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IMPACT FACTORS OF ULTRA LONG
RANGE FLIGHTS ON CABIN CREW
AND PASSENGERS

“Pushing the plane – pushing the people”

by

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Abstract

Long distance flight is an entrenched transportation mode that has brought with it a range of issues and impacts on the human cabin occupants. Development of ultra long range aircraft allows a single airline flight to last more than 16 hours in flight time which will have added impact on cabin crew and passengers.

This study was conducted to analyse the varied and diverse issues that ultra long range flights present in relation to the cabin and its occupants. Research included two surveys, one survey to international airlines from around the world and one survey to New Zealand based cabin crew who operate on international flights. Both surveys analysed current long range flight impacts and allowed respondents to identify new ultra long range flight issues.

The survey to organisations was responded to by seven airlines with three of the respondents currently operating ultra long range flights. The seven respondents rated operational issues as areas to be addressed including cabin crew issues related to duties, training and in-flight rest. Passenger related areas were mainly in relation to customer comfort.

The cabin crew survey had 119 respondents with a range of international cabin crew experience up to 36 years and averaging 5.7 long range flights per month. The respondents rated their cabin safety role as extremely important but did not believe their employers rated their safety role as highly. Respondents rated fatigue, sleep and dehydration as the main health impacts from long haul flights and 97.3% believed these health impacts will increase with ultra long range flight. In regard to rest and rest facilities 62% of respondents believed the current rest periods provided were inadequate and 70.7% believed the current rest facilities were inadequate. There was found to be a strong statistical relationship between rest adequacy and rest facilities adequacy. In relation to ultra long range flight respondents rated in-flight rest facilities as the foremost item to address for cabin crew and cabin air quality as the foremost item to address for passengers.

In general the survey of cabin crew identified the cabin environment, fatigue and lack of management emphasis on cabin crew as areas to be addressed for ultra long range flight. For passengers the cabin environment, facilities, and seating issues need addressing for ultra long range flight.

Further analysis based on the survey results found that ultra long range flight research has focussed on aircraft performance, engine reliability and the impacts of extended flight time on flight crew. Study on the impact of ultra long range flight on cabin crew and passengers are limited and lack the depth of research given to flight crew.

This study has identified that aircraft manufacturers and airline operators need to research and address a range of issues related to the cabin, in particular impacts related to cabin crew and passengers. Aviation regulators need to address many areas to improve regulations related to cabin crew and passenger health and safety. These areas need to be researched and addressed to ensure the impacts of ultra long range flight are reduced.

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Glossary

ACI – Airports Council International. An international association of airport operators.

Airbus – Airbus Industries. European airliner manufacturer.

Air operator – An organisation certificated and approved by an aviation regulatory authority to conduct air transport or commercial transport operations e.g. an airline.

ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc.

Boeing – Boeing Commercial Airplane Group. United States airliner manufacturer.

Cabin crew – Persons assigned by an air operator to a safety role in the cabin area of an aircraft. Also known as Flight Attendants or Cabin Attendants.

cfm – cubic feet per minute.

Circadian rhythm – The internal body biological clock that regulates human physiological functions according to the time of day through external cues and is reset every 24-25 hours.

CO – Carbon Monoxide. Carbon monoxide is an odourless, colourless and toxic gas.

CO² - Carbon Dioxide. Carbon dioxide is a colourless odourless gas.

CRM - Crew Resource Management. An airline training programme on team interaction and human factors.

DVT – Deep Vein Thrombosis. The formation of a blood clot within a vein.

EASA – European Aviation Safety Agency. An agency of the European Community tasked to further develop the work that the JAA performs in regard to setting aviation safety standards and regulations.

ETOPS - Extended Twin Operations Performance Standards. Regulatory aircraft operational performance requirements for twin engine airliners that operate further than 60 minutes from a suitable diversion airport.

FAA - The United States Federal Aviation Authority.

FARs – The United States Federal Aviation Regulations.

Flight crew – Persons assigned by an air operator to operate an aircraft. Includes Pilots and Flight Engineers.

FRMS - Fatigue Risk Management System. An integrated safety management system designed to ensure crew alertness and performance is not impaired due to fatigue.

GPS – Global Positioning System. Satellite based navigation system.

IATA – International Air Transport Association. An international organisation whose represents member airlines and air operators.

ICAO – International Civil Aviation Organisation. The specialized agency of the United Nations whose mandate is to ensure the safe, efficient and orderly evolution of international civil aviation. ICAO co-ordinates and establishes safety and technical standards for international civil aviation regulations with contracting states through establishment of standards and recommended practices.

IFALPA – International federation of airline pilot associations. The international organisation representing airline pilots.

JAA - Joint Aviation Authorities. Associated body of European civil aviation authorities which aims to set common safety standards and regulations.

JAR - Joint Aviation Regulations. Aviation regulations established by the JAA.

Long Range Flights – Aircraft flights of 10 to 16 hours in duration.

LROPS - Long Range Operations Performance Standards. Proposed new regulatory aircraft operational performance requirements for twin, triple and quad engine airliners that operate more than 180 minutes from a suitable airport.

MEL – Minimum equipment list. A list of equipment that must be installed and operable for the aircraft to be considered airworthy to operate.

nm - Nautical mile. A nautical mile is 1,852 metres, or 1.852 kilometres. In the English measurement system, a nautical mile is 1.1508 miles, or 6,076 feet.

NIOSH – National Institute for Occupational Safety and Health (United States). The main US federal agency responsible for conducting research into occupational safety and health matters.

NOTAM – Notice to airmen. Publication to inform pilots of new or changed aeronautical facilities, services, procedures, or hazards, temporary or permanent.

NPRM – Notice of Proposed Rule Making. An aviation regulator document detailing proposed changes to a rule or regulation which is published for public comment on the proposal.

NTSB – National Transport Safety Board of the United States of America. An independent US federal agency charged with investigating every civil aviation accident in the United States.

O³ - Ozone gas. Ozone is a pale blue gas irritating to the nose and throat.

ppm – Parts per million.

Relative Humidity – The amount of water vapour in the air expressed as a percentage of the maximum water vapour that air at that temperature can hold.

SARPS - ICAO prescribed Standards and Recommended Practices. A Standard is required to be complied with by ICAO member states. A Recommended Practice is not mandatory for ICAO member states but they should endeavour to comply with it.

Seat Pitch - The distance from the back of an aircraft seat to the same position on an aircraft seat directly behind.

ULR - Ultra Long Range Flights. Aircraft flights of greater than 16 hours in duration.

WHO – World Health Organisation. The United Nations specialised agency for health.

Chapter 1 Introduction

1.1 Background

Since the inception of passenger carrying flights aircraft manufacturers and airline operators have pushed to increase the operational capabilities of aircraft. In the glamour days of the 1930s flying boat flights from America to Asia and the South Pacific lasted periods of days and weeks. In the next two decades airliners using land based aerodromes ruled the passenger travelling skies, but these aircraft were slow and their piston engines unreliable. The advent of the jet powered airliner broke a new barrier in air travel with fast long distance flight connecting countries carrying passengers in comfort. The jet airliner development reached a watershed in the 1970s and 1980s as long haul flights became standard with the Boeing 747 and 767, and the tri-engine types such as the Douglas DC10 and Lockheed L1011. These long haul flights connected continents on trans-Pacific and trans-Atlantic routes.

Long distance flight has developed into mass transportation as aircraft have increased in size with the Boeing 747 “jumbo jet” carrying over 400 people and the new “super jumbo jet”, the Airbus A380, able to carry up to 800 passengers. Long haul flights are now the norm on the trans-Pacific and longer transcontinental routes with 10-16 hour flights connecting major centres. The development of mass transportation has come at a cost as airlines seek to maximise their revenue per seat kilometre with high density seating, reducing seat space and a perceived lowering of service levels.

1.2 Ultra Long Range flight

The next barrier in air travel is being pushed that of Ultra Long Range (ULR) flights consisting of a flight time of more than 16 hours in length. These flights include the use of the twin engine Boeing 777, operating under extended range operation procedures (ETOPS), and the four engine Airbus A340. These aircraft have the latest technology with elaborate systems and engine reliability levels that the pioneers of 1950s passenger flights could have only dreamed of. Engine and aircraft system reliability have improved exponentially since 1970 with the increased assistance of computerisation and “fly by wire¹” systems. Coupled with this have been developments in aircraft

¹ Systems that rely on electronic and computer systems rather than mechanical systems.

management using satellite navigation systems, increased automation, data link communication systems, and crew interaction through human factors courses.

1.2.1 Ultra-Long Range Task Force

In 1999 the Civil Aviation Authority of Singapore (CAAS) set up the Ultra-Long Range Task Force, consisting of the Civil Aviation Authority of Singapore, Singapore Airlines, and the Singaporean Airline Pilot Association, to develop recommendations on ULR flights. Following the initial work of the task force and the impending increase in airlines performing ULR operations a more global association was established to share information and analyse factors associated with ULR flights.

The ULR Crew Alertness Steering Committee was established in late 2000 with assistance from Boeing, Airbus and the Flight Safety Foundation. The Committee built on the Singaporean work with specific study of operational issues and analysis of ways to address them. The Committee has conducted four workshops:

1. Washington D.C. – June 12-14, 2001
2. Paris – March 4-7, 2002.
3. Kuala Lumpur – March 12-14, 2003.
4. Los Angeles – May 24-26, 2005.

The participants, from a total of 14 countries, included three airline associations, 16 airlines, two aircraft manufacturers, 12 pilot unions, three cabin crew unions, 14 scientific organisations, and nine regulatory authorities. From the proceedings of all four workshops it is evident that most of the research and development has centred on the operational aspects of the flights and particularly the impacts on flight crew.

The issue of cabin crew² and cabin issues has been largely overlooked and deferred for later research. However at the Paris workshop the cabin crew unions presented a paper on the issues that need to be addressed in relation to ULR flights and cabin crew. The paper focussed on the need for scientific research on adequate cabin crew complement, in-flight rest requirements, and crew operating patterns. Other identified cabin issues were increased passenger service demands, impacts of disruptions, and in flight medical emergencies on ULR flights.

R. Graeber from Boeing Commercial Airplanes (Flight Safety Foundation, 2005a), one of the members of the ULR Crew Alertness Steering Committee, noted that there has

² The use of cabin crew covers the terms flight attendant and cabin attendant throughout this Thesis for consistency.

been no scientific studies on cabin crew on ULR flights as the alertness and performance issues have been assumed to parallel those of pilots.

Some workshop presentations touched on passenger issues but mainly related to passenger behaviour or “air rage”, and medical conditions such as DVT.

1.2.2 Cabin environment

The cabin environment is important to cabin crew and passengers, this is the environment that these people will be confined in and exposed to for more than 16 hours. It could be said that the cabin environment has not developed in tandem with aircraft systems and the cockpit, indeed in some ways the cabin may have gone backwards. The quantity and quality of cabin air has changed in the last 30 years but many changes have been to assist aircraft fuel efficiency rather than assist passenger or cabin crew health. Seat pitch continues to be reduced, the amount of cabin fresh air has been halved, and new routes, flown for efficiency, are increasing occupant exposure to high levels of cosmic radiation. The cabin environment for cabin crew and passengers is an enclosure where they are influenced by temperature, air quality, humidity and seating (see Appendix 1). These influences are aggravated by increased exposure as flight times are extended. For cabin crew the exposure is repetitive and the impacts of low humidity and air quality cumulative.

When operating long range flights airlines spend large sums on in-flight entertainment to satisfy passenger needs but the cabin environment also needs to be improved for passenger health.

The increase from a 14 hour flight time to a 16 hour flight time seems minor, but these new aircraft can operate 18, 20, or 22 hour flights where the difference and impacts will be noticeable. The difference between a 14 hour flight time and a 20 hour flight time is 43%, a level where impacts will appear, that means 43% more exposure by occupants to the cabin environment and other aircraft influences.

1.3 ULR Research

Ultra Long Range flight is in its infancy beginning in 2004 with only a few airlines operating on very limited routes. In preparation for the operation of ULR flight aircraft manufacturers and airlines have invested extensively in flight crew research and aircraft systems development. From this research and development the aircraft and flight deck have been adapted to handle flights of greater than 16 hours.

No specific research can be found regarding ULR flights and the impacts on cabin crew or passengers. Review of present long range flight research can be used as a base but a 43% increase in exposure is large and needs to be specifically analysed.

Cabin crew are assigned primarily for the safety of the flight particularly the safety of passengers. On long range flights the cabin crew role seems to have shifted from operational, in regard to flight safety, to marketing in terms of in-flight service. The cabin crew role needs to be addressed by airlines to ensure that their key duties are recognised and appropriate action taken when considering longer flight times.

Even though they operate on the same aircraft, on the same flight there are many differences between the workplace and duties of flight crew and cabin crew. Cabin crew operate exclusively in the cabin exposed to a variable cabin air quality, humidity, and airborne pollutants. Their role is very physical walking through the cabin, mainly standing and moving heavy items like bags and food trolleys. Flight crew are in a small, controlled environment in a seated role that requires very low physical exertion.

Applying the results of studies of flight crew to cabin crew appears inappropriate and not representative of the differences identified.

In relation to the aircraft cabin and its occupants there needs to be specific research for ULR flights. The human body cannot be modified for ULR flights and its ability to adapt to extended periods of confinement in an artificial environment is dependant on aircraft manufacturers and airline operators addressing a range of impacts.

Questions in relation to ULR flights impacts on the cabin occupants include:

- What impacts will ULR flights have on cabin crew duties and health?
- What impacts will ULR flights have on passenger health?
- New routes and aircraft have been developed through the use of aircraft systems, but in the event of a diversion where would the aircraft and the passengers end up?
- From research on aircraft cabin environment have airlines actually made improvements to assist passenger health?
- Is the paying public treated as passengers or just walking cargo?
- Airlines have invested in technology to entertain their customers on these long flights but has the passenger comfort improved?
- Is the cabin environment affecting cabin crew and passenger health?

1.4 Organisation of this Thesis

This thesis will analyse the varied and diverse issues that ULR flights present in relation to the cabin and its occupants. Research includes analysis of the cabin crew role, the aircraft cabin environment and factors related to passengers.

Currently there are limited numbers of ULR flights operating but with new ULR aircraft deliveries in the next five years there is potential for ULR travel to become commonplace. This thesis is analysing a new area of aviation that has only just begun and as such the ability to do empirical research is limited. Taking this into account the aim is to identify pertinent factors as a base for further study on ULR operations and highlight the factors involved.

This thesis investigates the perceived and probable impact areas of ultra long range operations on passengers and cabin crew.

To identify these factors surveys were conducted to cabin crew and airlines to identify areas related to current long haul flights. The surveys also asked participants to identify potential ULR flight issues and sought identification of areas to address. The results of the surveys are further discussed looking at the identified factors in more depth to map the various issues and identify research on long range flights that could be applied equally to ULR operations.

Chapters One and Two provide the background and process used in this study. Chapter Three analyses what ULR flight is, the aircraft to be used and the flight routes to provide a background to the research. Chapter Four details the method used and the results of the survey to organisations. Chapter Five details the method used and the results of the survey to cabin crew. Chapter Six provides specific analysis and discussion into factors related to ULR flight including those identified in the two surveys. Areas covered include regulatory and operational requirements, the cabin crew safety role, cabin crew health impacts, the cabin environment and specific passenger issues. Chapter Seven summarises the study and makes findings that are supplemented by recommendations in regard to ULR flight.

Chapter 2 Literature Search

This thesis is based on research work performed in relation to long range flight, ultra long range flight, and aircraft cabin data. The literature search was performed using the following process:

Electronic database searching was done using keywords: ultra, long, haul, range, flight\, passenger\, cabin crew, impact\, effect\, cabin environment.

Electronic databases used were:

The internet search engine – Google

Massey University Library Database

Boeing Aircraft Company website – www.boeing.com

Airbus Industries website – www.airbus.com

Singapore Airlines Website – www.singaporeair.com

Emirates Airlines Website – www.emirates.com

Cathay Pacific Airline Website - www.cathaypacific.com

Qantas Airline Website – www.qantas.com

Flight Safety Foundation - www.flightsafety.org

The International Civil Aviation Organisation website – www.icao.org

The International Air Transport Association website – www.iata.org

Review was also made of relevant aviation industry publications, technical bulletins and aviation magazines including:

Flight International magazine

International Civil Aviation Organisation publications

International Air Transport Association publications

Flight Safety Foundation publications

There were 700 search results which were further refined using combinations of the search words and focus on areas of cabin crew, passenger and ultra long range flight research. Search results that focussed on flight crew were specifically excluded as they were outside the scope of this study.

From the search data specific to cabin crew and passengers for inclusion in this thesis the resulting matches were attained:

Flight attendant training – 6 Articles

Passenger health – 14 articles
Cabin environment – 15 articles
In flight medical events – 20 articles
Aircraft systems – 4 articles
Emergency evacuations – 3 articles
Airline seating – 5 articles
ULR flight – 11 articles
ETOPS/LROPS – 9 articles
Polar Routes – 6 articles
Alternate airports – 4 articles
Diversion costs – 2 articles
Sleep or fatigue – 12 articles
Crew Resource Management – 4 articles

Proceedings and papers from the Ultra Long Range Crew Alertness Steering Committee were also reviewed. The Steering Committee conducted four workshops between 2001-2005 sponsored by Boeing Commercial Airplanes, Airbus and the Flight Safety Foundation. From this review it was identified that the committee concentrated mainly on flight crew and operational impacts with little reference to passengers or cabin crew. From the literature search it was identified that studies on ULR operations have focussed on ensuring both aircraft systems resilience and engine reliability to handle extended range flights. Human factor studies have focussed almost exclusively on flight crew with airlines and institutions investing in research focussed on pilot awareness, sleep patterns and pilot comfort. No specific studies could be found relating to cabin crew or passengers in relation to ULR flights. It was evident that in relation to the aircraft cabin environment research seemed to be performed in isolation and specific to a topic with no correlated research found or combination of results to provide analysis of cabin impacts as a whole.

The literature search results are included in the relevant sections of this Thesis. This approach allows the literature and research found to be analysed and discussed in specific context.

Chapter 3 Ultra Long Range flight

3.1 What is ULR flight?

Long range or long haul flights are used as a general term for international flights. Long haul flights normally involve time zone changes and are four hours or more in duration. In the airline context a long range flight is of 10-16 hours flight time and an Ultra Long Range flight is greater than 16 hours flight time.

The Ultra Long Range Crew Alertness Steering Committee (Flight Safety Foundation, 2003) has defined that an ULR operation is:

“An operation involving any sector between a specific city pair (A-B-A) in which the planned flight time exceeds 16 hours, taking into account mean wind and seasonal changes.”

3.2 Aircraft development

In 1952 the world's first jet airliner the de Havilland Comet entered service with a range of 1,990 miles able to carry 36 passengers. It cut travel time in half and flew at a higher altitude than other airliners avoiding bad weather, providing a smoother ride, and helped to reduce air sickness. In 1957 the Boeing 707 was introduced with a 3,000 mile range, ceiling of 41,000 feet and able to carry 181 passengers. Mass transportation of large numbers of people at high speed between two points started with the Douglas DC10 and the massive 450 seat Boeing 747 in the late 1960s.

In the 1970s and 1980s many traditional airliner manufacturers closed as the aviation economic situation changed and demand for new aircraft reduced. In the early 1970s Airbus industries was created by a group of European aircraft manufacturers to take on the exclusive hold that the United States had on large airliner manufacture. The development of airliners in the last ten years has seen the two major airline manufacturers, Airbus and Boeing, diverging in terms of their product. Boeing is concentrating on the twin jet aircraft capable of longer range and increased frequency such as the Boeing 777 and the new technology of the Boeing 787. Airbus is pushing the mass transport hub to hub four engine aircraft with the Airbus A340 and the new massive Airbus A380 people mover capable of carrying 550-900 passengers. Both aircraft manufacturers are producing aircraft for ULR operations where the aircraft is pushing the traditional boundary of operations and at the same time will be pushing

the extent of human endurance. The increase in flight length is a result of both new technology and air operator's desire to connect major populations with point to point services. These new aircraft are being built to be more fuel efficient and give airlines better financial returns per passenger seat kilometre. The aircraft systems, engines and structure have been developed to cope with the extended flight time. Airlines have researched the impacts on flight crew and have modified the aircraft, operating procedures and crew workload to handle the extended operations.

