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Some comments on the capabilities of the current generation of civil aircraft to satisfy the evolving strategy of airlines offering ultra-long-range passenger flights

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Abstract

A number of full service network carriers have recently stated their ambition to develop certain ultra-long-range (ULR) routes, such as Doha to Auckland, Dubai to Auckland, Dubai to Panama City, Singapore to San Francisco, Singapore to New York, all of which require a great circle distance between 7,000-9,000 nautical miles (nm) with an estimated travel time between 15 and 20 hours. This paper examines the capability of the current generation of wide-bodied passenger aircraft to satisfy this evolving strategy, and the impact, if any, on the provision of air cargo transportation.

The key findings reveal that airlines wishing to pursue this ultra-long-range strategy currently have a surprisingly limited choice of passenger aircraft which are capable of flying the desired mission profile without compromising significantly on passenger numbers and cargo payload. The standout aircraft is the Boeing 777-200LR which offers a convenient blend of passenger numbers and cargo payload combined with true ULR performance; it therefore comes as no surprise that the airlines currently considering such ULR flights all have a number of Boeing 777-200LR aircraft models in their existing fleets and have stated their intentions to use them for such operations.

1. Introduction

Air transportation is defined as the carriage of persons, goods, property or postal mail by air. It comprises two primary segments, the transport of passengers and the carriage of air cargo. Each segment of the industry has its own unique characteristics, yet the two are difficult to consider in isolation (Dempsey and Gesell 1997), which is why air transportation is often referred to as a “bi-polar” industry. In 2014, the world’s airlines carried 3.3 billion passengers and some 50.4 million tonnes of cargo (International Civil Aviation Organization, 2015). The major world airlines typically structure their networks according to the hub-and-spoke principle whereby they link together smaller peripheral markets via their hubs so as to optimise passenger and air cargo connectivity. Many airlines also structure their route networks on short haul, medium-haul, and long-haul non-stop services. The focus of this study is on the latter, and more specifically, the newly defined niche strategy of operating ultra-long-range (ULR) services from hubs in an attempt to develop new market opportunities from a passenger and cargo perspective. The first airline to offer a true ULR service was Singapore Airlines, which, between 2004 and 2013, operated non-stop flights between Singapore and New York using Airbus A340-500s. These flights, which covered between 8,285 nautical miles (nm) on the Newark-Changi polar route, and 9,000 nm on the return Changi-Newark route, took approximately 18 hours, but were discontinued in 2013 due to declining passenger demand and falling profitability (Singapore Airlines Flight 21 2016).

Recently, airlines have shown a renewed interest in offering ultra-long-range (ULR) routes, such as Doha to Auckland (Qatar Airways 2016a), Dubai to Auckland (commenced in March 2016), Dubai to Panama City (anticipated start 2nd quarter 2016) (Mutzabaugh 2016), Singapore to San Francisco (anticipated start mid 2016) (United Airlines 2016), and Singapore to New York (anticipated start 2018) (Singapore Airlines 2015), all of which require a great circle distance between 7,000-9,000 nm with an estimated travel time between 15 and 20 hours. The aim of this study is to examine the ability of the current generation of wide-bodied civil aircraft to satisfy the ambitions of airlines to service such ULR routes. In light of the growing importance of air cargo as a strategic business segment, this paper also examines the ability of current wide-bodied civil aircraft to offer a worthwhile payload capacity on ULR routes that could be used for such cargo carriage.

This paper is organized as follows: the literature review presented in Section 2 commences with a brief overview of air cargo and a review of the civil aircraft payload-range envelope and its impact on aircraft performance. The research method used in the study is described in Section 3. The empirical examination of the current generation ULR capable aircraft and the Qatar Airways Doha to Auckland case study is presented in Section 4, and the concluding comments are discussed in Section 5.

2. Background

2.1. Ultra-long-range flights – key concepts

There is no absolute definition of ultra-long-range flight distances primarily because aircraft performance changes (improves) over time. In the 1970's, ULR was understood to mean any non-stop flight distance in excess of 5,000 nm, which was quite a remarkable achievement for that era, as typified by the first generation of wide-bodied "jumbo" jets such as the Boeing 747 and the McDonnell-Douglas DC-10. However, nowadays it is more appropriate to define ultra-long-range (ULR) as any non-stop flight carrying an economically meaningful payload over a distance in excess of 7,000 nm.

The emerging trend for airlines to offer ULR services fills a niche market requirement for travellers and air cargo shippers who demand the shortest possible journey time between a city-pair. In addition, by eliminating intermediate stopovers, passenger facilitation is simplified by avoiding the requirement for transit documentation, and new opportunities are created for cargo transportation, thus benefitting the economies of the states of origin and destination.

