The A340-500 and 777-200X provide unprecedented levels of range performance in standard conditions. How do they stack up on some of the world's most challenging routes?

The A340-500's & 777-200X's test of strength

Boeing has finally defined the ultra long-range 777-X. Airbus has has already won orders for the A340-500/-600 – the 777-X's competitors. The 777-X and A340 will have to compete for a limited market almost entirely on the basis of their payload-range performance. The 777-200X and A340-500 both have impressive still air range capability from sea-level airports, but how do they fare on the world's most testing ultra long-range routes?

Long-range mission

In most aircraft markets, the economics of seat-mile costs and revenue capacity are the deciding factors in aircraft selection. The performance of the aircraft has become less of an issue in many cases. The A320, for example, is mainly operated on 400–800nm sectors and still has a 3,050nm capability in standard conditions from a sea-level airport.

The markets in which performance remains an issue are at both ends of the air transport sector, that is, the regional markets and very long-range routes.

Range capability with a full load of passengers on ultra long-distance routes has always been an issue. The 747-200 for many years provided the longest range capability at 6,200nm. This capability eventually made non-stop operations between London and Hong Kong possible. The arrival of the 747-400, with a 7,200nm capability, made longer routes between west Europe and points in the Asia-Pacific possible, as well as trans-Pacific routes between mid and west coast US gateways and closer points in the Asia-Pacific region.

The A340-300E and 777-200ER have similar capabilities to the 747-400. The A340-300 has up to 7,300nm range and the 777-200ER a 7,720nm capability. These performances provide airlines with aircraft that can operate the same long-range networks as the 747-400, but with smaller capacity.

Nevertheless, these developments still left airlines without the ability to fly the longest sectors and avoid technical stops.

Examples of routes with technical stops are sectors flown by major US and Asian carriers across the Pacific, via international gateways. Many sectors from the US have to depart from international hubs on the west coast and routes via Tokyo, before flying to further destinations such as Singapore, Kuala Lumpur, Bangkok and Jakarta. Many of these routes require aircraft with the A340-500's and 777-200X's range performance. Dallas-Singapore, for example, has a great circle distance of 8,454nm.

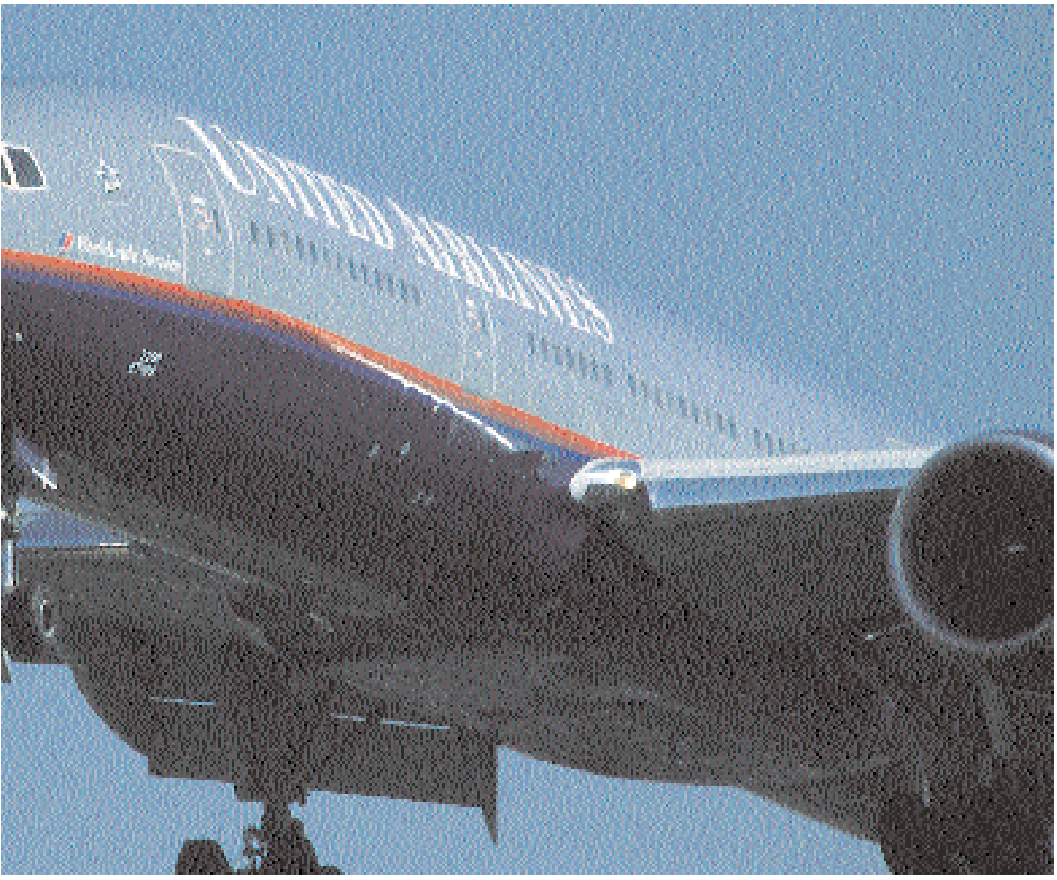
Similarly, routes across the Pacific from mid and east coast US points to New Zealand and Australia have to route via Islands in the mid-Pacific, because their tracked distance exceeds the capability of the A340-300 and 777-200ER.