3.3 ULR aircraft

The current Boeing 747-400 has maximum range of 7,200 miles and carries up to 530 passengers. In the early 1990s there were proposals by both Airbus and Boeing for a mega Boeing 747 able to carry twice the number of passengers over a longer distance. Airbus continued with the concept which has resulted in the Airbus A380 which is currently being test flown. Boeing has switched its focus to smaller longer range aircraft although it has announced plans to further develop the Boeing 747.

Airbus lagged behind Boeing in large aircraft orders until the 1990s when the Airbus A340 was introduced with modern technology and systems, which was able to successfully compete against the Boeing 747. For ULR operations Boeing and Airbus have competing but different products.

Airbus stole a march on Boeing with the introduction in August 2002 of the A340-600 with Virgin Atlantic airlines as the launch customer. This was followed in October 2003 by Emirates airlines introduction of the A340-500 (Kingsley-Jones and Sobie, 2005). The Airbus A340-500 is capable of carrying 313 passengers up to 9,000nm and is currently in service with several airlines including Singapore Airlines and Emirates. Airbus is also flight testing, for introduction in 2006, the massive Airbus A380 which will be the largest in-service passenger carrying aircraft capable of carrying 555 to 800 passengers over 8,000nm.

Boeing is behind its European rival in ULR aircraft actually in service. The Boeing 777 is the flagship of the company with two versions; the 777-300ER able to carry 365 passengers up to 7,880 miles which entered service in May 2004, and the smaller longer range 777-200LR able to carry 301 passengers up to 9,420nm due to enter service in 2006. The under development, smaller Boeing 787 is a new generation of aircraft constructed using new, lightweight carbon fibre that will enable the somewhat smaller aircraft to fly further than current similar sized aircraft. Boeing intends to develop a new

stretched Boeing 747-400 with an expected maximum range of 7,670 miles. The Boeing 787 is expected to carry 250 passengers with a maximum range of 7,500 miles. Table 1 details the number of ULR capable aircraft in service and on order. Comparison of ULR aircraft data is attached as Appendix 2.

Table 1
Ultra Long Range Capable Aircraft Statistics

Aircraft	In Service	On Order
Airbus A340-500	23	3
Airbus A340-600	60	60
Airbus A380		134
Boeing 747-400	442	4
Boeing 747-400ER	6	
Boeing 777-200ER	377	48
Boeing 777-200LR	2	38
Boeing 777-300	60	
Boeing 777-300ER	50	161
Boeing 787-800		275
Boeing 787-900		50

*As at 1 September 2006 – Details from the Airbus and Boeing websites

3.3.1 Two engines versus four engines

The difference in direction between the two major airliner manufacturers, where one is building twin engine aircraft and the other four engine aircraft, has become a major point of difference for airline operators. The operation of twin engine aircraft on long distance routes is covered by the extended range operations performance standards (ETOPS) which are discussed in more detail in Chapter 6.1. Four engine aircraft are not constrained by ETOPS requirements but some regulators are reviewing requirements for all aircraft operating more than 60 minutes from a suitable aerodrome.

The launch of the Airbus A340-600 at the 2002 Farnborough air show included the delivery of the first aircraft to Virgin airlines and highlighted the two versus four engine

debate. The Virgin A340 was emblazoned with “4 engines 4 long haul” on the engine nacelles (Kingsley-Jones and Sobie, 2005). The Virgin chairman, Sir Richard Branson, publicly stated that four engine aircraft may cost more but long term the economies of four is better than two. Backing this up was Virgin Airlines research that 18% of travellers would “go out of their way” to fly on four-engine aircraft (Kingsley-Jones and Sobie, 2005).

One advantage of the Airbus A340 over the Boeing 777 is that airline operators who want to start long haul services but currently do not operate ETOPS aircraft can perform long range operations without the additional expense and experience requirements that regulators require for ETOPS. The Spanish airline Iberia started long haul flights with the Airbus A340-600 in 2003 on three routes; Madrid to Buenos Aires, Lima and New York. The aircraft is used in a three class 352 seat layout. As the airline has limited ETOPS experience the A340 offers a choice away from the larger Boeing 747 but retains the benefits of four engines which was a factor in the airline’s 2004 decision to choose the A340 over the Boeing 777.

Boeing is confident that passengers want longer range aircraft and non-stop flights to reduce the total travel time and remove stopovers (Van den Bergh, 2005). On ULR flights passengers will want improved comfort over shorter flights, however Boeing admit that airlines want to maximise revenues and airlines will not want to lower seating capacity. To what extent have cabin environments been compromised in the pursuit of commercial gains, despite a range of cabin improvements?

3.4 ULR flight routes

The main markets for ULR routes would be:

Asia to America The Middle East to America Europe to South America
Australia\New Zealand to America and Europe

The Airbus A340 is currently in service with two Asian airlines; Singapore Airlines and Hong Kong based Cathay Pacific. Singapore Airlines began ultra long range A340-500 operations in February, 2004, in a two class 181 seat configuration. It is used on the 18 hour Singapore to New York (Newark 15,349 km) and Singapore to Los Angeles (18 hours on the western leg and 16 hours on the eastern leg). Cathay Pacific operates the A340 on their Hong Kong-New York route. In Europe the German airline Lufthansa introduced the Airbus A340-600 in December 2003. The aircraft flies Frankfurt to

Buenos Aires, and Santiago, Chile, in a two class 347 seat layout. The lower deck cargo area is configured for galley, toilet and crew rest.

The Singapore Airlines Los Angeles to Singapore flight travels up the west coast of the United States then tracks over Anchorage, Alaska, through Russian airspace over Beijing, then over Hong Kong and travels south abeam Vietnam. The flight then tracks from near Ho Chi Min City to Singapore. The flight uses one of the new Polar flight routes as discussed below.

Boeing is fighting for the same routes as the four engine Airbus A340 but with a two engine aircraft. Boeing states that the Boeing 777-200LR will be able to carry 301 passengers on the Singapore to New York route compared to the A340-500 at 181 passengers. The Australian based Qantas airline is looking at the 777-200LR to carry 295 passengers from Perth to both Los Angeles and London non-stop. Boeing promote that the Boeing 777 can fly the Singapore to London route with 301 passengers and baggage, as well as 18 tonnes of freight (Thomas, 2005a).

3.4.1 Polar Routes

To achieve the full benefit of ULR flights new polar air traffic routes over the Arctic and Antarctic have and are being developed. Flying over the Polar routes has advantages of reducing trip distance and flight time therefore reducing operating costs and opening new routes. In 1954 Scandinavian Airlines Systems began DC-6 flights from Copenhagen to Los Angeles via Sondre Stromfjord. Subsequent flights used Anchorage which became the primary stopping point. In recent years direct non-stop flights have come about as restrictions of Russian airspace are lifted and new bilateral agreements signed. These new routes connect eastern and central North America to most major Asian cities. Important to these new routes is the use of Chinese airspace to provide new, shorter flight paths to Asia and to the huge potential of China as the market opens up access for foreign operators.

North Polar routes operate in the area lying north of 78 degrees north latitude. In 1998 four cross-polar routes were defined and established for demonstration flights (Boeing, 2005). The New York to Hong Kong flight via the conventional route requires at least one intermediate fuel stop. With the Polar route the same flight is flown non-stop allowing more direct routing, time savings and fuel savings. However flight time savings are only available from North America to Asia as the reverse route is flown in a more southerly latitude to take advantage of strong tail winds.

Direct cost savings for airline operators on Polar Routes are substantial in flight time, operating costs, and fuel costs (See Table 2). Canadian air traffic services provider Nav Canada is leading the development in terms of systems and technologies for the Polar routes (Nav Canada, 2000). Nav Canada has worked with the Federal Aviation Authority of Russia in developing the Polar flight routes ensuring that both countries have the technology, systems and procedures in place. The flights over the Polar Regions are significant income earners for the two organisations and will continue to be so with exponential growth of flights estimated to be 5% annually.

Table 2

Polar Route Cost Savings – Identified by Nav Canada at 2000

Route	Time saving	Cost Saving (Canadian \$)
Atlanta – Seoul	124 minutes	\$44,000
Boston – Hong Kong	138 minutes	\$33,000
Los Angeles – Bangkok	142 minutes	\$33,000
New York – Singapore	209 minutes	\$44,000
Vancouver – Beijing	108 minutes	\$33,000
Vancouver – Hong Kong	125 minutes	\$33,000

Airlines using North Polar routes include:

Continental Airlines uses the Boeing 777 on the Newark to Hong Kong route which they started in March 2001.

United Airlines uses the Boeing 777 on their Chicago to Beijing route which started in April 2001.

Air China and United Airlines uses Boeing 747 on their Polar routes.

American Airlines, Delta Airlines, Garuda and Malaysian Airlines have flown demonstration flights over the North Polar region using Boeing 777s (Boeing, 2004).

Modern aircraft navigation systems, satellite communication systems and the opening up of Russian and Chinese airspace have all contributed to the ability to fly northern Polar routes. With the new systems and increased usable airspace the use of Polar routes saves the airlines time and is more convenient for the passengers. That is until they need

to make an unplanned landing. The environment is harsh with large areas of uninhabited land and remote aerodromes with limited facilities. This is reviewed more fully under Section 6.2 Diversions.

As part of Singapore Airlines Polar operations between Singapore and New York three requirements have to be met:

1. Solar radiation forecasts must be level S3 or lower³.
2. Available enroute alternate airport within 180 minutes of the Polar route.
3. Fuel temperature predication and fuel freeze analysis conducted for each flight.

From the Singapore Airlines experience the 180 minute requirement has often restricted the use of the Polar routes due to the unavailability of a suitable enroute alternate aerodrome (Flight Safety Foundation, 2005b). That is interesting as Singapore Airlines are using a four engine airliner not regulatory restricted to ETOPS. How would this affect a twin engine ETOPS operation? Would an airline with more financial constraints and lower standards operate when Singapore Airlines would not?

3.5 When will flights begin?

ULR flights began in February 2004 with Singapore Airlines flying direct Singapore to Los Angeles a trip of around 18 hours using an Airbus A340-500. This was followed in June 2004 by flights operating from Singapore to New York.

Singapore Airlines has configured the aircraft used on this route to a spacious 181 passenger seat layout. For these operations the number of flight crew is doubled to four with special rosters and rest time conditions which were extensively researched. Flight crew operate under a fatigue management programme of alternating time on the flight deck with a rest period; 2 hours on/ 4 hours off/ 5 hours on/ 5 hours off/ 2 hours on. The cabin crew complement has been increased by 50% using a two cabin team system. For ULR flights cabin crew have additional special training on crew alertness and planning of sleep. The cabin crew rest requirements are for in-flight sleep after four hours on flights less than 19 hours, and after five hours on flights over 19 hours, with a non sleep rest break after every two hours of duty.

The flight is scheduled in set departure windows to account for flight crew fatigue and circadian rhythm. The operational windows when flights can depart are detailed in Table 3.

³ The United States National Oceanic and Atmospheric Administration scale for solar radiation storms comprises S5 (extreme), S4 (severe), S3 (strong), S2 (Moderate) and S1 (minor).

Table 3*Singapore Airlines ULR Departure Times*

Flight Route	Preferred Departure	Alternate Departure
Singapore to Los Angeles	0800-1200	1600-2000
Singapore to New York	1010-1410	2200-0200
New York to Singapore	0930-1330	2300-0300
Los Angeles to Singapore	1200-1600	2000-0300

From Singapore Airline ULR operational data (Flight Safety Foundation, 2005b) between February 2004 and March 2005 there were 19 ULR flights with departure delays that ranged from 1 hour to 5 hours 45 minutes. There were three ULR flights with delays between five hours 45 minutes and 15 hours 17 minutes. Outside these times the flight is cancelled.

From the Singapore Airlines experience it is important that set departure windows are established through a validation plan that analyses flight and cabin crew fatigue to ensure the safety of the flight. Additionally a scientifically modelled and tested fatigue management programme is an important aspect of ULR operations.

Emirates, Cathay Pacific, and Qantas airlines are set to begin ULR operations in the next few years with the delivery of Airbus A340-500 and the new Boeing 777-200LR.

3.6 Chapter Summary

- Long range flights are 10-16 hours in flight length.
- Ultra Long Range flights are greater than 16 hours in flight length.
- Aircraft and their systems have been developed to cope with flights of more than 16 hours but cabin crew and passengers may not be adequately prepared.
- New aircraft to be used with operational range over 9,000 nm.
- Airbus aircraft are four engine including the A340 and soon to be introduced 555 seat A380.
- Boeing aircraft are twin engine including the B777 and the under development B787.
- Twin engine aircraft operate under ETOPS requirements.
- ULR routes cover most of the planet including Asia to America, Europe to South America and Australasia to Europe.

- New routes are crossing the Polar Regions mainly the North Pole above 78° north.
- Polar routes provide airline cost savings but also present new problems due to cosmic radiation and lack of suitable alternate aerodromes.
- Not all operators will provide the same high safety levels that Singapore Airlines does for ULR flights particularly on Polar routes.
- Specific aviation regulatory requirements needed for Polar routes.
- Singapore Airlines is operating 18 hour flight from Singapore to Los Angeles and also to New York.
- Specific flight departure windows are needed to ensure flight safety.
- ULR flights are due to begin in the near future by several airlines.

3.7 Research requirement

ULR flight involves new aircraft operating on new flight routes with new longer flight times. Research on long range flight has identified a range of factors impacting on both passengers and cabin crew. Extending the flight time may also impact on the currently identified long range flight factors as well as introduce new factors. Analysis is needed of ULR flight to allow the aviation industry to mitigate and address impact factors. The hypothesis is that ultra long range operations will have some impact on passengers and cabin crew.

Ultra long range flight brings a new dimension to air travel and with limited flights currently operating there is little opportunity for empirical data collection. From current studies of long range flight and the work of the ULR Task Force several areas of impact have been identified. To quantify current identified issues and ascertain other ULR issues two surveys were developed.

The first survey was to collect data about ULR operations from key airlines that either currently operate ULR flights, or currently operate long range flights and may operate ULR flights in the future. The second survey was to collect data from cabin crew who currently operate long range flights in regard to current long range flight impacts on cabin crew and passengers as well as potential impacts of ULR flights.

Chapter 4 Survey to organisations

4.1 Method

4.1.1 Participating airlines

Nine airlines based in Australasia, Asia, North America, Europe and the Middle East were invited to participate in the survey. There were seven airlines that responded to and fully completed the survey.

4.1.2 Participants

Initial contact was made to representatives from the nine airlines by phone or email including an overview of the research being undertaken and an invitation to take part in the survey on ULR flight.

The airlines invited to participate were selected based on the following criteria relating to ULR flight:

- Must currently operate international long haul flights or ULR flights.
- Must have a well developed international route structure that could be adapted or suited to ULR routes.
- Must be a standard full service carrier not a low cost carrier, this was to keep the data collected consistent to organisation type.

The airlines asked to participate had a varied range of fleet sizes and route networks. Although only seven airlines responded the data collected is of great value.

4.1.3 The survey

An internet based survey was developed that allowed participants to access a specific internet web page and input the required information. The internet based survey was one provided free by a large American market research company which included a secure website, storage of data facility, and tools for analysis of the raw data. The survey data was collected on the company's website and the resulting data downloaded into a spreadsheet.

The internet based website was selected as it enabled easy access by participants from anywhere in the world and at any time, this was particularly important for airlines based overseas. The internet based survey allowed better control of data collection than by

other paper based or interview methods, especially for initiation and closing of the survey.

The survey consisted of fifteen questions and one general comment section with a mix of question types using yes/no, ranking, and opened ended formats. Of the fifteen questions three were of a general ULR nature, then a filter question directed respondent's whose organisation currently operated ULR flights to five specific ULR operation questions, and if the respondent's organisation did not currently operate ULR flights they were directed to six questions related to future ULR operations.

The survey was constructed so that certain questions had to be answered for the person to continue and the survey could not be completed unless all mandatory questions were answered. A survey was only valid and recorded if the required questions were answered, the survey was finalized by clicking on the submit button and the survey data was then updated.

The survey to organisations including summary of the results is attached as Appendix 3.

4.1.4 Procedure

During May and June 2006 the survey was developed and questions finalized. The survey was trialed by several people before release to ensure the questions were clear and that the web survey system worked correctly. The research supervisors also reviewed and approved the survey.

The surveys were determined as low risk research involving human participants and a notification was forwarded to Massey University Ethic Committee which was noted in the Committee's Low Risk Database. The survey was confidential and personal details of the participant were not required.

On the June 22, 2006 the selected participants were emailed details on the research, survey information, and research contact details including the researcher and supervisors. The email included a link to the website where the survey could be completed and highlighted that the survey was active until Friday July 14, 2006.

A reminder email on the survey was sent on June 10, 2006.

Following the closing date of the survey a week was allowed to cover any late surveys before the webpage and link were closed off. The data collected was then transferred into a series of spreadsheets for data retention and analysis.

4.2 Results

The first three general questions were on issues related to ULR operations. The questions required the ranking of five items in order of importance to be addressed in relation to ULR flights. The ranking used a likert method from 1 to 5 with 1 being the most important to be addressed, 2 being the next most important through to 5 being the least important. Scoring was determined from the sum of the responses being the number of responses multiplied by the ranking number of the survey from 1 to 5. The resulting sum identified the ranking with the lowest number being the most important through to the highest number being the least important. The final sum was also divided by 5 to get the average for the identified factors.

4.2.1 General

ULR flights operations.

Organisations ranked five operational items in relation to ULR flight requirements.

Table 4 shows the summary and individual ranking.

Table 4

ULR Flight - Summary and Individual Ranking

Rank	(N=7)	Average Ranking	1	2	3	4	5
1	Regulatory requirements	2.8	28.6%	57.1%	0.0%	14.3%	0.0%
2	Aircraft performance	3.8	42.9%	14.3%	0.0%	14.3%	28.6%
3	Optimum flight route	3.8	14.3%	0.0%	85.7%	0.0%	0.0%
4	Diversion airport facilities	4.6	0.0%	28.6%	14.3%	57.1%	0.0%
5	Flight duration	6	14.3%	0.0%	0.0%	14.3%	71.4%

Cabin crew areas to address in relation to ULR operations.

Organisations ranked five areas to address in relation to cabin crew and ULR flights.

Table 5 shows the summary and individual rankings.

Table 5*Cabin Crew ULR Flight Areas to Address - Summary and Individual Ranking*

Rank	(N=7)	Average Ranking	1	2	3	4	5
1	Cabin crew rest facilities	3	28.6%	28.6%	42.9%	0.0%	0.0%
2	Impacts on cabin crew duties	3.2	42.9%	28.6%	0.0%	14.3%	14.3%
3	In-flight rest scheduling	3.6	14.3%	42.9%	14.3%	28.6%	0.0%
4	In-flight emergencies	5.4	14.3%	0.0%	14.3%	28.6%	42.9%
5	Impacts from cabin air quality and humidity	5.8	0.0%	0.0%	28.6%	28.6%	42.9%

Passenger areas to address in relation to ULR operations.

Organisations ranked five areas to address in relation to passengers and ULR flights.

Table 6 shows the summary and individual rankings.

Table 6*Passenger ULR Flight Areas to Address - Summary and Individual Ranking*

Rank	(N=7)	Average Ranking	1	2	3	4	5
1	Seating	2	57.1%	42.9%	0.0%	0.0%	0.0%
2	In-flight Boredom	2.8	42.9%	14.3%	42.9%	0.0%	0.0%
3	Cabin humidity	4.6	0.0%	28.6%	28.6%	28.6%	14.3%
4	Circadian rhythm	5.6	0.0%	14.3%	28.6%	0.0%	57.1%
5	Cabin air quality	6.0	0.0%	0.0%	0.0%	71.4%	28.6%

4.2.2 Respondents that currently operate ULR flights

Three of the seven respondents currently operate ULR flights. The aircraft used are the Airbus A340, either the 500 or 600 series, and the routes flown are operated between Asia and North America. The respondent's organisations were asked about areas to be addressed in relation to ULR flights from their organisation's experience with ULR flights; although this did repeat the general questions it allowed respondents to identify any additional areas.