In order to conduct ultra-long-range flights using large wide-body twin-engine aircraft, an airline must first gain ETOPS certification appropriate to the intended route. ETOPS stands for Extended-range Twin-engine Operational Performance Standards; it is a Federal Aviation Administration rule permitting modern twin-engine commercial transport aircraft to fly long distance routes, which, at some point, are more than 60 minutes' flying time away from the nearest airport suitable for emergency landing (Asselin 1997). ETOPS certification[1] requires both the aircraft and the airline to comply with a stringent set of regulatory standards. For the aircraft, the manufacturer must demonstrate the specific combination of airframe and engine satisfies the basic ETOPS requirements during its type certification. The airline must then demonstrate to its own country's civil aviation regulator that its flight crew training and maintenance procedures are of the highest standard, and its pilots, engineers and staff are specially qualified for ETOPS operations.

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[1] For example, if an aircraft is awarded an ETOPS-120 rating, this means that the aircraft is capable of flying in still air with a full load and with only one engine operative for 120 minutes (2 hours).

2.2. Provision of lower deck hold capacity on combination airline passenger services

Air cargo is also an important revenue source for the world's airlines. In 2014, the annual world air cargo revenues were around $USD 62 billion (International Air Transport Association 2015).

The *raison d'etre* of a combination airline is to provide a priority service to passengers; any remaining payload availability can then be devoted to cargo carriage. This arrangement, in which passengers are carried on the aircraft main deck and cargo is carried below in the lower deck "belly hold" compartments, is referred to as a combination aircraft (Dempsey and Gesell 1997). Whilst every wide-bodied civil aircraft is designed and built with a certain amount (volume) of lower deck cargo capacity, and sized to accommodate a number of industry-standard aircraft unit load devices (ULDs) such as containers or pallets, it will be shown in Section 2.3 that it may not always be feasible to use this capacity to its full extent because the aircraft may be weight-limited or even fuel-limited which will impose restrictions on the availability of cargo carriage (Billings et al. 2003).

2.3. Civil aircraft performance: The payload-range envelope

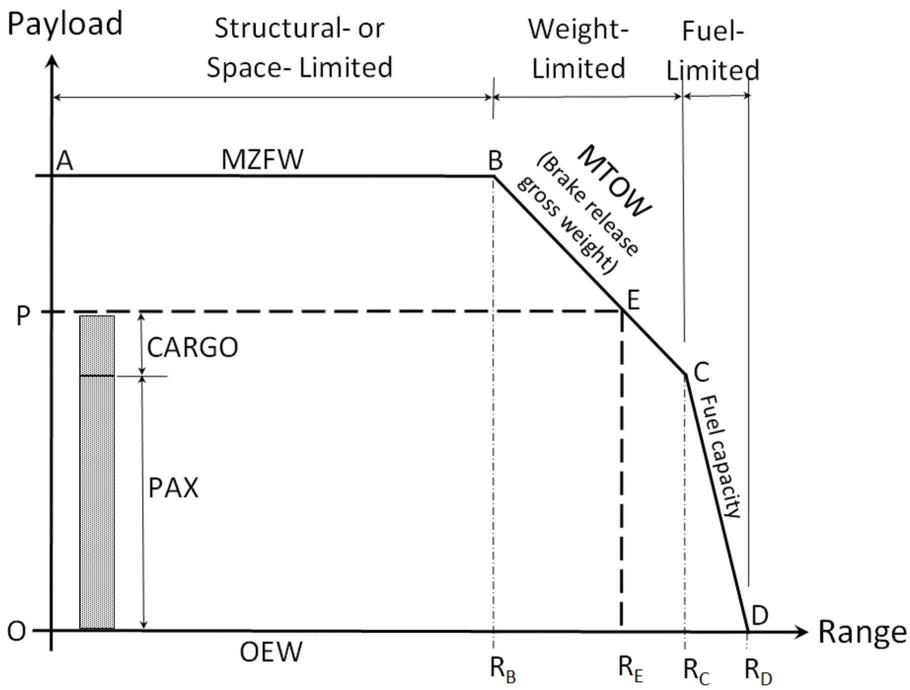
The primary means of assessing the overall performance of a civil aircraft is from its payload-range graph, which provides an envelope showing how payload capacity varies with flight range. Full details are available from other sources (Torenbeek 1976) and only a brief description is presented here. A typical payload-range envelope is shown in Figure 1 in which the range is plotted on the abscissa and the payload on the ordinate. Strict definitions of the various terminology used here are provided in Appendix A.

The vertical axis displaying the payload has a false origin that corresponds to the aircraft's Operating Empty Weight (OEW). The horizontal line AB is fixed at the Maximum Zero Fuel Weight (MZFW) of the aircraft. In the region AB, the difference between the MZFW and the OEW equals the payload capacity; since the fuel tanks are only partially filled in this region the full payload can be transported for ranges extending to R_B simply by increasing the fuel quantity. The gross weight of the aircraft increases along line segment AB but remains less than the maximum value, except at point B which corresponds to the maximum aircraft gross weight and maximum payload weight even though there still remains spare fuel capacity. Point B also gives the maximum possible flight range R_B whilst carrying the maximum payload, which Morrell (2011) identifies as the point of maximum efficiency.