The same is true for routes from west Europe to the furthest points in the Asia-Pacific and to Australasia. London to Perth, for example, has a great circle distance of 7,790nm. Flights between Europe and Australia and New Zealand have technical stops at airports such as Singapore or en route via the US.

On any route the equivalent still air distance (ESAD) flown will always be different to the tracked distance, because of headwinds or tailwinds.

Other routes with ESADs outside the A340-300's and 777-200ER's capability are those originating from Johannesburg (JNB) and Cape Town. JNB has the additional handicap of experiencing hot temperatures and having an elevation of 5,557 feet. This can limit aircraft permitted take-off weight and thus also payload and even make the route unfeasible. Examples of long-distance route great circle distances from JNB are Beijing (8,035nm), Taipei (7,850nm) and Seoul (8,478nm).

The problems of technical stops are increased operating distances, higher fuel consumption and the need to switch crews; which leads to poor crew utilisation and high subsistence and accommodation costs. While long-range aircraft that could avoid these stops would be economical for airlines, the demand for long-range capability has also evolved with growth in traffic. More routes are being opened and airlines want to bypass major gateways where passengers have been forced to interline for decades. Many of these routes require aircraft with the A340-500's and 777-200X's range performance. Passengers also prefer non-stop flights to ones with technical stops.



Analysis of the 777-200X reveals it to be an impressive performer. One weakness is limited MTOWs from hot and high airports, such as Johannesburg. The market for aircraft with the 777-200X's range is finite, and the A340-500 has already secured a portion of these orders.

A340 & 777-X

Only the A340-500 and 777-200X have range capability that exceeds previous aircraft and allows longer routes to be operated. The larger A340-600 and 777-300X models in both families have range performance similar to the 747-400.

The 777-200ER has a range of 7,720nm (GE90-powered). The newly defined 777-200X has a range of 8,865nm *(see table, page 24)*. Under Boeing's tri-class configuration it has a seat capacity of 301.

All 777-200 variants except the -X series have a choice of three powerplants. The limited market for very long-range aircraft led Boeing to give General Electric (GE) an exclusive supplier deal for the GE90 as its sole engine.

The A340-500 under Airbus' seat configuration has a tri-class capacity of 313 seats and 8,500nm range capability, 365nm less than the 777-200X.

The highest gross weight 777-300 variant has a 5,960nm range (Trent 800-powered). The 777-300X has a 7,230nm range. All 777-300 models have a tri-class seat capacity of 380, except the 777-300X, which has 359 seats.

The A340-600 has 380 seats and a 7,500nm range, 270nm more than the 777-300X.