Identified areas to be addressed in relation to ULR flights were:

- Crew training
- Rest facilities
- Crew Resource Management (CRM)
- ETOPS
- Aircraft operational capability

Identified benefits to the organisation from ULR flights were development of new markets, better corporate image, better connectivity and passenger convenience.

Identified benefits to passengers from ULR flights were cost benefits of non-stop operations, reduced journey time, better connectivity, greater convenience, and access to new markets.

4.2.3 Respondents currently not operating ULR flights

Four of the seven respondents did not currently operate ULR flights. Of these airlines three intend to operate ULR flights in the future using Airbus A340-500 or Boeing 777 LR aircraft on routes from Asia to the United States, and Asia to South America.

Identified areas to be addressed before operating ULR flights include:

- Customer comfort
- Regulations
- Crew alertness\rest
- Crew complement
- Emergencies
- Areas of operation (polar, alternates etc)

Identified benefits to the organisation from ULR flights would be:

- Efficiency

- Flag routes
- New routes
- Profile and public relations
- Market opportunity and route reach.

Identified benefits to passengers from ULR flights would be convenience, time saving, reduced flight time, comfort, reduced airport\transit time, increased sleep opportunity.

4.2.4 Summary

The key concept under investigation relates to ULR flights and their impacts. Surveying organisations provided data on the organisational viewpoint on ULR flight and issues related to cabin crew and passengers. The survey also provided an indication of how many airlines currently operate ULR and how many will begin to operate in the next five years.

From the survey on ULR operational aspects regulatory requirements are seen as the most important to address. This is followed by aircraft performance and the optimum flight route; both of these areas were reviewed in Chapter 3. These findings identify that the operational aspect of the aircraft is the prime airline operator focus. Regulatory requirements are reviewed in depth in Chapter 6.1 including the development of long range flight operational regulations.

Diversion airport facilities and flight duration were ranked as less important. These two areas are very important to the passengers and cabin crew. This may suggest that in relation to ULR flight the pure operation of the aircraft takes precedent over the cabin occupants. Chapter 6.2 reviews diversions to analyse the costs, reasons for diversions and the airports that the flight could end up at.

Organisations viewed cabin crew issues mainly in relation to rest and cabin crew duties. Once again these are operational factors which rated higher than cabin crew impacts from the cabin environment. In-flight emergencies rated low although in terms of cabin crew core functions this is particularly important, on ULR flights even more so.

These issues are reviewed in Chapter 6.3 and Chapter 6.4.

Organisations viewed passenger issues mainly in relation to seating and in-flight boredom which are widely publicised issues and areas that airlines are addressing presently. However the less evident passenger impacts and possibly more expensive to address in regard to cabin air and humidity rated lower. The impact on circadian rhythm

also rated low but can be addressed by better timing of flights for the passenger convenience rather than direct operational needs. Chapter 6.5 reviews the cabin environment in detail including seating. Chapter 6.6 reviews specific passenger factors including seating and air quality.

Overall from the survey to organisations their cabin crew issues focus on cabin crew duties, training, and in-flight rest. Passenger issues relate to customer comfort including seating and in-flight entertainment.

Chapter 5 Survey to cabin crew

5.1 Method

5.1.1 Participating cabin crew

A total of 119 cabin crew responded to and completed the survey. The cabin crew respondents were New Zealand based and covered a variety of international airlines.

5.1.2 Participants

Several options were considered for a cabin crew study including a survey to the cabin crew department of international airlines, an internet based survey open to all cabin crew or a better defined selected population. Following initial contact and a meeting with the New Zealand Flight Attendants and Related Services Association (FARSA) it was decided to undertake a survey using the FARSA members. FARSA is the cabin crew industrial organisation of New Zealand covering domestic and international cabin crew. It was selected as an independent organisation that covered a range of New Zealand airlines and provided an organisation whose members would participate in the survey without any influence from their employer. The FARSA executive was very supportive of the research and welcomed some independent analysis of ULR matters. The cabin crew participants averaged six long haul flights per month and an average of 12 years experience as cabin crew. The experience level ranged from less than one year to over 35 years. The survey to cabin crew provided feedback from a group of persons directly affected by the introduction of ULR flights and allowed identification of a range of issues. Cabin crew are a group underrepresented in studies on impacts of international flight, this is supported by the review of cabin crew in Chapter 6.3.

5.1.3 The survey

An internet based survey was developed in conjunction with FARSA that allowed participants to access a specific internet web page and input the required information. The internet based survey was one provided free by a large American market research company which included a secure website, storage of data facility, and tools for analysis of the raw data. The survey data was collected on the company's website and the resulting data downloaded into a spreadsheet.

The internet based website was selected as it enabled easy access by participants from anywhere in the world and at any time, this was particularly important for cabin crew. The internet based survey allowed better control of data collection than by other paper based or interview methods.

The survey consisted of twenty three questions and one general comment section. Of these questions;

- Four questions were details on the respondent's cabin crew experience, employment type and average number of long haul flights per month.
- Two were in regard to cabin crew roles.
- Five were regarding training and Crew Resource Management.
- Two were regarding cabin crew health.
- Three were regarding cabin crew rest and facilities.
- Two were regarding cabin crew regulation and licensing.
- Three were regarding cabin crew and ULR flight.
- Two were regarding passengers and ULR flight.

The survey was constructed so that certain questions had to be answered for the person to continue and the survey could not be completed unless all mandatory questions were answered. A survey was only valid and recorded if the required questions were answered, the survey was finalized by clicking on the submit button and the survey data updated.

The survey to cabin crew including summary of the results is attached as Appendix 4.

5.1.4 Procedure

During May and June 2006 the survey was developed and questions finalized. The survey was trialed on several people before release and by FARSA to ensure the

questions were clear and that the web survey system worked correctly. The research supervisors also reviewed and approved the survey.

The surveys were determined as low risk research involving human participants and a notification was forwarded to Massey University Ethic Committee which was noted in the Committee's Low Risk Database. The survey was confidential and personal details of the participant were not required.

On June 26 the survey was opened and a webpage was put on the FARSA website with details on the research, survey end date, and research contact details including the researcher and supervisors. The webpage included a link to the website where the survey could be completed and highlighted that the survey was active until Friday 21 July, 2006.

FARSA sent an email and a text message to their members about the survey.

A reminder email on the survey was sent on the 14th July, 2006.

The survey was confidential and personal details of participants that completed the survey were not required.

Following the closing date of the survey a week was allowed to cover any late surveys before the webpage and link was closed off. The data collected was then transferred into a series of spreadsheets for data retention and analysis.

When the survey was closed one hundred and nineteen fully completed and valid surveys had been submitted. Of that figure the number that answered individual questions varied.

5.2 Results

For the results detailed below the number of respondents are shown under the section heading e.g. For 109 respondents ($n=109$).

5.2.1 General

Respondent's experience

Of 119 respondents 115 were employed full time with 4 employed part-time. The average number of years experience as cabin crew was 12.4 years (+/- 9.5) with an average of 11.25 years (+/- 9.3) as cabin crew on international flights.

The respondents averaged 5.7 long range flights per month. Figure 1 graphs the respondents and the number of years as international cabin crew.

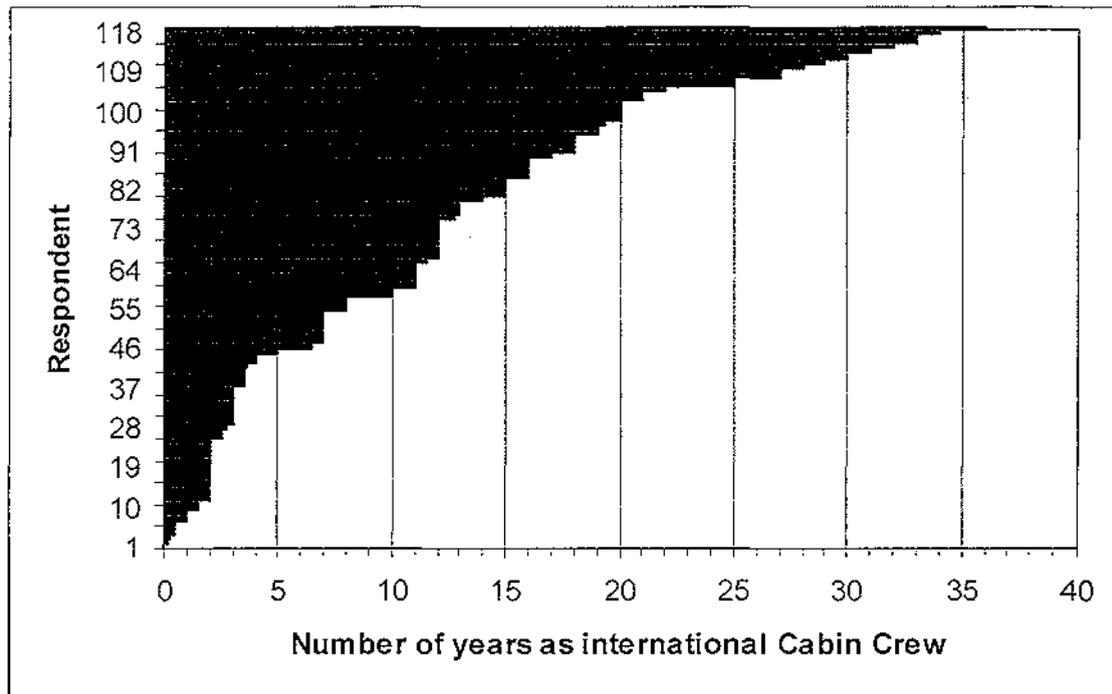


Figure 1 *Number of years international cabin crew experience of respondents (n= 119)*

Due to the range of cabin crew experience it was decided to compare the results of the survey between two levels of experience. In the last ten years aircraft technology has increased along with new longer range flights, also in this period health and safety awareness has also increased. Therefore ten years was selected as an appropriate division level for comparison. Analysis is made between responses from cabin crew with ten years or less experience and those with more than ten years experience.

Cabin crew role

(n=109)

When asked to rate the importance of the cabin crew role on an international flight, of 109 respondents 98.2% rated passenger safety as *Extremely Important* against 45.9% who rated in-flight passenger service *Extremely Important*.

When asked to rank how much importance they believed their airline places on the safety role of cabin crew the highest ranking was *Extremely Important* at 45%.

Cabin crew with more than ten years experience tended to believe their airline placed less importance on cabin crew safety role (See Figure 2). Analysis using a t-test shows no statistically significant difference ($T_{107} = 1.458$) between the group mean of the

cabin crew with more than ten years experience (mean=1.964, SD=1.11) and cabin crew with ten years or less experience (mean=1.660, SD=.732).

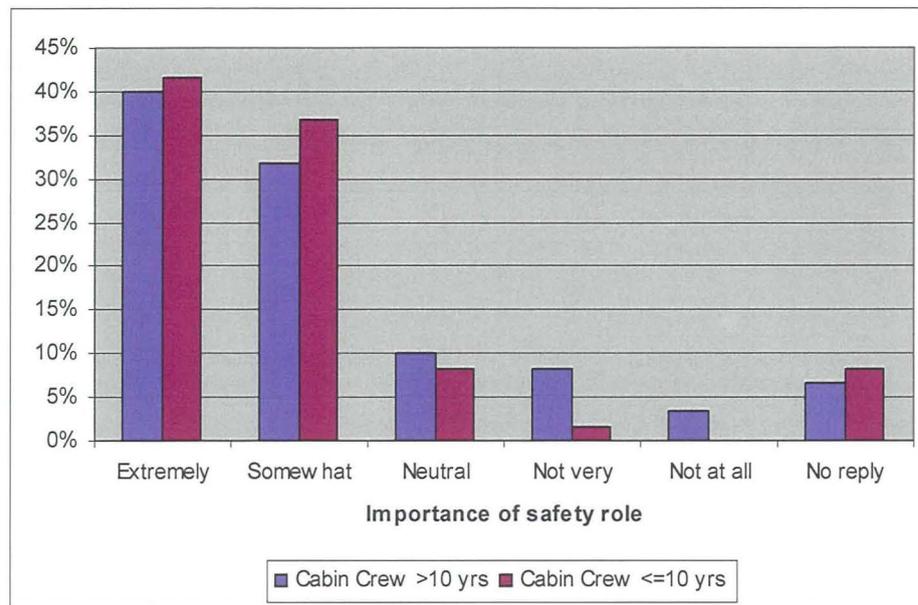


Figure 2 Importance that respondent's Airline places on Cabin Crew safety role (n= 109)

Training

(n=109)

When asked to assess the quality of their airlines initial training the highest percentage was *Very Good* at 40.4%. When asked to assess their airlines ongoing crew training once again the highest was *Very Good* at 43.1%.

95.4% of respondents stated that their airline provided Crew Resource Management (CRM) training.

47.1% of respondents believed that CRM helped *improve somewhat* the communication and teamwork between flight and cabin crew.

In relation to emergency training 74.3% responded that their airline's cabin crew emergency training involved flight crew.

Respondents who believed CRM improved communication and teamwork they were more likely to have flight crew involved in their emergency training (See Figure 3).

Analysis using a t-test shows no statistically significant difference ($T_{107} = 0.26$) between the group mean of the cabin crew whose emergency training includes flight crew (mean=1.975, SD=.724) and the cabin crew whose emergency training does not include flight crew (mean=1.928, SD=1.052).

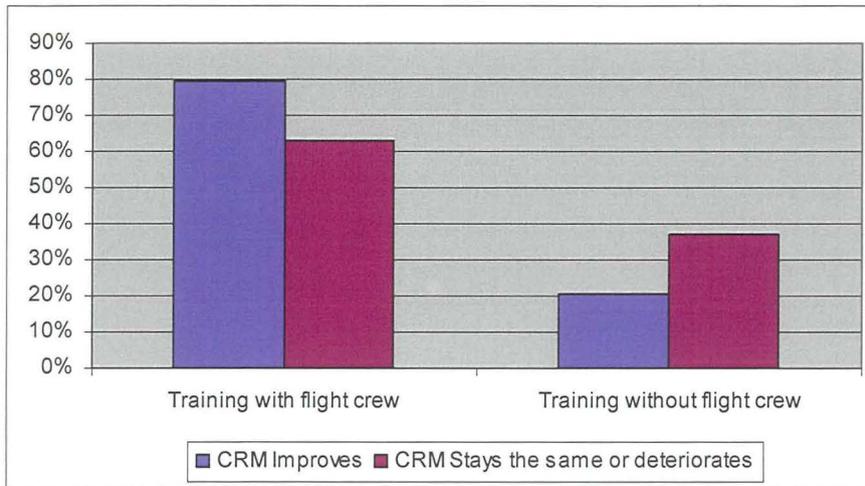


Figure 3 *Improvement in Crew Resource Management compared by flight crew involvement in training*
(n= 109)

Long Haul Flights

(n=92)

The top three rated health impacts on cabin crew from long haul flights were:

- Fatigue (27%)
- Sleep (14.3%)
- Dehydration (8.8%)

The top three improvements that cabin crew would like to see in relation to cabin crew health on long haul flights were:

- More rest at stopover (15%)
- Increased crew numbers (10.7%)
- Improved in-flight cabin crew meals (9.2%)

Cabin crew rest

(n=92)

Rest on long haul flights varied but was consistently in the 2-3 hour range.

For Boeing 767 and Airbus A330 aircraft the rest is taken in passenger seats.

For Boeing 777 aircraft the rest is taken in bunks in the centre section of the aircraft.

For Boeing 747 aircraft the rest is taken in bunks in the rear of the aircraft.

62% of respondents believe the rest period is adequate.

Of those respondents who did not believe the rest provided was adequate ($n=35$) the main reasons were:

- Sleep not long enough. ($n=6$)
- Night flight has major impact on sleep. ($n=6$)
- More crew needed. ($n=2$)
- Flight Service manager dictates rest periods. ($n=3$)
- Meal service timing has a bearing on amount of sleep. ($n=3$)

Of cabin crew replies those with more than ten years experience tended to rate the in-flight rest adequate (See Figure 4). Analysis using a Chi-square test gives a result of $X^2 = 3.006$, which shows no statistically significant difference. However there is a trend for the >10 years group to be happier. (See Table 7)

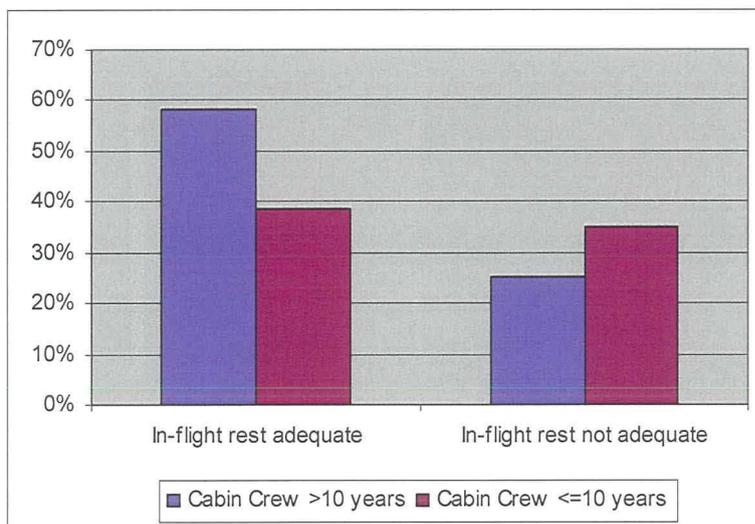


Figure 4 *In-flight rest adequacy compared by the number of years experience as international cabin crew ($n= 92$)*

Table 7

Analysis of in-flight rest adequacy and the number of years experience as international cabin crew

Frequency Count	Rest Period Adequate		Total
	No	Yes	
> 10 Years	15	35	50
<= 10 Years	20	22	42
Total	35	57	92

Of cabin crew replies those who operated more than five flights per month tended to rate the in-flight rest inadequate (See Figure 5). Analysis using a Chi-square test gives a result of $X^2 = .443$, which shows no statistically significant difference. (See Table 8)

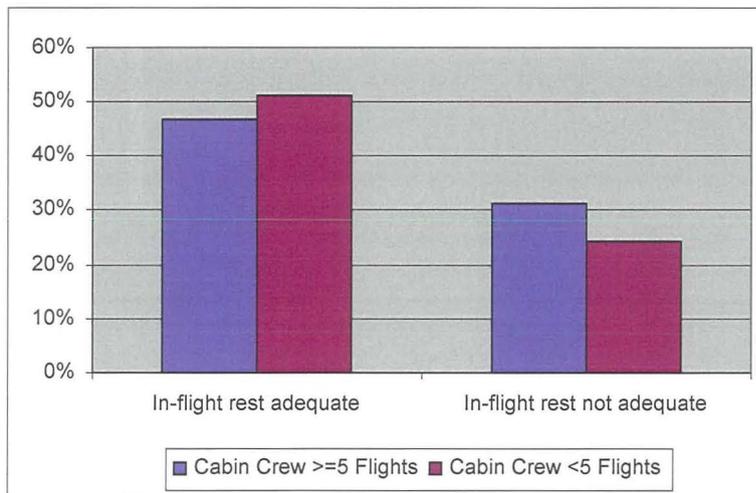


Figure 5 *In-flight rest adequacy compared by the average number of flights per month as international cabin crew (n= 92)*

Table 8

Analysis of in-flight rest adequacy and the average number of flights per month as international cabin crew

Frequency Count	Rest Period Adequate		Total
	No	Yes	
>= 5 Flights	24	37	61
< 5 Flights	10	21	31
Total	34	58	92

Of the 65 (70.7%) who believed the cabin crew rest facilities were not adequate, the main reasons were:

- Lie down sleep needed. ($n=17$)
- Rest facility is confined, noisy, unclean and needed more ventilation. ($n=12$)
- Facilities should match flight crew. ($n=7$)

Of cabin crew replies those who rated the in-flight rest inadequate also tended to rate the rest facilities inadequate (See Figure 6). Analysis using a Chi-square test gives a result of $X^2 = 18.505$, which shows a significant relationship between the cabin crew rest adequacy and the rest facilities (See Table 9). This could be due to the fact that if the rest is deemed inadequate then the people believe the facilities provided contribute to this. Therefore improvements in rest facilities could improve the adequacy of cabin crew rest.