Between points B and C, the Maximum Take Off Weight (MTOW) limits the gross weight of the aircraft, which remains constant along the line segment BC. From Point B, the range may now only be increased by exchanging fuel weight for payload weight, i.e. payload is off-loaded whilst fuel is added, thus maintaining a constant gross weight. Point C occurs when the fuel tanks are completely full, a limit that is set by the aircraft's fuel tank capacity.

Along the line segment CD, further increases in range can now only be achieved by progressively reducing the payload since no additional fuel can be accommodated. In this region the aircraft's gross weight is lower than the maximum value. For commercial use the region CD is unimportant and uneconomic, which explains why R_C (instead of R_D) is generally referred to as the maximum range. At Point D there is no payload remaining and R_D corresponds to the ferry range of the aircraft which is its maximum possible flight range when flown empty.

Figure 1. Generic payload-range envelope for a typical civil aircraft



With further reference to Figure 1, for an aircraft to achieve a desired range, e.g. R_E, the payload-range envelope is entered at point R_E and a line is projected vertically until it intersects the envelope at *E*. By projecting a horizontal line through *E* back to the payload axis at *P*, the total amount of payload that can be carried by the aircraft type over the desired range can be determined. Ideally, the payload availability *OP* will still be sufficient for a full complement of passengers in the airline's chosen seating configuration, plus some additional cargo, as indicated schematically in Figure 1. All ULR flights will occur in the region BC since there is no current civil aircraft designed to operate with a maximum payload for ranges $R_B \geq 8{,}000$ nm. Clearly, the aircraft offering the most promising ULR performance will be those for which Point E is closest to Point B on their specific payload-range envelope. However, in reality it may not be possible to attain the desired range without imposing considerable payload restrictions which in turn will impact an airline's ambition to offer a particular level of service. Ultimately all these variables are governed by the particular payload-range characteristics of a given aircraft type. Since most large full service network carriers operate a mixed fleet of aircraft types, a simple trade study based on the method described here should provide an interesting assessment of which aircraft type(s) is/are best suited to operate ULR missions.

3. Research method

Because the analysis of ULR flights is an emergent area of research, the most appropriate investigative method is a qualitative approach (Edmondson and McManus 2007). Data for this study was obtained from a range of documents, such as the aircraft manufacturers' airport characteristics handling manuals, corporate brochures, industry reports and press articles. The study therefore used secondary data in conjunction with content analysis to describe, analyse and summarise trends and observations from the data that have been collected in the study (Green 2011).

In addition, an exploratory case study is presented examining Qatar Airways' proposed route between Doha and Auckland, which will be the longest scheduled passenger flight in the world covering a range of 7,850 nm. Case studies use a variety of evidence gathered from different sources, such as documents, artefacts, interviews or observation (Dawes Farquhar 2012; Fasone and Maggiore 2012).

4. Results

4.1. Survey of current wide-bodied civil aircraft ULR capabilities

The aircraft types surveyed here are limited to those current wide-bodied models in service with major airlines and deemed capable of flight ranges in excess of 8,000nm. These include the Boeing models 747, 777, and 787 (including series derivatives), and the Airbus models A330, A340, A350 and A380 (including series derivatives). Older types, such as the McDonnell-Douglas MD-11 and DC-10, and the Ilyushin IL-96-300, IL-96M and 96T, are not included because they do not possess sufficient range capability; in addition, both McDonnell-Douglas types ceased commercial passenger service during 2014. The Boeing 747SP, which was specifically designed for ULR flights, is nearing retirement and only 12 aircraft remain in service at the time of writing (Boeing B747SP Website 2016) - this type is also excluded from this survey. The following assumptions are made:

- No attempt is made here to anticipate or predict any airline's operational procedures. The estimates made, and analysis performed, are based on generic information from the appropriate aircraft manufacturers' Aircraft Airports Handling Characteristics Manual, and are sufficiently accurate to support the main findings of this work.
- The payload-range data is taken directly from the appropriate aircraft manufacturers' Aircraft Airports Handling Characteristics Manual, and assumes a standard day with zero wind and a step cruise at the relevant Mach number.
- Where different engine options are available, those giving the payload-range envelope the most favourable characteristics are used.
- The passenger numbers used here follow from the standard configuration quoted by the manufacturer in the appropriate Aircraft Airports Handling Characteristics Manual. Where more than one seating configuration is quoted, the one with the least number of passengers is conservatively quoted.
- Passenger payload weight is based on the industry-standard value of 105 kg per person, which includes all his/her luggage. In addition, the weight of all the LD3 unit load containers required for passenger luggage must also be included. The required number of standard AKE LD3 containers, which each weigh 76 kg (Nordisk Aviation Products 2016), is estimated on the widely used assumption that on average each passenger has one item of luggage, and a standard AKE LD3 container holds approximately 35 bags. Thus an aircraft with 300 enplaned passengers would require (300 x 1)/35 = 9 (rounded up from 8.57) AKE LD3 containers for all the luggage, adding 9 x 76 kg = 684 kg to the payload.
- No account is taken of an airline's potential use of flexible routes, also known as "Flex Tracks" (Airservices 2013), on a generic ULR flight mission profile.