The issue of ability to operate ultra long-range routes not currently operable is therefore just down to the A340-500 and 777-200X. Although the A340-600's and 777-300X's range performances do not offer any new long-distance challenge, airlines will want to maintain commonality. The better performer of the A340-500 and 777-200X on ultra long-distance missions will then go a long way to dictating whether airlines select the A340-500/-600 or 777-X family.

The analysis here examines the fuel burn and payload performance of the A340-500 and 777-200X on routes now made possible by their range capability.

Examples of routes that have great circle distances which fall within the capability of the A340-500 and 777-200X are New York–Singapore (great circle distance 8,294nm), Los Angeles–Perth (8,109nm), Toronto–Sydney (8,388nm), London–Perth (7,790nm) and Dallas–Singapore (8,454nm).

Test of strength

Since performance on routes currently impossible non-stop will be main the selection criteria for the A340-500 or 777-200X, an analysis of their performance on a handful of challenging routes will test their appeal. The important features will be their flight time, fuel burn and available payload.

Analysing the performance of the aircraft requires the selection of suitable routes and assumptions about aircraft configuration to be made.

Etops

An additional consideration for the 777-X is the issue of extended range twin-engine operations (Etops) missions. The 777-X is already certified for 180 minute single-engine diversion Etops missions, but Boeing is pushing for 207 minute certification.

The A340-500 and 777-200X will be deployed on some the world's longest routes, many of which have never before been operated non-stop. The majority of new routes that can be operated non-stop by these airlines will be between North America, West Europe, Asia-Pacific and Australasia.

The great circle distances of many of these routes will be over oceans and polar regions, with long distances to suitable diversion airports. The issue of single-engine failure and the need to divert to an alternative, only concerns the twin-engined 777.

Boeing has certification for 180 minute single-engine diversion time for the 777. This will allow the 777-200X to operate many new ultra long-range routes without any restrictions, or the need to increase the certification for single-engine diversion time. One example is New York–Sydney. It has a great circle distance of 8,640nm and track that just misses one of the mid-Pacific no-go areas for aircraft certified for 180 minute Etops missions.

Great circle or direct tracking will not be possible on other routes, because their flight paths will route over areas that are more than 180 minutes' flying time to a diversion airport on single-engine power. An example is Chicago-Singapore, which has a great circle distance of 8,144nm. The route tracks over Siberia and enters a no-go area with 180 minute Etops

SUMMARY OF AIRPORT PARAMETERS FOR A340-500 & 777-200X PERFORMANCE ANALYSIS

Airport	Runway	Temperature (degrees C)	Elevation (feet)	Diversion airport
Auckland (AKL)	05	24	15	Christchurch
Atlanta (ATL)	09L	31	1,019	Huntsville
Bangkok (BKK)	03R	33	7	Phitsanulok
New York (JFK)	04L	29	12	Boston
Johannesburg (JNB)	03L	24	5,557	Gaborone
Los Angeles	07L	27	119	Las Vegas
London Heathrow (LHR)	09R	22	75	Manchester
Manchester (MAN)	24R	21	249	London
Beijing (PEK)	18L	31	110	Taiyun
Perth (PER)	03	31	67	Kalgoorlie
Seoul (SEL)	14R	29	34	Pyongyang
Singapore (SIN)	02L	31	21	Kuala Lumpur
Sydney (SYD)	16R	29	7	Canberra
Taipei	06	32	106	Makung
Toronto	15L	27	557	Detroit

A340-500 & 777-200X CONFIGURATION

Aircraft type	A340-500	777-200X
First class seats	12	16
Business class seats	42	58
Economy class seats	259	227
Total seats	313	301
MTOW (lbs)	804,700	750,000
Usable fuel (USG)	56,746	51,590
OEW (lbs)	375,535	342,800
Range (nm) with passenger payload	8,500	8,865
Total available payload (lbs)	113,890	118,200

restriction. This will cause longer routeings diversions, which will either force technical stops because the routeings are excessive, or at least increase tracked distance, which may limit payload. In either case the 777-200X will be made less competitive against the four-engined A340-500.

The biggest problems will be caused by the longest routes from North America and Europe to the furthest points in the Asia-Pacific and Australasia. The great circle tracks are either polar routes or the widest parts of the Pacific ocean. These routes track over areas with few (or no) poor quality diversion airfields.