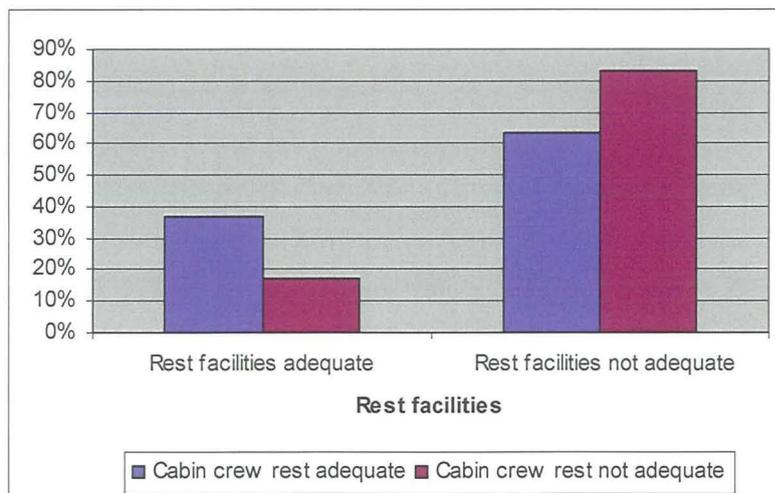


Figure 6 *Comparison of cabin crew in-flight rest adequacy and cabin rest facility adequacy ($n= 92$)*

Table 9

Analysis of in-flight rest facilities adequacy and in-flight rest adequacy

Frequency Count	Rest Facilities Adequate		Total
	No	Yes	
Rest adequate	21	36	57
Rest not adequate	29	6	35
Total	50	42	92

Regulation and licensing

(n=92)

80.4% of respondents believed the Civil Aviation Authority should regulate cabin crew flight and duty times including rest periods.

60.9% of respondent believed the Civil Aviation Authority should issue cabin crew licences as they do for pilots and engineers.

Two of the ULR specific questions required the ranking of five items in order of importance to be addressed in relation to ULR flights. The ranking used a likert method from 1 to 5 with 1 being the most important to be addressed, 2 being the next most important through to 5 being the least important. Scoring was determined from the sum of the responses being the number of responses multiplied by the ranking number of the survey from 1 to 5. The resulting sum identified the ranking with the lowest number being the most important through to the highest number being the least important. The final sum was also divided by 5 to get the average for the identified factors.

ULR flights

97.3% of respondents believed health impacts identified for long haul flights will increase with ULR flights.

Possible ULR flight impacts on cabin crew in order of importance to be addressed were ranked *(n=74)*:

1. In-flight rest facilities
2. Cabin crew duties
3. Cabin air quality and humidity
4. In-flight rest scheduling

5. Emergency training

The top three additional areas ($n=124$) were:

- Rest at destination ($n=28$)
- Crew numbers ($n=22$)
- Meals ($n=8$)

Of respondents those with more than ten years experience rated the cabin crew duties higher in importance to address for ULR flight. Cabin crew respondents with less than 10 years experience rated emergency training and in-flight rest facilities higher in importance to address for ULR (See Figure 7).

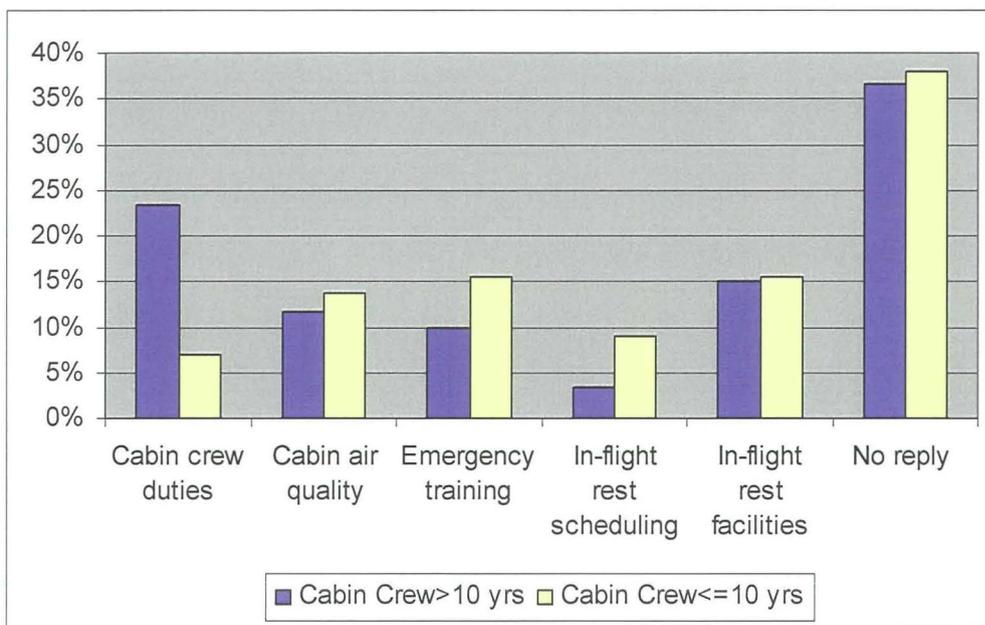


Figure 7 Importance of specific ULR issues to be addressed compared by number of years experience as international cabin crew ($n=74$)

Possible ULR flight impacts on passengers in order of importance to be addressed were ranked ($N=74$):

1. Cabin air quality
2. Seating
3. Cabin humidity
4. Circadian rhythm
5. In-flight boredom

The top three additional areas ($n= 89$) were:

- Meals ($n= 24$)
- Toilets – number of and hygiene levels. ($n= 9$)
- Seating and exercise areas. ($n= 5$)

A number of general comments were made by respondents and these are included at the back of the survey results in Appendix 4.

5.2.2 Safety role of cabin crew

Respondents rated the passenger safety role of cabin crew as *Extremely Important* (98.2%) with in-flight passenger service as being *Important* (47.7%). When asked to comment on the importance their airline places on cabin crew safety role there was a mixed percentage of replies in the *Somewhat Important* (37.6%) and *Extremely Important* (45%) range. There is a certain disconnect between what the cabin crew see as their prime safety role and how they view their employers emphasis on cabin crew safety role..The specific role of cabin crew is reviewed in Chapter 6.3, particularly the safety component.

5.2.3 Training

Organisations identified training as an area that needs to be addressed in relation to ULR flights. Cabin crew respondents generally found initial cabin crew training to be *Very Good* (40.4%) to *Excellent* (27.5%) but the ongoing training only *Good* (26.6%) to *Very Good* (43.1%). Although CRM is provided to nearly all respondents the effectiveness of the CRM training is mixed. This result is surprising given the emphasis and expenditure that airlines have placed on this area in recent years. It should be noted that 25% of cabin crew emergency training was undertaken without flight crew although no statistical significance was established between training with flight crew and improvement in CRM effectiveness. Given that in an emergency co-ordination of all crew is important then further research and analysis in this area is needed. Cabin crew training and emergency evacuation are reviewed in Chapter 6.3.

Given organisations and cabin crew have both identified training as important and present training provided is mixed then this area is important to be addressed in relation to ULR operations.

5.2.4 Cabin crew issues

From this survey there are a range of issues to be addressed several of which organisations did not rate highly or their research has not focussed on.

Cabin crew respondents identified that the cabin environment and cabin crew health are important issues in relation to long range flights. Fatigue, sleep and dehydration are noted physical impacts on cabin crew. These cabin crew health impacts are perceived by 98% of the respondents to increase with ULR flights and with a possible increase of flight time by 50% then these areas need to be properly analysed and mitigation measures put in place.

Improvements that cabin crew respondents would like revolve around rest and crew numbers. From cabin crew comments these areas have been reducing over the last few years as airlines strive to lower costs but it is affecting an important asset of the airline and the flight – cabin crew. Chapter 6.4 reviews the cabin crew health and safety in more detail.

Interestingly cabin crew diet and in-flight meals were areas that cabin crew see a need for improvement. This is an important aspect of cabin crew health but from my research no studies in this area have been found.

Cabin crew respondents identified that crew rest was short on long haul flights and although overall the rest period is adequate the rest facilities were not adequate. There was found to be a significant relationship between cabin crew rest facilities and cabin crew rest adequacy. In relation to flight crew, cabin crew have inferior in-flight rest breaks and facilities as noted by cabin crew, this is expanded upon in Chapter 6.4.

Cabin crew responses favoured (60.9%) licencing by the Civil Aviation Authority which is expanded on in Chapter 6.3. A point to note is that cabin crew strongly believe (80.4%) the Civil Aviation Authority should regulate cabin crew flight and duty times. Civil Aviation Authorities have differing requirements internationally however most regulate flight crew flight and duty time but let airlines set cabin crew flight and duty time. Clearly from this survey the cabin crew want independent regulatory action in this area.

5.2.5 Passengers

Cabin crew have the most contact with and feedback from passengers. Their rankings on passenger's issues would be expected to be close to that of passengers. They clearly

see cabin issues related to air quality and cabin humidity as very important (see survey data in Appendix 4). This contrasts to that of the organisations surveyed.

The additional issues that cabin crew identified related to meals, toilets and exercise areas, in general these are areas that all of us as passengers would agree with. Airlines in general have focussed on in-flight entertainment and seating rather than toilets and exercise areas that would be more expensive to provide.

The passenger dimension is expanded on in Chapter 6.6.

5.2.6 Summary

The cabin crew survey identified areas related to health and safety not only of themselves but also passengers. Most of these issues relate to the cabin environment, and the impact of long hours in an aircraft. From the survey data and results the following chapters explore these issues in more depth including any related research sourced from the literature review.

Points to note from the cabin crew survey are:

- Cabin crew rate cabin safety as the extremely important role of their job, twice as important as the in-flight service role.
- Nearly all cabin crew respondents are provided with CRM training by their employer. However only three quarters of respondent's emergency training involved flight crew.
- Both organisations and cabin crew identify training as important for ULR operations.
- A majority of cabin crew believe the Civil Aviation Authority should regulate flight and duty times.
- Cabin crew identified in-flight meals and their diet as an area that needs improvement.
- In-flight rest and the rest facilities currently provided for cabin crew are viewed by the majority as inadequate and need to be addressed for ULR flights.
- There is a significant relationship between cabin crew rest adequacy and cabin crew rest facilities.

Chapter 6 Analysis and Discussion

6.1 ETOPS and LROPS

6.1.1 Background

Airlines identified in the organisation survey (see Chapter 4) that regulatory requirement are the most important operational area to address. This section analyses long and ultra long range operations regulatory requirements in detail. ETOPS and LROPS regulations are essential for ULR flights.

Long range flights particularly on trans-Pacific and trans-Atlantic routes in the 1960s and 1970s were the exclusive domain of the four engine airliner. This was partially due to the 60-minute rule introduced in 1953 by the FAA based on the unreliability of piston engines. Additionally the range of twin engine aircraft at the time was very limited. The Federal Aviation Regulation 121.161 also limited commercial flights to routes within 60 minutes of an adequate airport. Three engine jets were also restricted to the 60 minute rule until 1964, when it was relaxed allowing increased operations for aircraft such as the Douglas DC-10 and the Lockheed L1011.

6.1.1.1 Introduction of ETOPS

In the 1980s following improved airline systems and vastly improved jet engine reliability air operators pushed for the ability to use twin engine aircraft on operations up to 120 minutes from a diversion airport. This would allow operators to use smaller, more cost effective wide body twin engine airliners on routes where passenger volumes meant the four engine airliner had surplus capacity. In 1985 Trans World Airways (TWA) operated the first ETOPS flight under new FAA rules using a Boeing 767-200 operating from Boston, USA, to Paris, France, a distance of 2,986 nautical miles. The flight followed a large amount of testing and analysis on twin engine aircraft operational requirements.

6.1.1.2 Increased ETOPS times

Since 1985 twin aircraft capabilities have increased especially with a reduction of in-flight engine shut downs. This has resulted in the maximum certified ETOPS time increasing from 90 to 120 to 180 to 207 minutes. In 1999, Boeing twinjets completed about 600 ETOPS flights per day for a total of 18,000 flights per month and almost 1.25

million since 1985 (Boeing, 1999). At that stage Boeing twin jets were dominating the North Atlantic and many airlines were planning ETOPS operations over the North Pacific using the Boeing 767 and Boeing 777. In 2004 Boeing aircraft ETOPS operations numbered 33,400 per month operated by 101 operators with a cumulative total of 3,447,000 ETOPS flights since 1985 (Boeing, 2004). The number of flights has nearly tripled in the last six years compared to the first fourteen years of ETOPS operations.

The success of ETOPS operations coupled with Boeing emphasis on twin engine aircraft has seen pressure on aviation regulators to extend ETOPS times.

6.1.2 Regulation and rules

The FAA has been the world leader in the development of ETOPS requirements and regulations. From the original FAR 121.161 to the development of 207 minute ETOPS the FAA has developed the regulations in tandem with aircraft developments. The FAA definition of ETOPS is Extended Range Operation with Two-engine Aircraft or Extended-range Twin-engine Operations Performance Standards.

Under the FAA Advisory Circular AC120-42A, ETOPS is further defined as flights that operate over a route that contains a point further than one hour flying time at approved one-engine inoperative cruise speed.

An ETOPS portion of a flight begins the moment an aircraft is greater than one hour flying time, at the approved single-engine inoperative cruise speed, from the nearest adequate airport, and ends the moment it is less than one hour from the nearest adequate airport.

ETOPS requires special aircraft equipment, a detailed maintenance programme, and specific operational flight requirements including alternate airport weather.

FAA ETOPS regulations require that diversion airports must:

- Be certificated under FAR Part 139 or meet equivalent criteria.
- Be suitable to safely operate the aircraft in accordance with FAR Part 121 i.e. length, width and strength.
- Have a minimum Airport Rescue Fire Index A (FAA) or Category 4 (ICAO) available within 30 minutes.
- Have field reporting conditions including (NOTAM), hourly weather reporting (METARS) and an instrument approach other than GPS.
- Be available but not necessarily continuously open.

Currently the Boeing 777-200ER is marketed as built certified for 180 minutes ETOPS on delivery. That is interesting as for ETOPS the operator, their systems and procedures dictate certification not the aircraft alone. Has the criteria changed?

6.1.3 Extended diversion times

ETOPS requirements were born of the increased reliability of aircraft engines and air operator desire to operate more economical twin engine aircraft rather than the more expensive three and four engine aircraft on certain routes. It has allowed routes restricted by the 60 minute rule to be flown profitably by twin engine aircraft. The early ETOPS operations were in smaller airliners especially the Boeing 737 & 767 and the Airbus A320 & A330. Manufacturers are now producing large ETOPS airliners such as the Boeing 777 with greater passenger carrying ability close to that of early model Boeing 747s.

6.1.3.1 Boeing Aircraft

Boeing has been an ardent supporter and developer of ETOPS beginning with the Boeing 737, 757, and 767. The Boeing 777 is marketed as ETOPS capable and Boeing is pushing for a permanent extension of the current maximum 180 minute restriction to 207 minutes and possibly longer. The Boeing 777 has demonstrated remarkable efficiency with engines and systems resulting in 29 in-flight shutdowns from 314,000 ETOPS flights of which 60% of the diversions involved 30 minutes or less (Klopfenstein & Smith, 1999).

ETOPS is a common aviation event with on average 1,000 ETOPS flights per day by 92 carriers. As at September 2004 there were a total of 101 ETOPS operators using Boeing Aircraft with 42 operators using the Boeing 777. Six operators had exemptions to operate 207 minute ETOPS operations comprising four United States airlines on the North Pacific route with Singapore Airlines and Korean Air. Eighty five percent of Boeing 777 operators are operating the aircraft under ETOPS.

Midway Island airfield is currently partly funded by Boeing to provide an ETOPS alternate essential to North Pacific operations. This funding however is not adequate to keep the airfield open and the United States Department of the Interior requested a review of Midway airfield operating costs (US Department of Transportation, 2005). The review has highlighted that although airlines rely on the continued certification of Midway as a diversion airport they are not charged for its continued certification. The

U.S. Department of the Interior's Fish and Wildlife Service (FWS) have looked at closing the airport for all but essential island aircraft which would have a major impact on ETOPS operations altering routes, flight times and fuel related costs. This shows the limitation of ETOPS and reliance on remote aerodromes. From the review of operating costs the Fish and Wildlife Service identified that Midway had a lack of facilities and services to handle a fully laden passenger jet.

6.1.3.2 In flight engine shut downs (IFSD)

The 12 month IFSD rate for the Boeing 777 is 0.006 per 1000 engine operating hours and during the period June 1995 to September 2004 there were 776 reported ETOPS relevant events out of 581,600 Boeing 777 ETOPS flights (Boeing, 2004). Only 28 or 3.6% of those events occurred in the ETOPS portion of the flight. For that period the top five causes of the ETOPS relevant events were:

1. Non-Technical – 45%
2. Engines – 15%
3. Air Conditioning – 8%
4. Electrical Power – 7%
5. Fuel – 5%

Of the 51 ETOPS in-flight shutdowns that occurred during the period June 1995 to September 2004 the single engine flight time was:

30 minutes or less:	25
31-60 minutes	9
61-90 minutes	9
91-120 minutes	5
121-150 minutes	2
151-180 minutes	1 (177 minutes)

The world fleet target for in flight shutdowns (IFSD) is 0.02 per 1000 engine operating hours for 180 minute operations. The Boeing 777 rate has consistently been at 0.01 per 1000 engine operating hours or below (Boeing, 2004). Boeing in-flight shutdown analyses indicate that maintenance error accounts for nearly one-third of all in-flight shutdowns (Flight Safety Foundation, 1999).

It is worth noting that not all engine problems result in a shutdown, some require the engine to be throttled back to idle power. The idling of the engine can assist

pressurisation, de-icing and electrical generation whilst providing minimal thrust. "Idling" of the engine does allow the flight to continue without diversion but can also cause the engine to fail completely. Such incidents are not recorded as an IFSD and this raises the question of engine reliability analysis.

6.1.3.3 In-flight engine shut downs (IFSD)

A two engine airliner flying from Milan, Italy to Barbados would save 1,300 nm flying distance using a 180 minute ETOPS compared to a route staying within the 60 minute diversion rule (FAA, 2003). The 180 minute ETOPS cost benefits are obvious and substantial for two engine aircraft.

On the North Atlantic routes twin aircraft now outnumber the three and four engine aircraft. The number of United States to Europe weekly non-stop one way flights number more than 1000 for twins and less than 100 for three or four engine aircraft. Across the North Pacific to Asia the Boeing 777 is reaching 200 weekly non-stop one way flights and eroding the Boeing 747 whose number is down 100 to 400 in the last two years.

From Boeing data (Boeing, 2004) the aircraft type used on the Trans-Pacific⁴ has changed markedly in the last twelve years due to ETOPS. In 1992 the number of one-way passenger flights per week for a twin engine aircraft was less than 50 with tri and quad engine airliners numbering around 1100. In 2004 the number of twins is close to 1000 with tri and quad engine airliners dropping to around 700. The Pacific is an area where the use of ETOPS allows twin engine airliners to maximise their operating cost savings but the distances flown are vast with a lot of over water flying and limited facilities at alternate aerodromes.

6.1.4 Extended ETOPS

Extended ETOPS is the use of 180 minutes plus an additional 15% to create a 207 minute ETOPS, which could be important for ULR operations. Airlines have applied for this in areas where the diversion airport to be used is slightly further than 180 minutes, mainly on trans-Pacific routes, and the airline has wide experience and successful history operating ETOPS aircraft. Accelerated ETOPS operational approval is a process

⁴ From America (North, Central or South, excluding Alaska) to Hawaii, Asia or Australia\New Zealand. And from Hawaii to Asia or Australia\New Zealand.

outlined in Appendix 7 to the FAA Advisory Circular 120-42A, or JAA IL20 where proven ETOPS operators gain the extra approval based on in-service experience on the airframe/engine combination. Approved 207 minute operators include Singapore Airlines, Continental Airlines, United Airlines, and American Airlines. Boeing in conjunction with airlines is now pushing aviation regulators for a 240 minute ETOPS. Are passengers aware of ETOPS provisions; the diversion times on one engine involved and the diversion airport they may end up at?