With reference to Table 1, for each aircraft considered in this study, the make and model is quoted in Column 1 and the master series is listed in Column 2. From the relevant payload-range envelope, the ranges R_B, R_C and the ferry range R_D are summarized in Column 3. Column 4 states the total passenger numbers from the standard seating configuration and their corresponding payload weight based on the industry-standard value of 105 kg per person (which includes all passenger luggage), plus the weight of the appropriate number of AKE LD3 containers required to store this luggage. The total payload availability for a prescribed ultra-long-range flight distance of 8,000 nm is then determined from the appropriate Aircraft Airports Handling Characteristics Manual payload-range chart by using the construction described in Section 2.3 and illustrated in Figure 1. This value is quoted in Column 5. If the total available payload in Column 5 is less than the passenger payload in Column 4, then it is concluded the aircraft type would not be able to operate on a given 8,000 nm ULR route with a standard passenger complement, and comments to this effect are added in Column 6. If, on the other hand, the total available payload in Column 5 exceeds the passenger payload in Column 4, then the amount of surplus payload – which would be available for cargo provision – is quoted in Column 7.

It is noted from Table 1 that whilst achieving an ULR distance of 8,000 nm is possible for all the aircraft types considered here, the challenge for the majority is retaining a worthwhile payload availability over the desired range; only the Airbus A340-500 and Boeing 777-200LR demonstrate this potential. (The A330-200 can just achieve the desired range carrying the standard passenger load, but there is minimal scope for cargo carriage). This simple exercise highlights the fact that there is a severely limited choice of aircraft types capable of servicing ULR flights with any positive commercial potential - it makes no economic sense to operate an aircraft in a niche market without a high passenger load factor and without any cargo availability. For example, the Boeing 747-8 Intercontinental could achieve the desired 8,000 nm range with 365 passengers and no cargo, or with just 200 passengers and 15 tonnes of cargo availability, but either scenario would likely prove too uneconomic to justify its regular use on an ULR route. In fact, the economics of 'long thin routes' – routes which need long range but do not have the demand for the largest aircraft such as the Boeing 747 or Airbus A380 – work in the Airbus A340-500's and Boeing 777-200LR's favour.

During preparation of this paper, Emirates Airline inaugurated their ULR service from Dubai (DXB) to Auckland NZ (AKL) using an Airbus A380-800, but were quick to point out that subsequent services would be offered exclusively on the Boeing 777-200LR (Emirates Airline 2016a). The reasons for this ought now to be clear from Table 1; comments from passenger blogs (Calder 2016) support this reasoning and it is certain the A380-800 used for this flight had to be operated with payload restrictions in order to achieve its 7,670 nm great circle range.

Hence, prior to the service introduction of the next generation of ULR-capable civil aircraft the default choice currently available is decidedly clear: the Boeing 777-200LR. This conclusion is perhaps not too surprising given that the majority of aircraft considered here were never optimised and intended for such extreme long range operations. The fact only 59 Boeing 777-200LRs were ever built between 2006 and 2013, of which 55 were still in airline revenue service in mid-2015 (Flight International 2015), is proof of the small numbers required to service these niche ultra-long-range markets that make up no more than a few percent of the world's airline route networks (Leeham News and Comment 2013). If the reader is wondering why the A340-500 is not a credible contender in this market-space, it is because by mid-2015 there were only 8 (eight) A340-500's in service worldwide, and all the major airlines currently operating this type are in the process of accelerating its retirement (Flight International 2015).

Table 1. Key performance measures for current wide bodied aircraft capable of ULR flights, including any payload availability to carry lower deck cargo. (See Section 4.2.2 for a sample investigation)