These problems can be avoided by increasing single-engine diversion time to 207 minutes. The effect is to reduce the average no-go areas and allow more routes to track along great circle paths. The Chicago–Singapore great circle track does not stray into a no-go area with 207 minute Etops certification. The 777-200X could then operate this route with the same tracked distance and ESAD as the A340-500.

Ultra long-range routes

The group of routes for the analysis have been selected on the basis of their great circle distances and the airports they serve.

There are many to choose from and the ones used have been selected to provide a range of great circle distances between 6,444nm and 8,562nm.

Although the shorter routes are easily within the aircraft's capability in standard conditions, headwinds and airport restrictions can limit the most capable aircraft.

The routes chosen for the A340-500 and 777-200X are listed *(see table, this page)*. This is representative of a larger number of routes with similar great circle distances. The performance of the aircraft will be analysed in both directions on the route.

Although the JNB routes are short compared to the A340-500's and 777-200X's standard condition, sea-level performance, they will be challenged by hot and high take-off conditions at JNB.

Longer routes between the north America and the Asia-Pacific track over the north polar region can face Etops restrictions, depending on which airports are accepted as suitable diversion airfields by the regulatory authorities.

Other routes also have long ranges, some over wide stretches of the Pacific, and operate from airports that often have high temperatures.

Aircraft configuration

Many factors will affect an aircraft's performance. These can be divided between the configuration of the aircraft and the operating conditions at the airports and en route.

The most important factors in aircraft configuration – besides weight, fuel and engine specifications – are seat numbers and interior configuration, aircraft operating empty weight (OEW), average passenger weight, passenger load factor, crew numbers and weight, catering and on-board equipment.

The aircraft configurations are summarised *(see table, this page)*. Seat numbers not only influence fuel burn and payload-range performance, but also dictate the economics of the aircraft in all other respects. Each manufacturer has its own standard interior configurations, but actual airline layouts are often unique.

The manufacturer's configuration is therefore intended to represent a 'typical' airline layout. In the case of all aircraft studied here, they are most likely to be operated by major airlines on scheduled services in a tri-class configuration.

The number of seats is ultimately determined by the available area in the cabin, but also by number of toilets, closets, galley space and ratio of first, business and economy seats.

Airbus' standard seat configuration for the A340-500 is 313. The ratio of first, business and economy class seats in the A340-500 is 3.8%, 13.4% and 82.8%, respectively.

The 777-200X has a Boeing standard tri-class configuration of 301 seats. The ratio of first, business and economy seat numbers is 5.3%, 19.3% and 75.4%, respectively. The 777-200X thus has a high proportion of premium fare seats.

Differences in the ratio of first, business and economy class seat numbers raises the issue that aircraft are not being

The A340-500 has already made it possible to operate ultra long-distance routes. Its four-engine configuration avoids Etops problems and it has a full payload only 4,300lbs less than the 777-200X.

compared on an equal basis. Boeing claims that with the same ratios of seat class numbers, the A340-500 would have 282 seats, giving the 777-200X a 19-seat advantage.

In an airline's situation, the ratio of seat numbers in the three classes may not be the same between competing Airbuses and Boeings. Following selection, airlines might configure either type with the same number of first and business class seats. The type with the largest cabin floor area would have an advantage in economy seats (in this case, the 777-200X).

Again, it is argued that aircraft should be compared with the same ratios of toilets, closets and galley volume per seat in each cabin class. The effect of toilet and closet numbers and galley volume is to determine aircraft OEW – and thus the aircraft's efficiency – available payload and fuel burn. The aircraft's OEWs are also shown *(see table, page 24)*.

Aircraft OEW is determined by the sum of manufacturer's empty weight, operator items and weight of containers and pallets. Operator's items include unusable fuel, engine and auxiliary power unit oil, water for galleys and toilets, toilet pre-charge, aircraft documents, passenger seats, in-flight entertainment equipment, galley structures, catering, emergency equipment and crew.