Safety regulators must protect the public interest when regulating these operations.

The FAA 207 policy letter 20-1 (Boeing, 2004) details the required operational requirements for 207 minute ETOPS:

Type Design Elements:

1. Numerical Probability Analysis for 207 minutes
2. Engine oil for 207 + 15 minutes
3. Cargo fire suppression for 207 + 15 minutes
4. Other time limited systems 207 + 15 minutes
5. FAR 25.903(d)(10) consider 207
6. In Flight Shut Down rate below .019
7. At least one fuel cross feed valve on backup power
8. At least one fuel boost pump in each main fuel tank on backup power
9. ETOPS essential loads on single generator

Operational Elements:

1. SATCOM (**Satellite communication**) voice and/or data link
2. Data link to update any revised flight plan
3. Single engine autoland capability for dispatch
4. Minimum Equipment List
 - Fuel Quantity Indicating System
 - Auxiliary Power Unit
 - Auto throttle
 - SATCOM voice and/or data link
5. ICAO Category 7 or higher Rescue Fire Fighting Service for ETOPS alternates
6. Inform the flight crew of ETOPS 207 when dispatched
7. Reporting of ETOPS 207 flights

The additional diversion time creates more efficient routing resulting in reduced operating costs and flight time reduction. In the FAA 2003 Notice of Proposed Rule Making (NPRM) cost savings were detailed for extended operations beyond 180 minutes based on data from one operator:

On a trans-Pacific flight that operated beyond 180 minutes diversion time:

- Extended ETOPS saved 27 minutes on the westbound flight and 11 minutes on the eastbound leg. Based on a single daily trip that equates to 231 hours saved per year.
- The estimated total annual savings would be US\$1,040,000 based on US\$4,500 hourly operating costs.
- The estimated cost to meet the increased requirements for operations over 180 minutes would be US\$10,000.
- Therefore the air operator stands to increase profit by nearly US\$1,000,000.

Air operators want ETOPS greater than 180 minute for operational efficiency and to increase profitability. The passenger benefits by shorter flights but possibly greater risk.

6.1.5 Long Range Operations - LROPS

Aviation regulators are considering ETOPS in a broader sense with the increased reliability of twin engine aircraft and their systems. ETOPS has brought better engine reliability, aircraft system monitoring systems, fire control systems and operational procedures. The United States Aviation Rulemaking Advisory Committee (ARAC) has been reviewing long range operations and has stated that ETOPS should now be interpreted as “extended operations” times not just applying to two engine aircraft. The Europeans have a different view and see “extended operations” as those over 180 minutes from a suitable airport defined as long range operations (LROPS) or Extended Diversion Time Operations (EDTO). Regulations for LROPS would be a single regulation for two, three and four engine airliners. Airbus wants the definition of LROPS to cover all operations 180 minutes from an airport irrespective of diversion times.

LROPS is seen by Airbus as an initiative to apply ETOPS requirements to other long range operations using three and four engine airlines to increase safety and operational performance. The basis of LROPS is to build on the ETOPS criteria by replacing the

current haphazard regulations, which are mainly regulatory advisory circulars and exemptions, with civil aviation rules.

Both the United States and Europe agree that new regulations would cover all flights operating more than 60 minutes from a diversion airport. This would include three and four engine aircraft when the 180 minute threshold is reached. ETOPS is based on diversion airports that are safe whereas LROPS is based on a diversion not been required at all. This new criteria is intended to use the experience from ETOPS to apply to all long and ultra long range operations.

The requirement that three and four engine airliners would need to meet the ETOPS operation criteria when they operate over 180 minutes from a diversion airport means these aircraft would need to upgrade some aircraft systems to ETOPS requirements. These upgrades would include cargo hold fire detection and suppression systems, on board medical kit, and system reliability monitoring. Other costs would include development of passenger recovery plans, increased ETOPS maintenance programme, and new failure reporting and investigation programmes. The FAA and the new European Aviation Safety Authority (EASA) along with other civil aviation authorities are working together to develop the new LROPS criteria. The new requirements would be an improvement on the present ETOPS standards which differ internationally and are based on advisory material and exemptions not regulations.

Appendix 5 to this thesis is a comparison chart of the effect of the proposed FAA ETOPS regulatory requirements contained in the 2003 NPRM for airliners with two engines or more. This chart shows how the FAA is proposing to tighten the regulations for ETOPS.

6.1.6 Section Summary

- The organisational survey in this study identified regulatory requirements as the foremost area to be addressed for ULR operations.
- ETOPS covers twin engine airliner flights that operate 60 minutes from a diversion airport.
- Specific ETOPS criteria are based on FAA Advisory Circular requirements and involve specific operational exemptions.
- Diversion airports must meet minimum criteria but some ETOPS flights rely on aerodromes with limited facilities.

- The number and routes of ETOPS flights have increased exponentially in the last 10 years with many operating on long routes over large areas of ocean.
- ETOPS times have increased steadily from 90 to 120 to 180 and now 207 minutes.
- In flight engine shut downs for ETOPS aircraft are now consistently below 0.01 per 1000 engine hours.
- Extended ETOPS is being promoted involving a 240 minute diversion time.
- LROPS is the new direction for aviation regulators covering two, three, and four engine aircraft operations.

6.2 Diversions

6.2.1 The Cost

Diverting an aircraft in flight to an alternate airport is not only costly to the airline but also to the passengers. The true cost to an individual passenger of an aircraft diversion varies but the cost to the airline can be quantified. From the survey to organisations the optimum flight route and diversion airport facilities are rated as very important.

Regulatory requirements and diversions are related with increasing regulatory pressure to raise the facility requirements for diversion airports. The opportunity cost of a scheduled airliner diversion has been estimated at between \$US50,000 and \$US100,000 for a wide body jet airliner carrying 200 passengers (Jenkins & Cotton, 2002). The same study estimated that if passengers had to stay overnight then the total cost would range from \$US89,000 to \$US181,000 including passenger costs, direct operating costs and indirect operating costs. This figure is supported by another study that estimated a diversion cost to an airline at \$US150,000 (Irrang, 1997). The cost of the missed connection for the airline has been estimated at an additional US\$50,000. However these cost estimates can double if the aircraft diverts to a remote aerodrome without adequate facilities.

The total cost of a diversion includes:

- Passenger accommodation costs and lost passenger time
- Crew salaries and accommodation costs
- Aircraft cost due to lost productive time and aircraft relocation cost
- Loss of passengers due to bad experience and lost future income

A medical diversion on Polar flight routes is estimated to cost an airline up to \$1 million (Jones, 2003) and it is not known if medical emergencies will increase with the increased ULR flight length.

6.2.2 Medical Emergencies

6.2.2.1 Background

The main non-aircraft systems related reason for an aircraft diversion is for a medical emergency. In the early days of air travel cabin crew were selected for passenger safety and most had a medical background normally as a medical nurse. However cabin crew today are selected more for their customer skills and appearance with medical training given as first aid training or basic medical training. This basic medical knowledge is fine on short haul operations where the short flight time can allow the passenger to wait for medical attention on arrival. On longer flights most airlines have on board defibrillators and in-flight communication with a medical professional, but these are no replacement for an on site trained professional. In most cases the airline hopes there will be a medical professional on the flight willing to assist, as a passenger I also hope so. With ULR operations advanced medical training of cabin crew is required or having a specialist medical person onboard needs to be seriously considered. The myriad of complex medical conditions of individual passengers, especially with more elderly travellers, is affected by the cabin air quality, humidity and lack of adequate body movement. With ULR flights passengers will be exposed to these conditions over a longer period.

6.2.2.2 In-flight medical emergencies research

Research varies on medical emergencies as airlines have different definitions on what is a medical emergency. One study showed medical emergencies during air travel which result in an unscheduled landing are uncommon, with 1 occurring per 14,000 to 40,000 passengers (Mortazavi et al, 2003). The main causes from this study were cardiac, respiratory and neurological problems. The incidence of death is very low at 0.3-1 per 3,000,000 travel episodes with cardiac etiology being the most frequent cause. An FAA survey (DeJohn et al, 1997) between 1986 and 1988 identified 2,322 instances of in-flight medical emergencies averaging 3 per day, with an annual diversion rate of 8%. A

further FAA survey in 1993 of 2,388 in-flight medical emergencies between 1990 and 1993 identified 190 diversions at an annual diversion rate of 8%.

6.2.2.3 Causes of medical emergency flight diversions

Diversions for medical emergencies depend on the routes flown and the suitability of the diversion airport's medical and aviation facilities. With increasing distances flown, more ETOPS routes and the use of Polar routes airport choice is further restricted. The most common reasons for diversions from a United States study of 1132 in flight emergencies (cited in Goodwin, 2000) were:

1. Cardiac Incidents – 28%
2. Neurological Problems – 20%
3. Food Poisoning – 20%

The study detailed that of 173 (15%) passengers admitted to hospital the average stay was 2.8 days and of that number 15 passengers (1.3%) died.

Other reports have cited causes including severe or uncontrollable bleeding and pain, major injury with shock, impending birth, and uncontrollable mental disturbance.

Virgin Atlantic Airways flights diverted for medical reasons eight times in 1998 and 10 times in 1999 out of 28,000 flights in total for the two years.

A United States survey from 1996/7 detailed there were fifteen passenger deaths out of the 1132 in-flight medical emergencies where the passenger died either in-flight, during transport to a treatment facility or at a treatment centre. Of all the in-flight medical incidents 145 (13%) resulted in an emergency diversion of the flight to an airport other than the destination airport. Of the 449 flights where a physician was on board 70 (16%) were diverted for medical reasons, on the 683 flights when no physician was on board 75 (11%) flights were diverted. Of the in-flight medical diversions 45.5% were due to Cardiac causes and 18% were due to Neurological causes. The in-flight medical kit was used in 65% of cases where the flight diverted and 48% of the cases where the flight did not divert. A further study of 2,042 medical incidents showed these incidents led to 312 diversions (Sirven et al, 2002). This study focussed on neurological symptoms which include dizziness, seizures, pain, and cerebrovascular (Stroke) symptoms, these accounted for 34% of the diversions.

6.2.2.4 On board medical assistance

Most airlines require cabin crew to have completed a first aid course and many include first aid training in recurrent cabin crew training. Some airlines include advanced medical training for senior cabin crew. Most airlines rely on the flight having a medical professional as a passenger. According to Goodwin (2000) there is an 8%-80% chance of a medical professional being among the passengers on any given flight worldwide. One major barrier to medical professionals assisting in flight is legal liability when giving assistance, this varies from country to country but most airlines now have insurance indemnifying medical professionals. Medical associations are also assisting by covering members against legal action.

In the year ending 31 March 1999 British Airways carried 36.8 million passengers and there were 3,386 reported in-flight medical incidents, an average of 1 per 11,000 passengers (Dowdall, 2000). Nearly 70% of these incidents were managed by cabin crew without on-board medical assistance, with about 1,000 incidents where medical doctors or nurses were asked to help. Virgin Atlantic Airways had four in-flight medical occurrences in 1997 and eight in 1998 where no medical professionals were on board the aircraft.

6.2.2.5 Causes of in-flight medical incidents

From British Airways data medical incidents normally include (Dowdall, 2000):

- Chest Pain
- Asthma
- Psychiatric Problems
- Diabetes
- Obstetric and Gynaecological emergencies.
- Collapse
- Head Injury
- Abdominal problems
- Allergic Reactions

A survey of five United States domestic carriers between October 1, 1996, and September 30, 1997, showed 1132 in-flight medical emergencies (DeJohn et al, 2000). The five air carriers represented 22% of the total number of emplacements for US domestic air carriers during this period. The mean age of passengers involved in an in-flight medical incident was 49 years old. In 40% of the in-flight medical events there was a physician on board, in 25% there was a nurse, and in 22% there were no medical personnel on board.

The top 5 causes of in-flight medical incidents identified in the survey were:

- Vasovagal (Fainting) – 22.4%
- Cardiac – 19.5%
- Neurological – 11.8%
- Respiratory – 8.1%
- Gastrointestinal – 7.7%

6.2.2.6 Factors related to medical incidents

The increasing age of passengers is related to the increased disposable income of the retired. Older and possibly less healthy passengers now fly considerable distances and they expect the airline to look after them should medical problems arise. In the air the aircraft cabin pressure drops to the equal of an altitude of 6-8,000ft. This pressure change causes a 30% gas expansion in the body resulting in less oxygen being available, with resulting symptoms of pain from the middle ear and sinus especially on descent (Goodwin, 2000). The dry cabin atmosphere irritates mucous membranes making passengers uncomfortable who then need to drink extra fluid to rehydrate. However in-flight service includes coffee and alcohol which only worsen the dehydration. Cabin air quality and humidity was rated high on the cabin crew survey as areas to be addressed for passengers.

6.2.2.7 ULR Strategies

Recently airlines have utilised the telecommunication capabilities of modern aircraft to communicate information on in-flight emergencies. This includes airlines setting up medical departments or 24 hour medical professional access to provide real time advice on medical problems to the air crew.

For ULR flights the increased flight time may result in more medical problems, and the airline cannot rely on the chance of a medical professional being on board to provide expert medical assistance.

To assist aviation medical physicians in developing strategies for airline medical requirements a central database for reporting in-flight medical events is needed.

Presently airlines do not have to report such incidents and therefore data for research must be comprised from several sources. A central database would identify trends in in-flight illness and injury which would assist in designing in-flight medical kits and training for cabin crew.

6.2.3 Air rage

In-flight disruptive passenger behaviour or *Air Rage* has become an increasing part of modern air travel but there seems no linkage to flight length. Indeed air rage is a spasmodic occurrence which involves individual factors including psychological state, alcohol intake, and drug use. The length of the flight may well impact on these factors but no research has been found on this area.

The ULR Crew Alertness Steering Committee identified air rage or inappropriate/abusive passenger behaviour as possibly increasing with the longer flights. The Singapore Airlines ULR flights have so far shown no greater incidence in the 15 months of operations on the Singapore-New York routes (Flight Safety Foundation, 2005c). Singapore Airline's cabin minor safety/security incidents monitoring system has recorded rates on ULR flights comparable to other types of flight. The cabin crew have not noticed any difference in terms of passenger behaviour incidents compared to other types of operations.

6.2.4 Aircraft system problems

Aircraft diversions for systems problems are generally caused by a range of events including (Fewings, 2005):

- Engine failure
- Cargo-hold smoke warning
- In-flight entertainment system smoke warning
- Avionic smoke warning
- De-pressurisation at cruising level
- Dual hydraulic failure

Detailed technical review of aircraft systems and problems is not part of this review but two instances of diversions, one when operating under ETOPS, are detailed to illustrate the causes and results. Reference should also be made to in-flight shut down information under Section 6.1.3.2 relating to in flight engine shut downs.

In 1998 Swissair Flight 111, a three engine MD-11 aircraft, developed serious in flight problems whilst the aircraft was enroute from New York to Geneva. The crew initially considered diverting to Boston as it was an airfield more suitable to the aircraft and could provide required maintenance, but as the situation worsened they opted for an emergency landing at Halifax, Nova Scotia. The aircraft crashed before it could be

landed, the cause of the diversion and subsequent crash was due to an onboard fire that rendered flight systems inoperative. The fire developed in an unseen section of the aircraft. Following this accident pilots were encouraged to land immediately in the event of smoke or fire.

In 1999 a United Airlines Boeing 777 from Auckland to Los Angeles developed an engine problem 1,100 nautical miles from Hawaii, they elected to divert to Honolulu but ended up landing at Kona, Hawaii due to pilot information on the aerodrome (NOTAM) and weather.

In the increasing push for relaxation of regulations on flight distances from an airport airlines and aircraft manufacturers have pushed the reliability of engines. However in flight smoke or fire is a more common event than an engine shutdown. In-flight smoke incidents occur on average once every 8,750 hours of operation, thus it is more likely than an engine failure (Klopfenstein & Smith, 1999).

Fire suppression systems are standard equipment on long range airliners but landing is the best and most appropriate course of action. Landing can be difficult when no suitable aerodromes are available for 180 minutes flight time.

A three hour diversion due to a fire, medical emergency or other systems failure is a long time even with all engines operating! But with only one engine operating, as would be the case under an ETOPS operation, it would be a frightening experience not only for the crew but even more so for passengers with a limited knowledge of the efficiency of modern aircraft. This is another factor related to cabin crew duties and their increased role in cabin safety.

The reliability of modern aircraft systems, especially engines, is extremely high but there can be failures as an airliner is a complex machine with a variety of different systems. Hydraulics, electrical, avionics, cargo and computer systems all contribute to an operational aircraft. A failure in any of those aircraft systems, albeit minor, can quickly escalate and the increased push for longer diversion times may be supported by engine reliability but not by the ability of other system failures.

Is aircraft system reliability on other than engines high enough to support longer diversion times?

6.2.5 Diversion airports

6.2.5.1 ICAO requirements

ICAO Annex 6, International Commercial Air Transport – Aeroplanes, defines an adequate alternative airport as being:

“an airport which there is a sufficient runway length to meet aircraft landing (and take-off) performance requirements, an airport that is available as and when required, and an airport that has the necessary support facilities and services such as air traffic control, lighting, communication, meteorological services, navigation aids and rescue and fire fighting services.”

The provision for medical facilities and passenger accommodation is not detailed in the Annex.

6.2.5.2 Polar routes

An essential component of an ETOPS operation is the diversion airport and equally this is the case for ULR operations regardless of the aircraft engine configuration. ULR operations are utilising the Polar routes to reduce flight times and distance. The Polar environment is harsh with variable weather, snow, ice and high winds along with temperatures down to -60°C. Most alternate airports currently used and to be used for Polar ULR operations are in the eastern region of the former Soviet Union, Greenland, or western Alaska. Most of these aerodromes do not handle regular air transport flights but are rather military bases or aerodromes built during the Second World War.

Many of these are basic aerodromes which do not meet the ICAO Annex 6 requirement and have limited facilities not designed for large passenger airliners. Analysis of cruise diversion rates has indicated that with Polar routes by 2010 up to six flights a year may need to divert in Siberia (Flight Safety Australia, 2002). These aerodromes are not used to large passenger aircraft and certainly not able to accommodate large volumes of passengers particularly those who have certain expectations of service and different languages. Aerodromes in Greenland, Alaska, Siberia and northern Canada are isolated, sparsely populated, remote for access and limited in facilities. Could these aerodromes really handle an aircraft with over 300 passengers on board?

6.2.5.3 Diversion airport data

The following diversion information is from a study by Bachtel (2005) along with airport data from AirNav.Com (Data accessed 1 September, 2005) detailing diversion airports on key long haul routes:

Alaska

Adak - Alaska

No Air Traffic Control on airport. Air traffic service handled by Cold Bay part time flight service.

Airport Rescue Fire Fighting Index B.

No service facilities.

7,790 ft runway.

Permission required prior to use.

Diversions:

1990: Boeing 747, Passenger heart attack

Cold Bay - Alaska

About 137 people live in Cold Bay.

Part time flight service station.

Limited repair service.

Accommodation limited to small groups.

There is not much sunshine and frequent high winds.

Adjacent to active Volcano which has been responsible for 2 all-engine flameouts.

Airport Rescue Fire Fighting Index B.

10,415 ft runway.

Diversions:

Late 1990s: Boeing 747, unanticipated headwind

Late 1990s: Boeing 747, smoke in cabin

Late 1990s: DC10, smoke in cockpit

June 2000: Boeing 777, oil problems

March 2001: MD11, smoke in cabin

October 2004: Boeing 777, engine oil loss

King Salmon - Alaska

300 miles southwest of Anchorage.

Population of 800, mostly government departments and military.

One motel and nearest hospital is Anchorage.