1	2	3	4	5	6	7
Aircraft Make & Model	**Master Series**	**R_B R_C R_D**	**Standard enplaned PAX [1] & PAX Weight [2]**	**Total payload availability at R_E = 8,000 nm [3]**	**Comments**	**Surplus payload availability at R_E = 8,000 nm**
Boeing 747	-400ER	6,200 nm 8,000 nm 9,100 nm	416 PAX 45,000 kg	36,000 kg	4-engines. Cannot carry standard PAX at 8,000 nm	NIL
Boeing 747	-8	5,900 nm 8,000 nm 9,000 nm	515 PAX 57,000 kg	41,000 kg	4-engines. Cannot carry standard PAX at 8,000 nm	NIL
Boeing 777	-200 HGW	5,750 nm 8,600 nm 9,600 nm	305 PAX 34,000 kg	32,000 kg	2-engines. Cannot carry standard PAX at 8,000 nm	NIL
Boeing 777	-300ER	5,600 nm 7,800 nm 8,500 nm	339 PAX 37,000 kg	14,000 kg	2-engines. Cannot carry standard PAX at 8,000 nm	NIL
Boeing 777	-200LR	7,500 nm 8,100 nm 9,500 nm	279 PAX 31,000 kg	45,000 kg	2-engines. Standard PAX plus extra capacity for cargo	14,000 kg
Boeing 787	-8	5,500 nm 9,500 nm 10,000 nm	242 PAX 27,000 kg	21,000 kg	2-engines. Cannot carry standard PAX at 8,000 nm	NIL
Boeing 787	-9	5,250 nm 8,250 nm 9,400 nm	290 PAX 32,000 kg	27,000 kg	2-engines. Cannot carry standard PAX at 8,000 nm	NIL
Airbus 330	-200	4,250 nm 9,150 nm 9,250 nm	246 PAX 27,000 kg	28,000 kg	2-engines. Standard PAX plus minimal capacity for cargo	1,000 kg
Airbus 340	-500	7,100 nm 9,100 nm 9,800 nm	313 PAX 34,000 kg	40,000 kg	4-engines. Standard PAX plus extra capacity for cargo.	6,000 kg
Airbus 340	-600	5,600 nm 7,800 nm 8,800 nm	380 PAX 41,000 kg	25,000 kg	4-engines. Cannot carry standard PAX at 8,000 nm	NIL
Airbus 350	-900	5,300 nm 9,400 nm 10,100 nm	315 PAX 35,000 kg	32,000 kg	2-engines. Cannot carry standard PAX at 8,000 nm	NIL
Airbus 380	-800	6,500 nm 8,800 nm 9,500 nm	555 PAX 60,000 kg	52,000 kg	4-engines. Cannot carry standard PAX at 8,000 nm	NIL

Source: Boeing Commercial Airplanes (2009, 2011, 2012, 2015); Airbus SAS (2014, 2015a, 2015b, 2015c).

Note – All PAX weights and payload availability weights have been rounded to the nearest 1,000 kg.

1. The passenger numbers used here follow from the standard configuration quoted by the manufacturer in the Aircraft Airports Handling Characteristics Manual. Where more than one seating configuration is quoted, the one with the least number of passengers is conservatively quoted.
2. Passenger weight is based on the industry-standard value of 105kg per person (which includes all his/her luggage), plus the weight of the appropriate number of AKE LD3 containers required to store all the passenger luggage.
3. Where different engine options are available, those giving the payload-range envelope the most favourable characteristics are used.

4.2. Qatar Airways Doha to Auckland ULR flight case study

4.2.1. Qatar Airways: A brief overview

Qatar Airways, the national carrier of the State of Qatar, has its headquarters in the capital city, Doha, and is one of the world's fastest growing airlines. Established in 1993, and re-launched in 1997, Qatar Airways operates a modern, mixed fleet of both narrow and wide-bodied passenger jets, with 179 aircraft in total. The airline operates both Airbus and Boeing aircraft, with 8 (eight) different types from the former, and 3 (three) different types from the latter. The entire fleet services more than 150 key business and leisure destinations across six continents. Qatar Airways has been the recipient of many accolades and awards, including Airline of the Year, Best Business Class Airline Seat and Best Airline in the Middle East (Qatar Airways 2016b).

In addition to Doha's function as a hub for Qatar Airways, the airline's business model also depends on negotiated 5th freedom traffic rights[2] that enable it to service the Australasian, Asian, South American and European markets; relatively little traffic through Doha qualifies as the origin-destination (OD) type. By pioneering ULR flights, Qatar Airways would significantly improve its share of OD traffic whilst also increasing Gulf airline capacity.

Qatar Airways is a member of the **one**world global airline alliance, consisting of airberlin, American Airlines, British Airways, Cathay Pacific, Finnair, Iberia, Japan Airlines, LAN, Malaysia Airlines, Qantas, Royal Jordanian, S7 Airlines, Sri Lankan Airlines and TAM Airlines. This enables the airline's passengers to benefit from more than 1,000 airports in more than 150 countries, with the alliance members operating 14,250 daily departures (**one**world 2015).

4.2.2. Qatar Airways proposed Doha to Auckland ULR service – aircraft performance

Qatar Airways has 9 (nine) Boeing 777-200LR aircraft in its current fleet (Qatar Airways 2016b). These aircraft are operated on a variety of long-haul routes in which they are configured with only two classes of service, consisting of 42 (J) Business Class seats and 217 (Y) Economy Class seats. Qatar Airways has stated its intention to use its existing Boeing 777-200LR aircraft for its proposed Doha-Auckland ULR service, and hence for the purposes of this case study, the aircraft is assumed to retain the standard long-haul seating configuration. The following sample analysis also showcases all the steps involved in determining the various payload-range investigations shown in Table 1.

The passenger payload is calculated as follows:

Total PAX: 217 + 42 = 259.