Average passenger weight has been taken as 210lbs. Passenger load factor is taken as 100%, except where the aircraft is subject to a payload restriction on a particular route.

Crew numbers used reflect what most airlines will configure during a typical operation. On ultra long-range routes where the A340-500 and 777-200X are analysed, airlines are likely to roster three flight crew.

The number of cabin crew on the A340-500 and 777-200X is 13. Crew weight is taken to be 210lbs per person. This takes total crew to 16.

Finally, catering is taken to be 70lbs per first class seat, 44lbs per business class seat and 26lbs per economy class seat.

Operating conditions

Factors outside the design and configuration of the aircraft are fuel density, airport and diversion airport parameters and en route conditions. Fuel density is assumed to be 6.7lbs per US Gallon.

Airport and diversion airport parameters include runway used and length, obstacles to be cleared, temperature and airport elevation.

A summary of the airport conditions in each of the routes analysed and diversion airfields is summarised *(see table, page 24)*. The performance analysis for the aircraft uses 85% hottest month temperature.

En route conditions affecting aircraft performance are cruise speed and altitude, en route wind, route taken, mission rules and payload carried.

For all aircraft, long-range cruise speed has been used and the performance computations have used optimum altitude for every phase of the flight. En route wind has been calculated using 85% annual winds, which then influences the tracked distance. For each route analysed there are many possible routeings an airline can take on the actual day of operation. Each one has a different tracked distance and encounters varying wind speeds and strengths. For simplicity this analysis uses the great circle distance plus 2% to allow for departure and arrival routeings. When 85% annual winds are applied, the ESAD for each route is calculated. The ESAD then affects the payload that can be carried and the fuel burn and flight time.

Mission rules used here are the same as Airbus' and Boeing's long-range rules. This includes taxi in and out times of nine and five minutes. The payload carried is assumed to be 100% passenger load factor plus any permitted freight that can be carried.

Performance results

With the routes selected, aircraft configurations finalised and operating conditions defined, the performance of each aircraft on the selected routes can be determined.

The prime concern for airlines will be payload limitations in terms of passenger numbers. This is because the economics of the aircraft are determined by available seats, both in cost and revenue.

The 777-200X has a 365nm range advantage over the A340-500. Both will fly the same ESADs on each route and will not experience any passenger number restrictions on a route with an ESAD shorter than their full passenger payload ranges.

The 777-200X's small range advantage means that it is limited in passenger numbers on three of the routes studied here. The A340-500 is limited on seven routes. If the A340-500 had fewer seats, as Boeing suggests, it would be

ROUTE PERFORMANCE OF A340-500 & 777-200X

Route	Great circle distance (nm)	ESAD (nm)	A340-500 Fuel (USG)	A340-500 Pax	A340-500 Cargo (lbs)	777-200X Fuel (USG)	777-200X Pax	777-200X Cargo (lbs)
JNB-TPE	6,319	6,358	37,465	313	48,160	30,701	301	47,390
TPE-JNB	6,319	6,578	39,442	313	48,160	32,157	301	52,590
JNB-PEK	6,444	6,365	37,758	313	47,230	30,940	301	43,740
PEK-JNB	6,444	6,888	41,778	313	48,160	33,978	301	52,640
JNB-SEL	6,854	6,784	40,510	313	48,160	33,127	301	35,440
SEL-JNB	6,854	7,392	44,527	313	36,014	37,007	301	46,890
JNB-JFK	7,062	7,564	45,120	313	31,209	37,933	301	11,390
JFK-JNB	7,062	6,947	42,104	313	48,160	34,351	301	52,640
YYZ-BKK	7,492	7,651	45,660	313	27,021	38,657	301	38,190
BKK-YYZ	7,492	7,685	45,797	313	25,700	38,963	301	36,840
YYZ-AKL*	7,639	8,295	48,566	305	153	43,507	301	10,490
AKL-YYZ*	7,639	7,406	44,446	313	35,002	37,642	301	42,140
LAX-SIN	7,762	8,828	50,932	271	40	46,552	301	1,790
SIN-LAX	7,762	7,480	44,811	313	31,579	37,940	301	39,590
LHR-PER	7,986	7,870	46,623	313	15,910	40,500	301	26,840
PER-LHR	7,986	8,462	49,350	313	3,287	43,866	301	14,590
ATL-BKK	8,091	8,388	48,981	313	4,160	43,485	301	15,340
BKK-ATL	8,091	8,177	48,068	313	12,157	42,060	301	22,740
LAX-PER	8,254	8,844	51,002	245	156	46,694	288	70
PER-LAX	8,254	8,019	47,335	313	14,220	41,343	301	23,890
JFK-SIN	8,443	8,532	49,599	313	403	44,619	301	9,840
SIN-JFK	8,443	8,753	50,578	282	130	45,992	301	4,390
YYZ-SYD	8,562	9,255	52,268	197	125	48,410	257	130
SYD-YYZ	8,562	8,285	48,519	313	6,969	43,104	301	15,840
ATL-SIN	8,821	9,265	52,117	180	75	48,440	248	70
SIN-ATL	8,821	8,802	50,801	281	24	46,358	301	3,040

