a 119,000lbs higher MTOW than the -200ER and 8,000lbs higher than the -200LR, higher-rated engines than the -200ER, and about 1,600nm longer range than the -200ER, and about 200nm longer range than the -200LR *(see table, page 10)*.

The 777-8X's longer fuselage gives it a standard two-class capacity of 365 seats, compared with an average airline two-class capacity of 304 seats for the 777-200ER.

The 777-8X is the second variant to be developed, and is due to enter service in 2022. To date, the 777-8X has won 53 firm orders, from the big three Persian Gulf airlines: Etihad, Qatar Airways and Emirates.

The 777-9X is closer in the main specifications and configurations to the earlier 777 generation counterparts than the -8X. The two 777-X aircraft have the same MTOW of 775,000lbs, and the -9X has a fuselage that is just seven feet longer than the -300ER. The -9X has a wing area of 5,025 square feet compared to the -300ER's wing area of 4,702 square feet, and a fuel capacity of 52,300USG compared to the -300ER's 47,890USG. The 777-9X has lower-rated engines than the -300ER, at 105,000lbs thrust. Overall the -9X has a range of 7,525nm, just 155nm longer than the -300ER *(see table, page 10)*. The 777-9X has reached the stage of first assembly, and is due to enter service in 2020.

The 777-9X is therefore primarily configured to carry about 30 passengers more than the -300ER over a similar range. The 777-9X has won 263 firm orders. The largest is from Emirates for 115 aircraft, and Qatar Airways for 50. Other major customers include All Nippon Airways, Cathay Pacific, Lufthansa, Etihad and SIA.

The core of the 777-X family is the General Electric GE9X family, whose main features are a 134-inch wide intake fan compared to the 128-inch fan on the GE90-115B powering the 777-200LR and -300ER; a bypass ratio of 10.0:1 compared to the GE90-115B's bypass ratio of 9.0:1; and an overall pressure ratio of 60:1, compared to the GE90-115B's pressure ratio of 42:1. Moreover, the GE9X is rated at 105,000lbs thrust, 10,000lbs less than the GE90-115B.

The GE9X's main technological features are an increase in overall pressure ratio, to which an 11-stage high pressure compressor contributes. The engine also uses ceramic matrix composites (CMCs) in the non-rotating parts of the combustor and high pressure turbine (HPT). These include the two stages of the nozzle guide vane (NGV), and the HPT shroud. The use of CMCs allows high combustion temperatures because they require less cooling. In turn, higher combustion temperatures contribute to a leaner fuel burn. The GE9X is expected to be 10% more fuel efficient than the GE90-115B.

The 777-X family been conceived to provide an increase in seat numbers over their predecessors. There is no detail of the 777-8X's cabin configuration, but the 777-9X has a standard layout of 414 seats. This comes from an economy cabin in a 10-abreast arrangement at 32-inch pitch, providing 372 seats, plus a business-class cabin in seven-abreast and 85-inch pitch providing 42 seats.

Most 777-300ER operators configure the aircraft with a nine-breast economy cabin. Those that use a 10-abreast layout in the economy cabin have an average of 351 economy- and 39 business-class seats. All these airlines, however, have business-class cabins with a seat pitch smaller than 85 inches. This suggests that, on an equal cabin configuration basis, the 777-300ER would have 20-25 fewer seats than the -9X because of its seven-feet shorter fuselage.

The 777-8X has a standard two-class configuration of 365 seats, although no detail is given about how this is split between business and economy cabins. The 777-8X's fuselage is 223 feet, while the 777-200ER is 17 feet shorter at 206 feet. If configured on an equal basis, the -200ER would have up to 60 fewer seats. That is, six rows of economy-class seats in 10-abreast. The aircraft would have about 305 seats. Few 777-200ER operators have a 10-abreast economy class cabin, however. The average airline two-class configuration is 304 seats. This comprises a business class cabin of 33 seats and an economy class cabin of 272 seats. AC