Passenger weight (including all luggage) at 105 kg per person: 259 x 105 = 27,195 kg.

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[2] ICAO (2016) offers the following definition of the ***Fifth Freedom of The Air*** - the right or privilege, in respect of scheduled international air services, granted by one State to another State to put down and to take on, in the territory of the first State, traffic coming from or destined to a third State. (The fifth freedom is sometimes called "Beyond Rights", since it refers to the right to carry passengers from one's own country to a second country, and from that country to a third country).

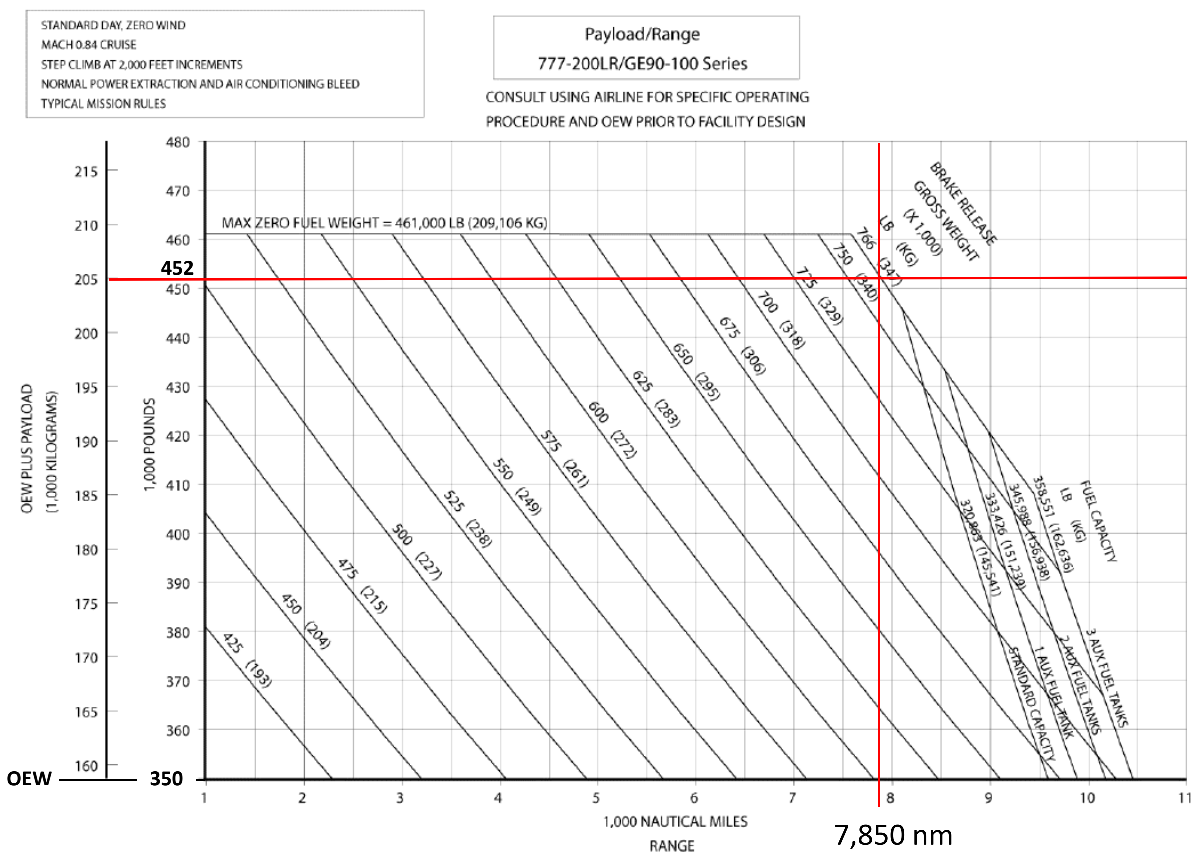
The AKE (LD3) containers for baggage hold approximately 35 bags each. Assuming on average each passenger has 1 item of luggage, then the number of containers required = (259 x 1) / 35 = 8 (rounded up from 7.4). Each AKE container weighs 76 kg, so the additional container weight is 8 x 76 kg = 608 kg.

Hence, the total passenger payload amounts to 27,195 kg + 608 kg = 27,803 kg, which, allowing for minor variations, is conservatively rounded up to 30 tonnes.

The proposed Qatar Airways non-stop route from Doha (DOH) to Auckland (AKL) covers a great circle distance of 7,850 nm (Great Circle Mapper 2016). With reference to Figure 2, which shows the aircraft manufacturers' payload-range envelope for the Boeing 777-200LR, it is evident that the total payload availability over such a distance is approximately 46 tonnes (452,000 lb – 350,000 lb OWE = 102,000 lb or 46,250 kg). Hence, in addition to the passenger payload of 30 tonnes, there is a surplus payload of 16 tonnes (46 tonnes – 30 tonnes) available for cargo carriage. The aircraft lower deck has a standard cargo configuration of 32 (thirty-two) LD3 containers (or equivalent) plus 17 m^3 of bulk cargo (Boeing Commercial Airplanes 2009). So, with 8 (eight) LD3 containers reserved for passenger baggage, the lower deck design of this particular aircraft still affords more than sufficient volumetric capacity for 16 tonnes of cargo transport.