Limited service facilities.

Airport Rescue Fire Fighting Index B.

8,500 ft runway.

Diversions:

1995-2000: 18-20, mostly Boeing 747s due to weather or fuel

Shemya (Eareckson Air Station) - Alaska

No Air Traffic Control on airport. Air traffic service handled by Cold Bay part time flight service.

No service facilities.

Medical assistance needs to be flown in.

9,990 ft runway.

Military Base. Permission required prior to use.

Diversions:

April 1993: MD11, inadvertent slat extension

August 1996: Boeing 747, crew illness

November 1996: Boeing 747, unanticipated headwind

December 1998: MD11, smoke in cabin

Norway

Longyearbygen Airport – Spitzbergen island.

Most northerly aerodrome in the world.

Surrounded on three sides by mountains.

Notorious for bad weather with temperatures down to -60°C.

North Pacific

Honolulu, Hawaii

Full international airport with extensive maintenance facilities, accommodation and medical facilities.

One 12,300 ft and one 12,000 ft runway.

Diversions:

2003: 10 - 4 due to sick passengers and 6 due aircraft systems

Kwajalein Atoll – Marshall Islands

United States Military Base.

No Air Traffic Control on airport. Air traffic service handled by Honolulu flight service.

Service facilities.

6,673 ft runway.

Very limited accommodation.

Permission required prior to use.

Diversions:

2002: Boeing 727, engine out

2002: Boeing 727, hydraulic problems

Midway Atoll*

No Air Traffic Control on airport. Air traffic service handled Honolulu flight service.

No service facilities.

7,904 ft runway.

Permission required prior to use.

Very limited accommodation facilities.

Diversions:

1981: Boeing 747, passenger heart attack

1998: Boeing 747, passenger heart attack

2003: L1011, engine oil loss

2004: Boeing 777, in flight engine shut down

Wake Island*

Military Base.

No Air Traffic Control on airport. Air traffic service handled by Honolulu flight service.

No service facilities.

9,859 ft runway.

Very limited accommodation facilities.

Permission required prior to use.

Diversions:

1999: Boeing 747, Engine out

1992-2002: Total of 11 aircraft saves

*Wake Island and Midway Island are not funded by the FAA but by other United States government agencies such as the United States Fish and Wildlife Service. In 2004 Midway aerodrome was due to be closed down to all but essential aircraft movements to support the island. This was as a result of reduced funding and increased maintenance requirements for runways. But the Boeing 777 diversion noted above resulted in additional federal funding being found to keep the airport open in the short term. This incident was also a wakeup call to lawmakers over the complacency of such aircraft operations.

North Atlantic

For Atlantic routes diversion airports include Shannon in Ireland, Keflavik in Ireland and St Johns in Canada for the northern routes, with Lajes in the Azores in a southerly routing. These are large airports with regular scheduled international operations and related facilities.

6.2.5.4 Diversion airport requirements

The FAA was the original initiator of regulations and requirements for ETOPS flight, and most countries have followed their ETOPS requirements. However the FAA diversion airport requirements which relate to airport requirements under FAR 139 do not adequately cover rescue fire fighting requirements. The FAR 139 regulations for airports were first published in 1972, prior to ETOPS, and were designed for takeoff and destination alternates not for in-flight. This issue was addressed in the FAA NPRM of November 2003 (FAA, 2003).

An airliner diversion to a remote Arctic aerodrome with temperatures below freezing and high wind speed is a possibility, coupled with very basic aerodrome instrument landing systems. Once safely on the ground there would be minimal help for the aircraft

and occupants from an aerodrome with basic facilities, limited or no medical facilities, difficulties with language, and passengers having to remain on the aircraft due to lack of accommodation.

Factors to be considered in selection and use of an airport as a diversion destination include:

- Airport facilities.
- Effects on aircraft.
- Remote aerodrome facilities.
- Passenger accommodation.
- Logistic support.
- Runway capability.

Aviation regulators need to be more stringent in the requirements for diversion aerodromes on ULR routes. Passenger safety is not only essential in flight but also during diversions.

Basic questions on the diversion airports are:

- Does the aerodrome meet regulatory requirements, especially FAA or JAR-OPS airport requirements?
- Can the aircraft land safely at the aerodrome given runway length, width, and runway strength?
- Can an aircraft under emergency conditions land at the diversion aerodrome given aircraft weight, engine power and related emergency conditions?
- Can the reason for the diversion be dealt with at the aerodrome i.e. medical, mechanical, fire etc?
- Can the aircraft be cleared from the runway so that a recovery aircraft can land for the passengers or maintenance support?
- Can the passengers be deplaned and adequately accommodated with food and shelter whilst repairs are undertaken or until another aircraft arrives?

Some operators have been allowed to designate alternates that do not meet the ICAO Annex 14 requirements for the particular aircraft type especially in terms of equipment and facilities. Due to the present wording of FAA ETOPS requirements the FAA has identified that not all ETOPS operators have put in place the required diversion airport contingency plans. The new extended range regulations that the FAA has proposed in a

NPRM issued in November 2003 aims to address diversion airports more effectively (FAA, 2003).

Diversion airport specifications required by aviation regulators should be assessed by:

- Runway length compatibility for both landing and takeoff
- Runway Pavement Strength
- Rescue and Fire Fighting Service
- Airport services and facilities - Fuel, de-icing equip, aircraft tow tug
- Air traffic and meteorological services
- Airport opening hours
- Passenger accommodation
- Medical facilities

Aerodrome suitability is the major factor in a flight crew deciding to divert to an alternate airport or to continue the flight even in emergency situations.

Diversion aerodromes are important aspects of ETOPS and ULR flights but what if the weather removes the ability to divert to that field?

What if the weather conditions deteriorate on arrival at decision height or minimum descent altitude or wind conditions preclude a safe landing?

Has the reliance on technology, especially engine reliability, seen the boundary of safe flight being pushed?

Will it take a fully laden airliner crash for airline operators, aircraft manufacturers and regulators to review these operations?

6.2.6 Section summary

- The survey to organisations identified the optimum flight route and diversion airport facilities are important for ULR operators.
- An airliner diversion can cost the airline between \$US50,000 and \$US200,000. This can double for a remote aerodrome diversion.
- There are a range of diversion causes but most are related to medical emergencies and aircraft system problems.
- Top two medical causes for diversions are cardiac and neurological.
- For ULR flights airlines and regulators need to address who provides on board medical assistance and what minimum medical equipment needs to be carried.
- No central database of in-flight medical incidents to allow trend monitoring.

- Air rage may be a problem but present ULR operations have shown no increase in such events.
- Aircraft system problems are mostly related to smoke or fire and secondary aircraft system failure.
- Are secondary aircraft systems reliable enough and have adequate redundancy for longer diversion times.
- In relation to diversion airports a number of questions need to be addressed including suitability, facilities, medical services and passenger related services.
- Questions remain over what happens if the aircraft cannot land at diversion aerodrome due weather, airport system failure or other problem.
- Polar and Pacific region aerodromes have adequate runways but mostly inadequate passenger accommodation, basic medical facilities and limited technical support.
- It is suggested that the capacity of Polar region airports to handle aircraft with 300 or more passengers is dangerously limited.

6.3 Cabin Crew

6.3.1 The role of cabin crew

ULR flight will potentially have its greatest impact in the cabin and this is an area where airline operators and aircraft manufacturers as well as regulators have concentrated little or no effort. Increasing flight length means the safety role of the cabin crew will expand and in-flight duties increase in importance.

6.3.1.1 Definition of cabin crew member

The traditional image of cabin crew by the public is to serve food and drinks on the flight, attend to the passenger comfort needs and be very attractive. This view is reinforced and used by airline marketing divisions to generate business and attract passengers. The job of cabin crew is seen as a service occupation rather than a serious career.

The ICAO definition is:

***Cabin attendant** – A crew member who performs, in the interest of safety of passengers, duties assigned by the operator or the pilot-in-command of the aircraft, but who shall not act as a flight crew member.*

A recent definition by the president of the Flight Attendants Association of Australia (Commonwealth of Australia, 2005) refines the role of cabin crew as “safety professionals who are principally there in the event of in-flight emergencies....provide the ability for passengers to feel safe on board the aircraft”.

6.3.1.2 Safety crew or marketing crew?

Cabin crew are the airline safety personnel who are responsible for passenger safety in the cabin. The vexed question is who are they really responsible to; the flight operation department or the marketing department?

In the survey conducted for this thesis cabin crew identified that their primary role is passenger safety.

For the sales and marketing department ensuring that their airline has an edge over other airlines means that cabin crew must attend to passenger needs and provide high levels of customer service. This service role has muddled the real purpose of cabin crew and thus diluted their safety worth.

The cabin crew role is not seen as technical or as essential to the flight, unlike that of pilots. Cabin crew are treated differently to flight crew which was reflected in the rest period and rest facilities identified in the survey to cabin crew (see Chapter 5). The perceived non-essential role of cabin crew gives them less bargaining power for cabin improvements and often results in their suggestions or complaints being ignored.

6.3.1.3 Cabin crew safety role

The assignment of cabin crew for safety related duties on board an aircraft is a prescribed standard of ICAO Annex 6 to the Convention on International Civil Aviation. The forward to Annex 6 states that cabin crew are required on board aircraft to ensure passenger safety. It also states that the term *Cabin Attendant* is used to identify crew members required on board an aircraft to affect a safe and expeditious evacuation of the aeroplane and to perform the necessary functions in an emergency or a situation requiring emergency evacuation.

The ICAO Training Manual of Annex 6 E1-2 paragraph 1.2.1.3 states the major function of cabin crew is to “*ensure passenger safety by preventing and managing adverse situations which may develop in the aircraft cabin and to provide guidance to all persons on board during an emergency*”.

In the United States from December 11, 2004, the Federal Aviation Administration has begun to issue cabin crew certificates. This was in response to the United States Congress which acknowledged “flight attendants perform vital crewmember functions onboard aircraft, including emergency functions for aircraft evacuations, fire fighting, first aid, and response to security threats” (FAA, 2004)

From the cabin crew survey undertaken for this thesis the respondents valued their safety role over that of their service role. This seems somewhat at odds to what the general public perception is. How many people listen and take notice of the passenger safety briefing before a flight departure? How many people would listen to this briefing if the Pilot was doing it?

Cabin crew form an integral part of the aircraft operation both on the ground and in-flight. They directly handle serious emergencies related to the cabin and passenger safety including fire, decompression, evacuation, and air rage. Prior to boarding the cabin crew ensure the aircraft cabin is safely setup for boarding and the subsequent flight. On arrival the cabin crew flight safety duties include safe deplaning of passengers, securing of the aircraft and reporting inoperative or defective equipment to the maintenance personnel.

Low cost airline operators and airlines seeking to reduce costs have lobbied to reduce cabin crew to passenger ratios. The need for trained and adequate ratios of cabin crew to passengers has been reflected in the Air France A340 Toronto crash in Canada where the aircraft crashed on landing resulting in the hull being ruptured with a resulting fire. All passengers and crew survived and were evacuated. This was not due to the flight crew or the airport rescue fire service but to the professionalism of the cabin crew and their training.

6.3.2 Cabin crew training

6.3.2.1 ICAO Requirements

ICAO Annex 6 is the international standard for cabin crew and includes details on cabin crew training requirements. However ICAO does not set standards for cabin crew licensing although they are the cabin safety personnel. Under ICAO Annex 1 Personnel Licensing the international licensing requirements for flight crew are detailed including pilots, flight engineers and flight navigators. Other operational personnel including aircraft maintenance, air traffic controllers, flight operations officers and aeronautical

station operators are licensed in accordance with ICAO Annex 1. There is no international standard for cabin crew licensing despite ICAO and aviation regulatory bodies recognising their important operational role for passenger, cabin, and flight safety.

From the cabin crew survey for this thesis over 80% of respondents believed the aviation regulatory authority should regulate cabin crew flight and duty times. Over 60% of the survey respondents wanted the aviation regulatory authority to issue a cabin crew licence.

ICAO Annex 6 states that civil aviation authorities should ensure that operators implement a training system for cabin crew which is no less than a minimum level of proficiency. ICAO does identify that there is a need for minimum qualifications for cabin crew. Chapter 1, Paragraph 1.2.2.1 of the ICAO Doc 7192 (ICAO, 1996) states:

Cabin crew as crew members responsible for the safety and well-being of passengers in the aircraft cabin make it essential that a minimum standard of medical standard, knowledge, age, and other qualifications are met.

ICAO Annex 6 Training Principles cover:

1. Aviation indoctrination including regulatory aspects
2. Duties and Responsibilities
3. Emergency Procedures
4. Carriage of Dangerous Goods
5. Human Factors
6. Hygiene, aviation medicine and first aid

Globally cabin crew training is the responsibility of the airline with little regulator oversight. Although the training programmes must meet the ICAO training requirements the lack of regulations mean that the selection, training and ongoing competency requirements do not match the integrity of Annex 1 licences.

6.3.2.2 Crew Resource Management

In the 1980s the need to improve flight crew communication for the safety of the flight was addressed with the introduction of Cockpit Resource Management programmes by airlines. In the 1990s Cockpit Resource Management was expanded to Crew Resource Management (CRM) in recognition of roles that both flight crew and cabin crew have in the safe conduct of a flight. This integrated approach to safety developed from human

factors research has greatly improved flight safety with the total crew communication improving. But it is now time for the next step with an increased emphasis and acknowledgement of the cabin safety role.

Research has shown that effective communication between the cockpit and the cabin is hampered by traditional barriers that exist between the two types of crew and the lack of interactive training. Even though CRM is designed to involve cabin and flight crew, most flight and cabin crew training especially for aircraft evacuation is done in isolation of each other. It has been identified that cabin crew are not adequately trained in technical aircraft knowledge to assist the flight crew when problems develop and conversely the flight crew do not see cabin crew as a source of information on problems (Dundar et al, 1997). This lack of cabin crew technical training has been identified in a number of reports resulting in the loss of valuable time for the flight crew when an incident occurs by them addressing the wrong problem through poor information transfer by the cabin crew. An evaluation of cabin crew technical knowledge noted 37% of pilots and 40% of cabin crew believe technical knowledge to be one of the five most important cabin crew training needs (Dundar et al, 1997). The survey also showed that 62% of pilots had received important safety information concerning the aircraft (aside from cabin equipment) from cabin crew with 69% of cabin crew reported providing the flight crew with important safety information.

The cabin crew survey conducted for this thesis showed that nearly 95% of respondents were involved in CRM training. The effectiveness of the CRM from the survey was unclear with 25% of respondents believing that communication and teamwork stayed the same after the CRM training. There is more work to be done on Crew Resource Management.

6.3.2.3 NTSB review of cabin crew training

In 1992 the United States National Transport Safety Board completed a special investigation on cabin crew training which had several important findings:

- Lack of guidance was provided to FAA inspectors on cabin crew training particularly recurrent training.
- Some cabin crew were not proficient in knowledge of emergency equipment and procedures.
- Most carriers did not have standard locations for emergency equipment.

- Most carriers did not limit the number of aircraft types the cabin crew were qualified on. (Would this happen for pilots?)
- Many air carriers did not perform evacuation drills during recurrent training. (What were they testing? Food delivery?)

6.3.3 Emergency evacuation

The evacuation of an aircraft in an emergency is crucial to the safety of passengers and the preservation of human life. The cabin crew are essential components of an evacuation and are critical in ensuring the evacuation is performed quickly and effectively.

A number of countries have performed studies on aircraft evacuations identifying consistent themes with reoccurring recommendations. Although many of these recommendations are promoted there are few that have been acted on.

6.3.3.1 North American studies

The United States National Transportation Safety Board (NTSB) has performed extensive research and study on emergency evacuation from commercial aircraft. In 1970 the Safety Board made recommendations about the designation of cabin crew for specific duties during an evacuation and the conveyance of safety information to passengers (NTSB, 2000). These recommendations were to highlight the cabin crew safety role in air operations and ensure cabin crew were adequately trained for emergency situations.

In 2000 the NTSB studied 46 aircraft evacuations during a 16 month period to review the causes and the results of the evacuation. From the case studies it was estimated an evacuation occurred on average every 11 days from an average of 336,328 departures (NTSB, 2000).

Of the 46 evacuations the top five events consisted of:

Engine fire	18
Cargo smoke or fire	8
Smoke in cabin	4
Gear failure	4
Smoke in cockpit	3

In the 46 evacuation cases, 92% of the occupants on board were uninjured, 6% sustained minor injuries, and 2% sustained serious injuries. It should be noted all

reviewed evacuations occurred on airport property. FAA regulations for airline certification require all passengers and crew to be evacuated from the aircraft and be on the ground in 90 seconds or less (14 CFR Part 25).

In 1995, the Transportation Safety Board (TSB) of Canada studied a large number of air carrier evacuations. The TSB recommended a re-evaluation of escape slides, a review of the adequacy of public address systems, implementation of joint crew training, and detailed briefings to prepare passengers for emergencies (TSB Canada, 1995).

6.3.3.2 United Kingdom studies

The United Kingdom Civil Aviation Authority (UKCAA) commissioned several studies with Cranfield University on cabin safety issues between 1989 and 1996 (NTSB, 2000). The first study (Muir et al, 1989) suggested that aircraft bulkhead passageway should be 30 inches wider and the distance between over wing exit rows should have a vertical seat projection of 13 to 25 inches⁵. The second study (Fennell & Muir, 1993) assessed over wing exits, it found that the hatch weight of the exit needed to be reduced by 50% and the seat space needed to be increased to reduce the time taken to open the hatch. The third study (Muir & Cobbett, 1996) was jointly commissioned by the UKCAA and the FAA. The results showed the performance and number of cabin crew significantly influenced evacuation rates and passenger behaviour. The findings have implications on the selection and training of cabin crew.

Both the flight and cabin crew need to communicate in an evacuation so that the procedure is well co-ordinated. From the NTSB study (NTSB, 2000) it was found that even though CRM programmes are in place with air operators the flight and cabin crew do not always practice emergency evacuations together. Indeed communication problems during evacuations have been found to be common in real evacuations and the roles of the two crews can become muddled. From a related survey in regard to passenger safety briefings 13% of passengers indicated they watched none of the briefing while 48% reported they watched at least 75% of the briefing (NTSB, 2000). Many respondents stated they did not watch the briefing because they had seen it on previous flights, however aircraft vary greatly even between models and the safety briefing includes important information relevant to the particular flight. From the survey

⁵ Vertical seat projection is the distance between two rows of seats from the seat back of the front row to the seat cushion of the following row.

conducted with this thesis over 25% of cabin crew respondents stated that flight and cabin crew did not perform emergency training together.

6.3.4 Human error and cabin crew

Human error has been cited in research as a major contributor to aviation incidents and accidents. Research in the area of human factors began in the 1970s with the SHELL framework which had four components: Software, Hardware, Environment and Livewire. This was further developed by Edwards (1972) and modified by Hawkins (1987) by including an extra Livewire component. The inclusion of the second Livewire was the initial driver for CRM.

The interpretations are:

Software- Policies, procedures and processes.

Hardware- Technology

Environment- Situation and Culture

Livewire- Human

The Livewire is the central component and the interaction of this component with the other components determines a successful outcome. But within the *Livewire* interaction are human errors made up of slips, lapses or mistakes. This concept is important in understanding human factor research which is the study of the SHELL relationships and the resulting errors in order to reduce or eliminate these errors. The importance of human factors in aviation has steadily increased and developed.

In the early development of human factors the Cockpit Resource Management programme was established as a means of addressing accidents and incidents where flight crew interaction was a causal factor. This programme included such items as cultural diversity, power distance difference and team performance. The programme was further developed to include the cabin crew and changed to CRM where the whole crew is involved in human factors training and development of team issues.

ICAO CIR300 Human Factors Digest No. 15 (ICAO, 2003) covers human factors in cabin safety. This digest aims to provide the latest information on human factor considerations for passenger aircraft cabin safety, items covered include:

1. Human Factors in teams and team performance.
2. Communication and coordination.
3. Abnormal events and conditions. Passenger management and aircraft evacuation.