* Route is 180 minute Etops restricted. ESAD for 777-200X is increased by 30–50nm.

limited on a smaller number of routes.

The test for the aircraft is not only the number of routes with passenger number restrictions, but also the degree of restriction.

The longest route, for example, is YYZ-SYD with an ESAD of 9,255nm. The A340 is limited with 197 passengers versus 257 for the 777-200X. A similar example is ATL-SIN with an ESAD of 9,265nm, where the A340-500 is limited to 180 seats and the 777-200X, 248 *(see table, this page)*. Another example is LAX-PER with a ESAD of 8,844nm.

The other important consideration is restriction in cargo payload. The 777-200X's structural payload is 115,850lbs, but only 1,950lbs more than the A340-500's payload.

The freight payload will not only be affected by permitted passenger numbers, but also required fuel weight when the aircraft is operating on longer ranges and so will have reached its maximum take-off weight (MTOW). The A340-500's higher seat numbers under Airbus' own tri-class configuration means its remaining cargo payload is smaller than the 777-200X's. The A340-500 has a remaining cargo payload of 48,160lbs, while the 777-200X has a cargo payload of 52,640lbs.

Differences in cargo payload reveal a major difference between the two aircraft. Although the shortest routes from JNB are within the full passenger range capability of both aircraft, operating conditions at JNB have serious consequences for the 777-200X. On routes departing from JNB the aircraft has a limited MTOW. Although this does not affect permitted passenger numbers, it does reduce cargo payload. This is revealed by the higher cargo payload on routes to JNB, where the 777-200X has fewer take-off restrictions.

The A340-500 does not have the same MTOW limitations when departing JNB and thus carries more cargo *(see table, this page)*. This is explained by the A340's four-engined configuration.

The situation is reversed on longer routes where the 777-200X does not have any MTOW limitations and so carries more freight. The 777-200X's freight weight and total payload advantage also becomes greater on the longer ESADs *(see table, this page)*.

The A340-500 is overall a heavier aircraft than the 777-200X, with a 554,700lbs higher MTOW. This is reflected by the higher fuel burn on every route *(see table, this page)*. The A340's higher fuel burn is largely accounted for by its four-engine design. These higher fuel burns are also a factor with the A340 carrying a smaller total payload, despite having a 12-seat larger standard tri-class configuration. The fuel burn difference is as high as 22%.

This analysis only examines a small sample of routes. Other routes with more severe Etops or MTOW restrictions could reveal other differences between the two. Even though the 777-200X has demonstrated more advantages here, the A340-500/-600 has won orders from major carriers while the 777-X has not been available. The relative importance of range and operating performance between the A340 and 777-X depends on the route networks and requirements of the few remaining airlines likely to order the A340-500/-600 and 777-X. AC

The fuel burn and payload performance comparison between the A340-500 and 777-200X revealed that the 777 generally has better payload and fuel burn performance on ultra long-distance routes. This is achieved, however, by the 777-200X using two auxiliary tanks.