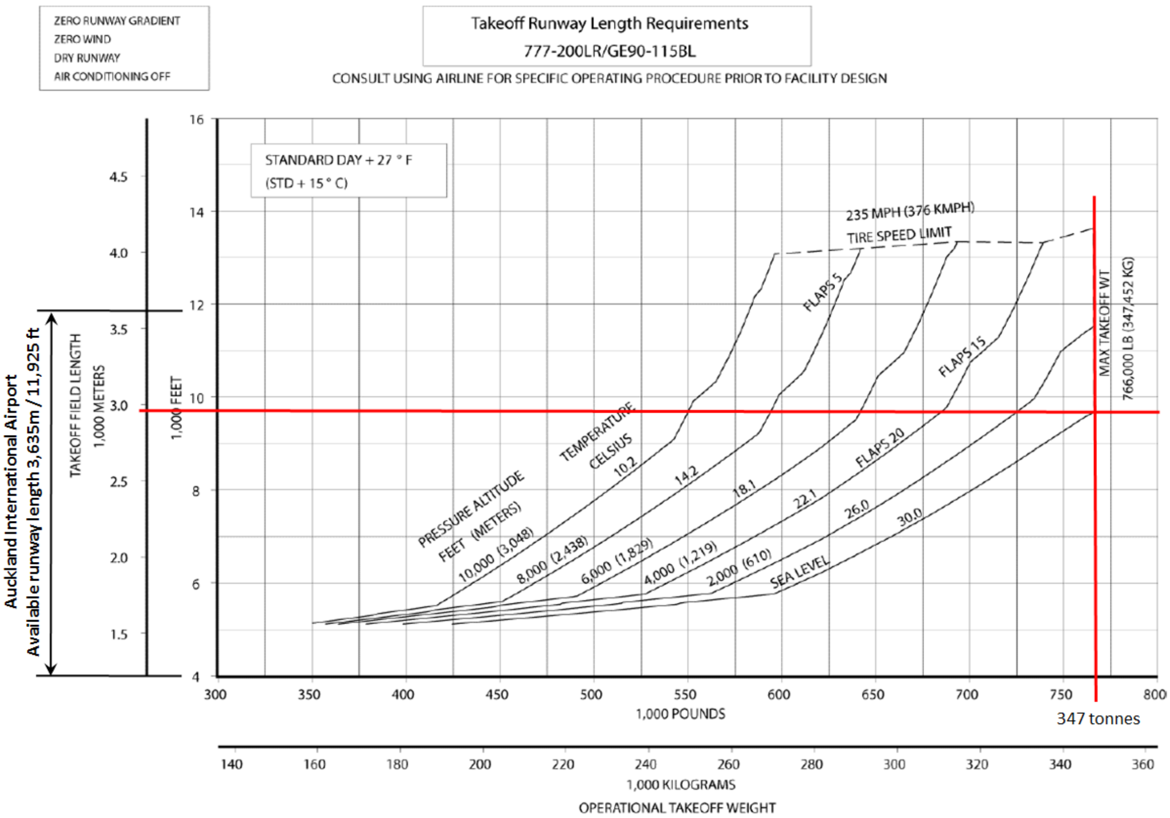
It is noted from Figure 2 that the aircraft is weight-limited, as expected, with a MTOW equal to 347 tonnes. It is also noted that the standard fuel capacity of 145,540 kg is sufficient for the proposed mission and there is no need to take advantage of the provision for up to three optional fuel tanks that may be added in the aft cargo area. (The three sets of extension lines shown in Figure 2 for 1, 2 or 3 auxiliary fuel tanks show the sort of range increases that are possible).

Figure 2. Payload-range envelope for a Boeing 777-200LR (Boeing Commercial Airplanes 2009)



Hamad International Airport serves Doha, the capital city of Qatar, and has two main runways at sea-level (11m), the Eastern Runway (16L/34R) of length 4,850 m and the Western Runway (16R/34L) of length 4,250 m (Hamad International Airport 2014). In contrast, Auckland International Airport has a single runway (05R/23L) at sea-level (7m), and of length 3,635 m (Auckland International Airport 2013). For this city-pair, the Auckland runway is critical when determining the take-off runway length requirements; for the Boeing 777-200LR, landing distances are comfortably enveloped by take-off distances, and hot-day take-off distances are more critical than those required for a standard day. Assuming the GE90-115B engine option applies to Qatar Airways' Boeing 777-200LR, then from Figure 3 it can be seen that at MTOW this aircraft type would require a runway length marginally less than 3,000m. (Note: A Federal Aviation Regulation (FAR) standard day temperature at sea-level is 15°C. Hence the runway length chart corresponding to a standard day +15°C has been chosen to represent a hot summer's day in New Zealand). Hence the runway at Auckland is quite sufficient to support the proposed mission.