4. Organisational including culture and policy development.

Most airlines have human factor programmes and human factor management systems. Additional to this are human factor reporting, monitoring and analysis systems. Many airlines only have human factor systems or programmes for flight crew. It is important that cabin crew are included in these systems particularly with ULR flights and the increased impacts these operations will bring.

6.3.5 Section summary

- Cabin crew have an important safety role for the flight especially in regard to emergency evacuation and passenger safety.
- Cabin crew survey identified that cabin crew value their safety role over their service role.
- Unlike other aircraft crew members, cabin crew are not licensed or covered under ICAO standards.
- Cabin crew safety role is detailed by ICAO but is often clouded by their service role.
- Cabin crew survey identified that cabin are supportive of licensing by aviation regulators and want the aviation authorities to regulate their flight and duty time.
- CRM is important to reduce errors and mistakes as well as improve the interaction with flight crew.
- Cabin crew survey identified that cabin crew had mixed opinions on CRM effectiveness.
- Cabin crew must be fully included in CRM programmes especially technical training and joint emergency training to achieve the full benefit.
- Recent incidents and evacuations show the importance of highly trained cabin crew and low passenger to cabin crew ratios.
- There is a need for increased emphasis on cabin crew safety role by both airlines and aviation regulators especially training requirements and emergency actions.
- Cabin crew training and ongoing competency must have the same integrity as ICAO Annex 1 licences.
- The performance and number of cabin crew influence passenger behaviour and assist successful evacuations.

6.4 Cabin Crew health and safety

6.4.1 Cabin crew health

6.4.1.1 Cabin crew health research

Increasing flight length will have a major affect on the cabin crew whose work place is the aircraft cabin and who are subjected to the cabin environment longer than any other person. Globally aviation regulatory authorities, governments, and academics have focussed cabin environment research in relation to passengers with little studies related to cabin crew (Nagada & Koontz, 2003). Of the few studies most identify barometric pressure changes, immobility, jet lag, noise and seating as major impacts. The lack of identified epidemiological studies on the health effects for cabin crew was identified in a study 20 years ago (Kraus, 1985).

Cabin crew health, including work related stressors, have not been fully studied whereas flight crew have been intensely researched this was reinforced by the literature search for this thesis. Also unlike flight crew, cabin crew mostly do not undergo regular employment related health checks or tests.

The survey to cabin crew conducted with this thesis identified fatigue, sleep and dehydration as impacts on cabin crew from long haul flights. Over 90% of respondents believe these impacts will increase with ULR flights.

6.4.1.2 ULR Task Force

The ULR task force “parked” the issue of cabin crew for later review whilst the bulk of presentations and research at all four meetings focussed on flight crew. For flight crew both aircraft manufacturers and airline operators have researched intensely the impacts of ULR operations in particular focussing on fatigue and in-flight rest. Research included specialised actowatches to measure physical impacts, the recording of data in sleep/fatigue diaries, and monitoring of EEG recordings. For cabin crew none of this technology has been employed yet their job is very physically demanding and requires constant interaction with passengers. Indeed for flight crew the increased technology of the aircraft, systems and air traffic control means that apart from take-off and landing their role is purely as a systems monitor and when required intervention for an unexpected event resolution. The extensive ULR research identified that two flight crews were needed for the system monitoring in ULR flight. For cabin crew the impacts

in the cabin may be greater due to the physical nature of the role, for passenger management and during flight diversions. There is a need for research to assist in identifying and addressing these issues.

6.4.1.3 Possible effects of ULR flights

The basic equation in relation to a negative factor is the greater the exposure to this factor then the greater the impacts:

$$\text{NEGATIVE FACTOR} \times \text{EXPOSURE} = \text{INCREASED IMPACTS}$$

Following a review of studies related to cabin crew health, a 2003 survey (Nagada & Koontz, 2003) listed the types of negative factors shown by the complaints and symptoms reported by cabin crew:

- Respiratory Symptoms (Inc colds, blocked nasal passages and breathing difficulties)
- Dryness or irritation of skin, eyes or throat
- Nausea, intestinal complaints or bloating of stomach
- Swelling or aching of legs
- Lower back pain
- Head or earache
- Dizziness or faintness
- Fatigue, sleep disorders or disruption of circadian rhythm

Potential causal agents or factors of the negative factors in the reviewed studies include:

- Tobacco smoke (older studies)
- Relative humidity
- Ozone
- Cabin air quality
- Disruption of circadian rhythm
- Activities or lifestyles of cabin crew

The combined effect of long distance travel without adequate rest may lead to neuropsychological problems amongst cabin crew including anxiety, stress and fatigue. These factors could also lead to depressed immune systems with increased susceptibility to infection, gastrointestinal and kidney disruption, and menstrual problems. Add in irregular work patterns and long shifts then the health effects are magnified (IEH, 2001).

Relative humidity or dryness is a symptom that many cabin crew have identified in cabin crew health studies, including the cabin crew survey conducted for this thesis. The average measured cabin air humidity ranges from 2-15% (Nagada & Koontz, 2003). This low humidity or dry air is suspected to cause dryness or irritation of skin, eyes or throat, such complaints increase with flight duration (Ross et al, 2000). “Sick building syndrome” was identified in the 1970s as a series of non-specific symptoms related to low humidity which caused a range of health problems for affected health workers. A 10% increase in relative humidity in the aircraft cabin has been stated to alleviate such symptoms and would assist in reducing health impacts on the cabin crew (Nagda & Hodgson, 2001).

6.4.1.4 ULR occupational factors

Airline crew have six main concerns in relation to occupational factors (Brown et al, 2001) comprising:

- Deep vein thrombosis
- Air quality
- Infection
- Cosmic radiation
- Jet lag
- Work patterns

From late 1990s research (Lindgren, 2003) the airline crew health findings were:

- Fatigue – 21%
- Nasal irritation – 15%
- Dermal symptoms from face – 12%
- Eye complaints – 11%
- Dermal symptoms – 12%

Pilots had fewer ocular, nasal or dermal symptoms than cabin crew which may be related to the differences in their work activity and environment between the cockpit and the cabin. Pilots on long haul flights are not exposed to pollutants related to passenger activity, or cabin related emissions, they also have better ventilation that they can directly control. From this research comparing airline crew with office workers the level of stress related to work was 42% for pilots, 94% for office workers, 91% for cabin pursers, 88% for cabin stewards, and 82% for air host/esses.

6.4.1.5 Cosmic radiation

Cosmic radiation has been identified as an increasing risk for cabin crew but controversy remains over the effects, and the amount of radiation cabin crew are exposed to. Several respondents to the cabin crew survey conducted for this thesis commented on cancer and cosmic radiation including the lack of empirical research. The International Federation of Airline Pilot Associations (IFALPA) has identified radiation exposure as an important issue for flight crew and has reviewed the research on radiation effects. The IFALPA released a discussion paper on cosmic radiation (IFALPA, 2002) which although related to aircrew is also relevant to cabin crew. The discussion paper noted that air crew members are exposed to more cosmic radiation than the general population or other occupationally exposed workers. They are the only group continuously exposed to high energy neutron and proton radiation which have a high potential of causing biological damage. The less dense, high altitude atmosphere offers less protection against ionising radiation which can cause cancer, genetic defects and foetal damage, with some of these effects on tissue being cumulative.

Most exposure to increased ionising radiation occurs at higher altitudes and higher latitudes, further from the equator.

At 35,000ft the ambient radiation dose is about 4-6 μ Sv⁶ per hour, at 41,000ft at Polar latitudes the ambient dose is about 8-12 μ Sv per hour and the rate of radiation is estimated to double every 4,500ft. In the Polar Regions above 60° latitude the radiation intensity is about twice as high as that near the equator due to the inclination of the earth's magnetic field. A typical flight from New York to Tokyo of 13 hours is calculated to have a dose of 0.0644mSv varying with height, latitude and solar cycle. Therefore on 16 such flights cabin crew would be exposed to a dose close to 1mSv. However it has been noted that crew members on ULR Polar routes may exceed 6 mSv per year. This level of exposure should be avoided by crew scheduling but currently there is little or no regulatory requirement to do so (The United Kingdom Parliament, 2000).

The cosmic radiation at high altitudes has been found to be more energetic than at lower altitudes and therefore more penetrating (BALPA, 2002). The human body can repair a certain amount of biological damage from exposure but further exposure increases

⁶ The Sievert (Sv) is the international measure for ionising radiation. It measures the biological effect of the ionising radiation. Smaller quantities are measured as millisievert (mSv) which is one thousandth of a Sievert and microsieverts (μ Sv) which is one thousandth of a millisievert.

health risks including the risk of cancer, effects on egg or sperm cells and risk of damage to an embryo or foetus. No epidemiological studies have shown increased cancer rates from cosmic radiation but scientific data is limited. However studies do suggest that long term exposure of 10mSv per year in high altitude flight may increase the risk of death from cancer by 0.5% to 4% compared to a fatal occupational rate of approximately 0.1% in general industry workers (IFALPA, 2002). The International Commission on Radiological Protection, the United States FAA and the European Union having varying maximum radiation exposure levels, but 20mSv per year seems to be a weighted average. ICAO Annex 6 requires all aeroplanes operated above 15,000m (49,000ft) to carry equipment to measure and indicate the dose rate of cosmic radiation with a cumulative total for each flight and a display of the rate visible to flight crew. The FAA has limited regulation and guidance to air crews on radiation mostly contained in an Advisory Circular whereas the European Joint Aviation Regulations - Operations (JAR-OPS) contains regulations and detailed guidance.

Emirates airlines aviation medicine specialist Ian Hosegood has stated that the average dose for a long haul pilot is 3-4 mSv per year and using computer simulation of the worst case of 1,000 hours flying over Polar routes the dose was estimated to be about 5.6 mSv per year, well below regulatory limits (Jones, 2003).

6.4.2 Cabin crew rest

The role of the cabin crew is seen by most airlines as important but not as operationally important as that of the flight crew. Indeed the power difference between the two is reflected not only in pay rates and conditions but in research on health effects. In the literature search performed for this thesis it was obvious that research was focussed on the flight crew when studies referred to aircrew. Any cabin crew research appears to be less well funded due mainly to the fact that it was not performed by the airlines, and as a result the information was not as detailed or as comprehensive as it could have been. The cabin crew survey repeatedly identified fatigue and lack of rest as impacts on cabin crew. Fatigue was identified in various ways and further study is required on fatigue is needed to identify the various types and sources. Given the importance of the safety role that cabin crew perform fatigue is a danger to passengers and cabin safety.

6.4.2.1 Fatigue

Fatigue in relation to cabin crew would appear to be related more to the duty time and time zone changes than the work effort of the cabin crew duties. Collective studies indicate that symptoms related to circadian rhythm or fatigue tends to increase with longer flights, rapid changes in time zones, and early morning or late night departure times (Nagada & Koontz, 2003). The end of day fatigue is related to fatigue at the start of day, length of duty cycle, and amount of walking performed in flight.

Fatigue is a combination of many physiological states including sleepiness, tiredness, exhaustion and reduced performance. It is a combination of impacts both physical and mental which impact on a person's ability to perform a task. Factors that influence fatigue include:

- time of day – circadian rhythm
- time since sleep – Length of time awake and lack of sleep
- quality of sleep – the quality of sleep including sleep disorders, interruption of sleep and fragmentation of sleep
- time on duty – time at work and performing a task
- workload – amount and stressful nature of work
- stimulation level – boring or repetitive task, sleep inducing environment (hot and low humidity) or reduced need for vigilance (periods of inactivity)

Fatigue leads to personal indifference to one's performance, delayed reaction time, decreased concentration, fixation, short-term memory loss, impaired judgement, impaired decision making, personality changes and depression (Printup, 2001). These show through in poor communication, mood changes, errors or slips, poor performance and personality changes. Fatigue also degrades cognitive abilities including memory, perception, performance monitoring, motivation and communication.

6.4.2.2 Regulatory requirements

ICAO Annex 6 prescribes flight time and flight duty period limitations for flight crew but the Annex does not prescribe any such requirements for cabin crew. The FAA is a leading regulator for aviation rules and regulations. The FAA prescribes in Federal Aviation Regulations (FARs) the requirements for participants in the aviation system. These FARs are also used by other countries as a basis for the development of their aviation regulatory requirements. The FAA 14 CFR Parts 121, 125, and 135, for

Domestic, Flag, and Supplemental Air Carriers and Commercial Operators of Large Aircraft, detail cabin crew duty period limitations and rest requirements.

The FARs detail the duty period requirements for cabin crew but not flight duty time which they do for flight crew. Duty period is defined as *“the period of elapsed time between reporting for an assignment involving flight time and release from that assignment by the domestic, flag, or supplemental air carrier or commercial operator”*.

For ULR flights the FARs requirements for cabin crew are:

- Scheduled Duty period 14 to 16 hours the air operator must assign one additional cabin crew to the minimum number of cabin crew required
- Scheduled Duty period 16 to 18 hours the air operator must assign two additional cabin crew to the minimum number of cabin crew required
- Scheduled Duty period 18 to 20 hours the air operator must assign three additional cabin crew to the minimum number of cabin crew required
- For all 14 hour or longer Duty periods the cabin crew must be given a scheduled rest period of at least 12 consecutive hours. This period is from the completion of the scheduled duty period and commencement of the subsequent rest period.

Unlike air operator and flight crew requirements the regulations for cabin crew are not as closely monitored nor enforced by the FAA. Indeed this is the case for most aviation regulators worldwide where rules and regulations for cabin crew are minimal and not enforced at the same level as those of the flight crew. The cabin crew respondents to the survey conducted for this thesis strongly supported (80%) the regulation of flight and duty times by the Civil Aviation Authority. Is now the time for action?

6.4.2.3 Crew rest and sleep

Physical comfort and location of rest facilities was identified in the cabin crew survey conducted for this thesis as areas that need to be addressed. Sleep for all air crew is important on long range flights as it is the only physiological mechanism that can reverse sleepiness. Therefore effective sleep is necessary on long and ULR flights to reduce fatigue. From the cabin crew survey 62% of respondents believed the cabin crew rest period provided was adequate but only 30% believed the cabin crew rest facilities were adequate. Respondents identified that sleep facilities need to provide lie down rest and not be confined, noisy or poorly ventilated.

The National Aeronautical and Space Administration (NASA) under request from the FAA conducted a survey on sleep quality and on board crew rest facilities for long haul flights (Rosekind et al, 2000). The research was conducted due to long haul flight operational fatigue which resulted in sleep loss, decreased alertness, and degraded performance mainly from multiple time zone changes, long and irregular work schedules, sleep disturbances, and circadian disruption. The research was the twelfth in a series relating to flight operations and to flight crew. There was no research in the series related to cabin crew.

The NASA survey finding was that nearly half of the “good sleepers at home” reported having regular difficulties sleeping in the bunk. The average sleep duration in the bunk was 1.5 hours. Random noise was a major disturbance to sleep along with heat and light. Findings suggest that bunk sleep can be improved by maximising physical comfort (pillows, blankets) and minimising random noise (location of bunk away from service areas).

Fatigue is derived from a lack of sleep, a lack of effective sleep or disruption of the circadian rhythm. Fatigue is a latent failure as defined in the Reason Model (Reason, 1990). Latent failures are not obvious failures, normally they appear as a minor incident, but if they combine with other factors and breach the system defences they develop into an accident. On ULR flights fatigue will occur and simply increasing cabin crew numbers is not the answer. There needs to be more research on the differences between long and ULR flights so that the duties and requirements of cabin crew can be amended scientifically. ULR flights require cabin crew to be on duty when the circadian rhythm affects the body most with performance and alertness at their lowest and fatigue at the highest. It also requires the cabin crew to rest or sleep when their body wants to be awake resulting in poor rest or sleep and impacts on the performance levels when back on duty. This is when errors, slips or mistakes occur.

Table 10 shows how on long haul aircraft the cabin crew and flight crew facilities vary. Both aircraft have an optional lower lobe cabin crew rest area that can be located in the forward end of the aft cargo bay, it contains bunks and storage compartments (Boeing, 2003).

Table 10*Boeing 777 Crew Rest Facilities*

Aircraft type	Flight Crew	Cabin Crew
Boeing 777-300	Overhead Rest Area	Overhead Rest Area
	2 Seats	4 Modules with 2 Bunks
	2 Bunks	per module
Boeing 777-200	Overhead Rest Area	Overhead Rest Area
	2 Seats	2 Modules with 3 Bunks
	2 Bunks	per module

6.4.2.4 Fatigue Risk Management System

Science is playing an increasing role in risk management to assist in analysing and managing fatigue. A Fatigue Risk Management System (FRMS) is an integrated safety management system designed to ensure crew alertness and performance is not impaired due to fatigue. The aim of a FRMS is as a safety tool to prevent errors, incidents and accidents due to fatigue factors.

The ULR Crew Alertness Steering Committee identified the use of a FRMS as an important component of ULR flights. The Committee focussed the need for a FRMS primarily at flight crew, but for ULR flights this should also be extended to cabin crew and other operational staff.

An effective FRMS requires company commitment with set policy, efficient reporting systems and tailored education and training programmes. Importantly, the reporting methods and related analysis must be rigorous to correctly define the problem areas so that effective solutions to fatigue related issues can be instituted.

For ULR flights a FRMS is essential for flight crew, cabin crew, and related operational staff essential to the operation of the flight.

Below is a generic FRMS developed by the ULR Crew Alertness Steering Committee.

Fatigue Risk Management System Structure



Figure 8 *Structure of a Fatigue Risk Management System*

Reproduced with permission of the Flight Safety Foundation from the Flight Safety Digest August-September 2005 based on the ULR Task Force work.

6.4.2.5 Singapore Airlines ULR cabin crew experience

Singapore Airlines as the innovator of operational ULR flights has developed a Crew Alertness Management Programme (CAMP) based on the Airbus ULR fatigue management recommendations. Cabin crew are involved in the CAMP programme in addition to the base training on the aircraft type and specific aircraft emergency procedures training.

The classroom-based training covers:

- Why have ULR Training?
- Basic Knowledge
 - Sleep & napping, biological rhythms & jet lag.
 - Caffeine intake, boredom & monotony
- General Presentation of Recommendation Principles
 - Before flight and in-flight
 - Layover periods

- General guidelines:
 - Planning personal sleep/wake phases one day before operating a flight
 - Use of light and activities to induce sleepiness or extend wakefulness
 - Understanding biological rhythms
 - Use of caffeine to extend or enhance wakefulness

Singapore Airlines has also found many challenges in relation to cabin crew and ULR operations.

- Different crew categories
- Onboard challenges
 - In-flight Rest Periods
 - Crew Rest Facility
 - Crew Relationship
 - Crew-in-Charge Management Style

For Singapore Airline's ULR flights there are 14 cabin crew at a ratio of 1 cabin crew to 9 passengers (1:9) in Raffles Class (Business Class), and 1:23 in Economy Class. This compares to 1:13 and 1:32 respectively on the Singapore Airlines long range operations using the Boeing 747-400.

For flights which exceed 14 hours in duration, Singapore Airlines provides nine seats in economy class and each crew is allowed three hours of undisturbed rest during the flight. Their duty roster for long-haul flights does not tend to exceed 13 hours.

The Civil Aviation Authority of Singapore requires cabin crew on ULR flights to have four hours of in-flight rest during a flight duty period of less than 19 hours and five hours of in-flight rest for a flight duty period of 19 hours or more.

On ULR flights Singapore Airlines have two cabin crew teams with alternating duty and rest periods. Cabin Crew working on the ULR flights between Singapore and Los Angeles and between Singapore and New York are scheduled to have a horizontal, undisturbed rest time of 5 hours each. The option of a five hour rest period has been added recently but this was always provided for flight crew. However in practice they tend to have a two or three hour rest period rather than the four or five hours that the flight crews get. These rest periods can be modified to give a longer or shorter break as required. This reflects the ongoing problem of the differences that the two crew types, cabin and flight, get with opposing views on stress levels, alertness needs and work environment.