A340-500 & 777-200X performance comment

The published article 'The A340-500's & 777-200X's test of strength', page 20, of the March/April 2000 issue of *Aircraft Commerce* had some data on the 777-200X with statements that may have been misleading.

Payload

The first of these was the aircraft's maximum structural payload, quoted as being 115,850lbs.

The 777-200X has a maximum zero fuel weight (MZFW) of 456,000lbs and an optional MZFW of 461,000lbs. The operating empty weight (OEW) of the aircraft is 342,800lbs.

These two MZFWs provide the 777-200X with a maximum structural payload of 118,200lbs and 113,200lbs. This can accommodate passenger payload and freight. The article stated incorrectly that the 777-200X has a structural payload of 115,850lbs.

This compares with the A340-500, which has a MZFW of 489,426lbs and OEW of 375,536lbs. This gives the aircraft a maximum structural payload of 113,890lbs.

The 777-200X's higher MZFW therefore gives it a 4,310lbs higher payload than the A340-500. The article incorrectly stated the 777-200X's payload advantage is 1,950lbs. With the smaller MZFW, the 77-200X has a 690lbs disadvantage.

Boeing's standard tri-class seat configuration for the 777-200X of 301. The performance A340-500 and 777-200X were analysed on an equal basis, and standard passenger weight was taken as 210lbs. The 777-200X's full passenger load payload would then be 63,210lbs. This leaves a structural payload for freight of 54,990lbs or 49,990lbs, depending on MZFW configuration.

The A340-500 has a tri-class capacity of 313 seats, and so a 65,730lbs passenger payload. This leaves 48,160lbs structural payload capacity for freight. This is 6,830lbs and 1,830lbs less than the 777-200X.

These configuration weights for the 777-200X are for the aircraft with two auxiliary centre tanks (ACTs) installed. Airbus says despite the structural payload capabilities, the 777-200X would have volumetric capacity equivalent of two LD-3s, or 3,000lbs, less than the A340-500. This is because the A340-500 has a longer fuselage and holds more LD-3 containers.

Seat capacity

The article based performance data on the manufacturers' standard tri-class seat capacities. This is 313 for the A340-500 and 301 for the 777-200X.

The 777-200X has higher proportion of seat numbers for first and business class seating; at 5.3% and 19.3%. The A340-500 has 3.8% and 13.4% first and business class seating.

Boeing argues that on the same proportions of first and business class seating as the 777-200X, the A340-500 would have only 282 seats; a 19 seat disadvantage.

Airbus counters this by saying both types are likely to be configured with five abreast seating in first class and six abreast seating in business class, despite the 777's wider cabin. The A340 would have an eight abreast economy configuration and the 777 nine abreast. In this situation Airbus says the A340-500 would have 284 seats, 24 more than the 777-200.

Fuel burn

The fuel burn, payload and range data in the article was based on fuel capacities of 56,746 US Gallons for the A340-500 and 51,590 US Gallons for the 777-200X.

The article stated that, according to the fuel burn data, the A340-500's block fuel burn was up to 22% higher than the A340-500. This is for the worst case scenario.

The A340-500's fuel burn is in fact 7.5-22.6% higher than the 777-200X, on the group of routes analysed. The difference between the two aircraft reduces as distance flown increases. This illustrates how the fuel efficiency of four-engined aircraft on long distance missions improves compared to a twin-engined aircraft.

The performance of both aircraft was analysed using the same mission rules, including diversions, which affects reserve fuel.

On most routes both aircraft are able to carry more than 4,000lbs reserve fuel. On the YYZ-SYD and ATL-SIN sectors the 777-200X only has room for 3,180 and 3,150 US Gallons. This is where fuel burns of 48,140 and 48,440 US gallons have been made. These reserves are about 1,400 and 1,600 US Gallons less than the A340-500's.

On some routes the 777-200X has the capacity for more reserve fuel than the A340-500. This is because the A340-500 burns more fuel.

With the standard configurations stated the A340-500 has a 8,500nm range, and the 777-200X a 8,865nm capability. The 777-200X only achieves this with two ACTs installed. Airbus says it can match the 777-200X's range without using removable fuel tanks. AC