Figure 3. FAR takeoff runway length requirements - standard day +15°C: Model 777-200LR (GE90-115B engines). (Boeing Commercial Airplanes 2009)



4.2.3. Qatar Airways Doha to Auckland ULR service – economic and cultural benefits

In September 2015, New Zealand's Minister of Trade signed an "open skies" air services agreement (ASA) with Qatar which provided Qatar Airways with the opportunity to serve New Zealand (Civil Aviation Authority, Qatar 2016). Following the signing of the ASA, on 9 March 2016, Qatar Airways formally announced the commencement of a daily non-stop ULR flight from Doha, the airline's hub, to Auckland, New Zealand, commencing later in 2016 - this will be the longest non-stop air route in the world (Qatar Airways 2016a).

Shortly before the announcement of Qatar Airways' decision to operate an ULR non-stop service from Doha to Auckland, Emirates Airline also announced a new ULR non-stop service from Dubai to Auckland, which commenced on March 1, 2016 (Emirates Airline 2016b). In contrast, Etihad Airways, the third of the major airlines based in the Middle East, does not operate services to New Zealand in its own right preferring to transfer passengers and cargo to Air New Zealand and/or Virgin Australia on a code share basis.

The key benefit of the new ULR flights to Auckland (both Emirates Airline and Qatar Airways) is the reduction in journey time to and from New Zealand by around 3½ hours (Bradley 2016), as there is no longer the necessity to make a stopover in Australia (or another intermediate point). This is beneficial to time-poor passengers and to air cargo shippers; in the latter case, the reduced journey time can help sustain the product quality of high-value perishable air cargoes exported from New Zealand, such as fresh fish and chilled meat.

5. Conclusions

This study has examined the recent strategy of several major full service network carriers (FSNCs) to operate new ultra-long range (ULR) services from their hubs with flight distances in excess of 7,000 nm and flight durations in excess of 15 hours. In the first phase of the study, the overall performance of every wide-bodied civil aircraft currently in service and capable of achieving a non-stop flight range of 8,000 nm was assessed. The study found that airlines wishing to pursue this ultra-long-range strategy currently have a surprisingly limited choice of passenger aircraft which are capable of flying the desired mission profile without compromising significantly on passenger numbers and cargo payload. The standout aircraft is the Boeing 777-200LR which offers a convenient blend of passenger numbers and cargo payload combined with true ULR performance. It is no coincidence, therefore, to note that the airlines currently considering such ULR flights all have a number of Boeing 777-200LR aircraft models in their existing fleets and have stated their intentions to use them for such operations.

The second phase of the study examined Qatar Airways' proposed route between Doha and Auckland, which will be the longest scheduled passenger flight in the world covering a range of 7,850 nm. The analysis has revealed that despite the extremely long distance, by operating Boeing 777-200LR's, Qatar Airways will retain the ability to carry an economically significant payload of both passengers and air cargo. The latter availability will be very important given the significance of high-value perishable export goods from New Zealand like fresh fish, meat, and dairy produce, and their critical time-to-market.

This work has addressed some of the key technical issues associated with the recent resurgence of interest in ULR flights in what is arguably an emergent area of aviation research. The topic of ULR flights is of local interest to Qantas, which has ambitions to operate non-stop flights from Australia to Europe, but is currently unable to do so given the severe payload restrictions that would be required with its current fleet of long-range aircraft, thus rendering such a venture commercially unviable. Further study is needed to assess the potential and viability of operating such ULR routes with the next generation of long-range wide-body twin-engine civil aircraft currently under development (e.g., the Boeing 777-8 and 777-9, and the Airbus A350-900ULR), paying particular attention to the governing economics of these "thin" routes, the level of anticipated passenger demand, and the potential to offer a true combination service that includes cargo carriage.

APPENDIX 1. Key Definitions

Operating Empty Weight (OEW): Weight of structure, powerplant, furnishing systems, unusable fuel and other unusable propulsion agents, and other items of equipment that are considered an integral part of a particular airplane configuration. Also included are certain standard items, personnel, equipment, and supplies necessary for full operations, excluding usable fuel and payload. The OEW will vary airline by airline.

Maximum Design Zero Fuel Weight (MZFW): Maximum weight allowed before usable fuel and other specified usable agents must be loaded in defined sections of the aircraft as limited by strength and airworthiness requirements.

Maximum Design Takeoff Weight (MTOW): Maximum weight for takeoff as limited by aircraft strength and airworthiness requirements. (This is the maximum weight at the start of the takeoff run.)

Aircraft gross weight (all-up weight (AUW)): This is the total aircraft weight at any moment during the flight or ground operation. An aircraft's gross weight will decrease during a flight due to fuel consumption.

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