6.4.3 Cabin crew and ULR flights

Increased flight length has been identified by the American Association of Flight Attendants (AAFA) as producing a range of problems including (Kolander, 2002):

- Unruly Passengers
- Safe carriage of infants and children
- In-flight medical emergencies
- Turbulence
- Baggage stowage
- Air quality
- In-flight service
- Adequate in-flight rest provisions

The AAFA also presented to the ULR Task Force (Kolander, 2002) the issues they believe need to be addressed regarding cabin safety, passenger safety and comfort. These include:

Crew Roster – Protection of time off before and after the flight. Prevent unexpected delay or interruption to a rest period before, during or after the flight. These must be addressed by regulatory agencies.

Trip Scheduling – Ensure the flight is scheduled when the cabin crew are at peak performance levels for the flight segment. This also includes strategies for delays or disruptions.

Crew Complement – The management of passengers for 16 hours or longer with minimum cabin crew would exponentially increase the flight attendant's stress and fatigue. There needs to be a formula to allocate cabin crew with involvement of the regulatory authority to ensure appropriate duty periods.

Strategies are required to address increased in-flight medical incidents especially from increased passenger exposure to adverse cabin conditions.

In Flight Roster – Minimum Equipment List (MEL) status for rest facility, MEL for cabin entertainment or service items, pre-flight planning of in flight rest and duties, and quality of rest. Ensure minimum aircraft equipment and passenger requirements will be met for the ULR flight.

Design Issues – Regulations should require that adequate rest facilities be mandated for cabin crew including bunk and seating equipment. The location of cabin crew rest areas should assist rest and sleep.

Personal Strategies – Training and education for cabin crew on sleep and physiological effects of ULR flight. This includes coping strategies for sleep debt and fatigue management with information on medications.

Communication – Strategies for effective communication on new larger aircraft, enlarged crew complement and communication with the flight deck.

6.4.4 Section summary

- Cabin crew survey identified fatigue, sleep and sleep facilities as areas to be addressed with 90% saying impacts will increase with ULR operations.
- Cabin crew survey identified low humidity and dryness as factors of the cabin environment.
- Lack of research of ULR flights impacts on cabin crew health especially the impacts of repetitive exposure to the cabin environment.
- Possible cabin environmental impacts include respiratory symptoms, skin dryness, fatigue and neurological effects such as dizziness.
- Cosmic radiation increases with altitude and latitude with increased exposure having a range of bodily impacts that are cumulative.
- A lack of research on ULR impacts on the cabin crew role and duties, especially compared to flight crew.
- Fatigue is influenced by circadian rhythm, work load and type of in-flight rest.
- Aviation regulators need to set maximum cabin crew flight and duty times for ULR flights with required rest periods.
- There is a need for research and scientific analysis of cabin crew rest and sleep requirements.
- For ULR flight systems needed to identify and manage fatigue such as FRMS.
- There are different standards and research between cabin crew and flight crew.

6.5 Cabin Environment

6.5.1 General

In the pioneering days of air transport operations passengers were treated to spacious cabins which resembled lounges with sofa type chairs, large desks, and separate dining rooms. The development of the airliner as a mass transportation mode and the passenger demand for low cost travel has seen the cabin become more crowded. Seats are now

arranged more closely much like movie theatres and the airline need to maximise the revenue has seen the space between seats decrease. The quantity of external air supplied has halved in the last 30 years and the humidity levels continue to be very low.

From the survey to organisation conducted for this thesis cabin air quality and cabin humidity rated low on areas to be addressed. The cabin crew survey rated these higher for cabin crew and the highest for passengers as areas to be addressed. There is a degree of mismatch here and the cabin air quality needs more analysis.

6.5.1.1 United States study on airliner cabin environment

In 2000 the United States Congress commissioned the National Research Council (NRC) to conduct a study on airliner cabin environment (FAA, 2002). The report was issued in December 2001 with ten recommendations for new regulations, investigations and research on airliner cabin environment and effects on crew and passengers.

The recommendations were to look at:

1. Air Quality Regulations
2. Regulations for Ozone
3. Air Cleaning Equipment
4. Carbon Monoxide Monitoring
5. Allergens
6. Health Information
7. Ventilation Shutdown
8. Surveillance Program
9. Research Program
10. Research Program Lead Agency

The FAA review of the recommendations generally agreed with the NRC report and included actions to address the recommendations (FAA, 2002). Interestingly the NRC conducted a similar study in 1986 which resulted in some actions, notably the ban on smoking on United States domestic flights, being implemented but further research and monitoring was required. The FAA review of the NRC document stated “the report should be seen as evidence that passengers and crew members on commercial aircraft have a continuing concern about a variety of health and comfort problems that they ascribe to poor air quality in airliner cabins”. The key recommendations are explored in more detail later in this section.

6.5.1.2 United Kingdom studies on cabin impact on passenger health

The United Kingdom Government commissioned a number of studies in the period from 2000 to 2005 into the effects of the aircraft cabin on passenger health. These studies were commissioned by four government departments; The Department of Transport and Regions, the Department of Health, the Health & Safety Executive and the Civil Aviation Authority of the United Kingdom. The second study which focussed on the possible health effects of the aircraft cabin found that further research was needed on many items and categorised them in priority order (Building Research Establishment Limited, 2001):

High Priority

Deep Vein Thrombosis – Improved case\control studies and interaction of risk with hypoxia and exercise.

Cabin Air Quality – Investigate key parameters: blood oxygen saturation of crew and passengers, pressures and rates of change, temperature, air movement, humidity, ventilation rate, pollutants.

Jet Lag – Effect on DVT, Cabin Air Quality and infection risk.

Medium Priority

Deep Vein Thrombosis – Effects of decreased cabin pressure, low partial pressure of oxygen and stress.

Cabin Air Quality – Interactions of the parameters related to Cabin Air Quality listed above. Intervention trials on impacts of altering parameters that affect health outcomes. Measurement of exposure from insecticides and organophosphates.

Transmission of infection – Incidence of TB infectious agents in the air, furnishings and filters on flights from TB endemic countries.

Cosmic Radiation – Exposure monitoring of cabin and flight crews. Development of biological markers for cancer risk.

Low Priority

Deep Vein Thrombosis – Clarify estimates of the incidence of recent travel in DVT patients.

Cabin Air Quality – A survey of filter condition and maintenance.

Transmission of infection – Effect on the movement of pathogens of adjustable air supply nozzles.

Cosmic Radiation – Epidemiological study on the magnitude of risk, including discrimination of skin cancers from Cosmic Radiation and Ultra Violet exposure.

Jet Lag – Study of short and long term health and safety implications of jet lag, and the economic implications.

6.5.1.3 Passenger sleep factors

Sleep is an important factor to reduce fatigue for passengers, flight crew and cabin crew. Five cabin environment factors have been identified as impacting on passenger sleep (Signal et al, 2004):

- Altitude: Sleep efficiency reduces at altitude.
- Temperature: Too hot or too cold.
- Noise: Background noise.
- Lighting: Impacts on sleep and circadian rhythm.
- Seating: Impact on sitting upright

6.5.2 Cabin pressure

An important aspect of the cabin is that modern commercial airliners generally cruise at altitudes between 22,000 and 44,000 feet (6,500 to 13,500 metres). Without cabin pressurisation the hypoxic and hypobaric conditions at these altitudes would be lethal to humans. Cabin air is pressurised to the equivalent of 5,000 to 8,000 feet (1500 to 2500 metres) (Mortazavi et al, 2003). The FAA requires an internal cabin environment of no higher than 8000ft (2440m) under normal operating conditions (Signal et al, 2004). At this cabin altitude the oxygen level in the arterial blood (PaO_2) drops to around 69 mm Hg from a sea level value of 103 mm Hg, which is a drop in average blood saturation to 90% from the sea level saturation of 97% (DeHart, 2003). It has been argued that maintaining a minimum cabin pressure at an equivalent of 6,000ft would assist the well being and alertness of passengers and crew. This would also lower the risk of low partial pressure to those with compromised respiration (Hocking, 2002). The partial pressure of oxygen is 24% lower above 12,000 metres and can cause a range of health impacts (Lindgren, 2003) including:

- Reduced lung pressure which may affect subjects with impaired lung function.

- Low oxygen which may influence colour vision.
- Impact on the middle-ear when people have a cold or allergy.
- Expansion of intestinal gases causing stomach pain especially in persons with gastro-intestinal infections.

Shown as a graph in Figure 9 the reduction in partial pressure of oxygen diminishes exponentially.

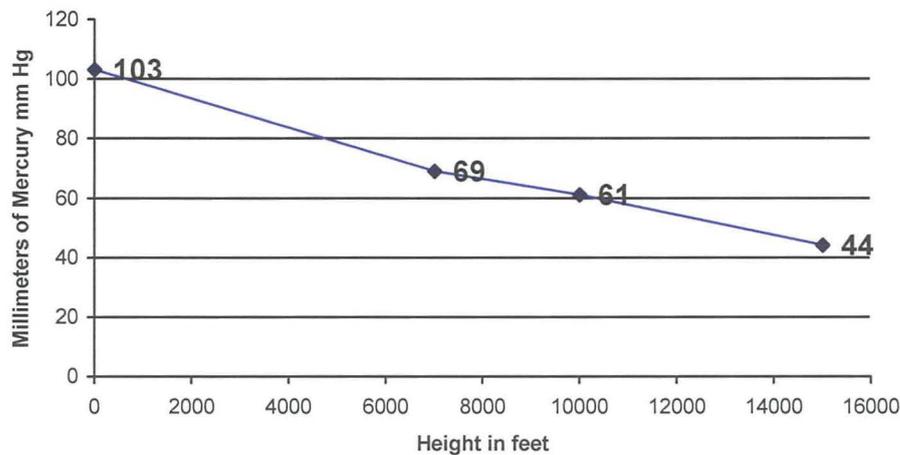


Figure 9 *Changes in Partial Pressure of Oxygen as altitude increases*

6.5.3 Air quality

Air quality is the foremost environmental factor for persons on board an aircraft, the quantity and quality of air affects the basic physiological needs of humans. The survey to cabin crew conducted for this thesis identified air quality as the most important area to address for passengers. The quality of air can be measured in various ways including airflow, filtration, pressure, ventilation, humidity and gas components.

6.5.3.1 Airliner air supply

External air is supplied from the aircraft engine where it becomes sterile from passing through the heat zones of the engine (400°C). The air then passes through an ozone converter, converting ozone to oxygen by catalyzing action, and enters the air conditioning pack. For most modern aircraft the air-conditioning pack provides

10 ft³/min⁷ of 100% external air or about 25-30 air changes per hour (Lindgren, 2003) with 50% outside air and 50% filtered recirculated air. Some aircraft have the option of 100% outside air supplied to the cabin or a mixture of outside air and recirculated air. In 1970 the average passenger aircraft provided 15 ft³/min per person of outside air with no recirculated air used, presently some modern commercial airliners provide as little as 5 ft³/min per person of outside air, this reduction is due to the move to cut fuel usage and reduce airline costs (Hocking, 2000). Air travel requires a diverse range of people to sit in very close proximity for long periods within a constrained air space. It has been estimated that a fully laden aircraft has 35-70 cubic feet of available air available per passenger. Therefore the quality the air in that space and the replacement of stale air with fresh air is important for health. The American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc (ASHRAE) healthy building requirements are for 15-20 ft³/min per person of outside air (Hocking, 2000). In 1974 the energy crisis resulted in a lowering of required building air supply levels to save energy costs. The result was the “sick building” phenomena where the reduced air quality caused health impacts of eye, nose and throat irritation, headaches, and a general feeling of unwellness.

People in an aircraft cannot open a window, walk outside or increase their air supply unlike people in a building; therefore the air supply in aircraft needs to be at optimum levels to assist passenger comfort and health.

6.5.3.2 Cost of supplying outside air to an airliner

The cost of providing 100% outside air is claimed by airlines to be very expensive. Published estimates of these costs are 15 cents per passenger hour, \$US 60,000 per average aircraft per year or, 1-2% of operating fuel costs (cited in Hocking, 2000). The cost per passenger from the same estimates is \$US1.20 per passenger for a 10 hour trip. Increased outside air will contribute to a better cabin air quality, reduce carbon dioxide levels, and help ensure a lessening of the effects of jet lag. In 1990 the two major aircraft manufacturers reported on the mix of fresh and recycled air as being 20 cfm per passenger split 50/50 for Boeing and 60/40 for Airbus (The United Kingdom Parliament, 2000). Some reports have put the percentage of recycled air as high as 80% of the cabin air quantity.

⁷ Cubic feet per minute abbreviated to ft³/min or cfm.

6.5.3.3 FAA cabin air regulations

The FAA requires 10 cfm of fresh air per cabin occupant and the JAA has no specific passenger cabin ventilation requirement (The United Kingdom Parliament, 2000). From analysis and review it is apparent most aviation regulators have little or no regulation on cabin air quality.

The National Research Council (NRC) study (FAA, 2002) recommended that the FAA continuously review, monitor and update FARs. In particular the NRC recommended the use of quantitative evidence when establishing regulations on air quality and operational standards for aircraft cabins. The view detailed in the NRC report is that present FAA standards based on carbon monoxide (CO), carbon dioxide (CO²), Ozone (O³), ventilation and cabin pressure should evolve into a comprehensive environmental health standard. These increased environmental issues include increased ventilation, wider focus on other air contaminants (other than CO, CO² and O³), needed review of the appropriate cabin pressure attitude, humidity levels and temperature ranges.

There are three FARs covering the cabin environment:

FAR 25.831 – Ventilation

FAR 25.832 – Cabin Ozone Concentration

FAR 25.841 – Pressurised Cabins

The FAR 25.831 requires ventilation airflow of 0.55 pounds per minute of fresh air per occupant which provides more oxygen than is necessary to carry out normal activities. In 1999 the FAA concluded an internal review of the FAA event database Accidents and Incident Data Systems (AIDS) of events between January 1978 and December 1999 pertaining to air quality. Of 240 identified events 60 were “airplane ventilation toxic contaminant events”. Of these 60 there were 24 that stated that crewmembers indicated their performance was impacted. In 2000 the FAA expanded their review to include smoke in the cockpit or cabin which resulted in 416 events which revealed that the number of events per flight was “statistically low” 2.2 events every 1,000,000 aircraft hours. The FAA has noted (FAA, 2002) that it is concerned that the reported number of air quality events in the AIDS database differed greatly from that reported by industry organisations.

6.5.3.4 Cabin air quality studies

Various studies on airliner cabin air quality contain differing results:

A Harvard School of Public Health study on the Boeing 777 found that airliners had the lowest CO₂ concentrations of all vehicle types but there were high concentrations of CO₂ and high temperatures during boarding which can last 30-60 minutes (Splengler et al, 1997). In general aircraft indicated a good quality of supply air but also had the lowest humidity level during the cruise period resulting from low water content in the air supply.

The ASHRAE performed data measurement on the Boeing 777-200 (ASHRAE, 1999). Carbon dioxide levels averaged 1,500 ppm which is 50% higher than levels recommended in ASHRAE Standard 62-1989 for public buildings. The report stated that although this level was high it would be below the levels in a normal residence and it would appear that a possible threshold for aircraft would be higher than the 1,500 ppm measured. The ASHRAE Standard 62-1989 for public buildings is set to satisfy the body odour perception of 80% of unadapted persons (visitors) in an occupied space. Results of the study indicated oxygen levels constant at 21% and this is not affected by the recirculation system used on modern airliners. What is apparent is that the partial pressure of oxygen is lowered from 160mm Hg at sea level to 124mm Hg at 7,000 feet. This reduction has the potential to affect people with related health problems who should consult their doctor before flying; more data needs to be collected to analyse potential negative relationships. The relative humidity of the economy section of the aircraft was averaged at 14% with the lowest at 6.4%.

The American National Institute for Occupational Safety and Health (NIOSH, 1993) studied McDonnell Douglas MD-80s, Boeing 727s and Boeing 737s aircraft cabin environments. This study did not reveal a health hazard with all measured data within national limits. It was noted that the ASHRAE comfort criteria for temperature, relative humidity, and carbon dioxide concentrations may not be met during gate and ground time.

Measurements were:

- CO₂: 550-1191 ppm
- Cabin air pressure: 654-656 millimetres of mercury
- Oxygen: 20.75-20.84%
- Ozone: 0.005-0.017 ppm
- Temperature: 23- 24°C

- Relative Humidity: 20-21%

The results of a recent study directly related to cabin crew (Lindgren, 2003) and the cabin environment on intercontinental flights provided some interesting results. The research was performed on 26 intercontinental flights between 1995 and 1998 on Scandinavian Airline Systems Boeing 767s operating between Scandinavia and Asia, or Scandinavia and North America. Nineteen of the flights were operated when smoking was permitted on board and seven flights were non-smoking.

The findings were:

- Average temperature: 22.2°C (Range 17.4-26.8°C)
- Relative Air Humidity: Low (Range 3-8%)
- Mean CO² concentration: 709 ppm
- Average airflow: Calculated to be 30ft³/min

Of note from this research was that the rear of the cabin the readings differed with a lower temperature at 21.9°C but higher CO² at 734 ppm and relative humidity at 7.6%.

A United Kingdom study (Building Research Establishment, 2004) found the following levels:

Air temperature: Below 26°C

Relative Air Humidity: 12.7% BAe 146 100% air mode

20.0% Boeing 737 in recirculation mode

Mean CO² concentration: 700-2000 ppm

Airspeed: typically 20 cubic metres per second at head height

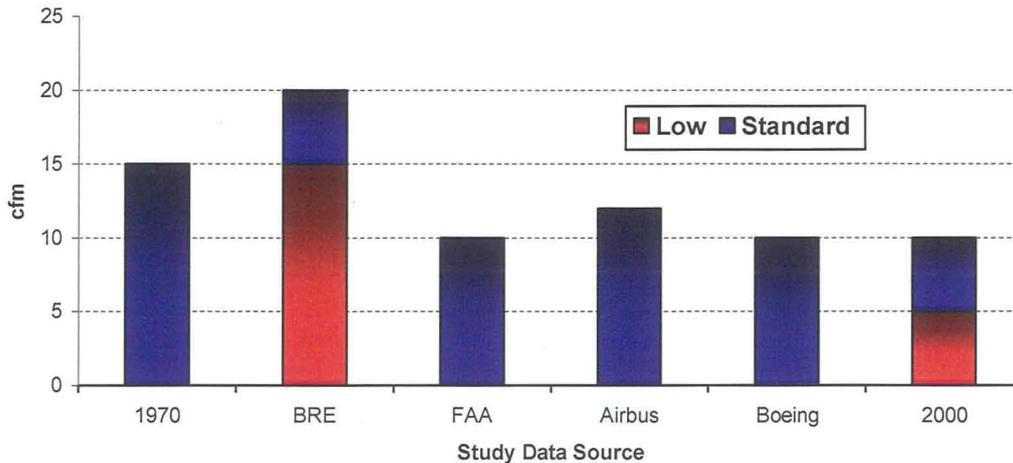


Figure 10 Comparison of the quantity of aircraft cabin fresh air supply from various studies

6.5.3.5 Air filtration

The NRC report recommends the FAA should investigate and publicise the need for the installation of air-cleaning equipment for removing particles and vapours from the air supplied in the aircraft cabin. None of the three FARs pertaining to cabin air (FARs 25.831, 25.832 & 25.841) require an aircraft manufacturer to have a particle filtration or gas absorption system in the aircraft environmental control system. It is the aircraft purchasers who request air filtration systems.

The two types commonly installed are:

- High Efficiency Particulate Air (HETA) Filters
- Particulate Filters

The FAA Report (2002) rates the efficiency of both systems with the HETA rated at 99.7% removal efficiency for 0.3 μm particles and the particulate filters at 97-99.5% removal efficiency for 0.3 μm particles. It is worth noting that although there are levels for air contaminants there is no requirement for warning or detection systems. Aircraft operators have procedures in the event of smoke, unusual odour, or an unknown containment in the cockpit but there is no requirement for a detection system to trace the exact location or origin of the containments. Therefore there is no mandated system to provide a real time alert of, for example, carbon dioxide presence. Donning of oxygen masks is a mitigation method but damage to the respiratory system may have been done

by the time the masks are used. It is critical for ULR flights operating under extended diversion procedures that they are equipped with early alerting systems for cabin air contamination.

6.5.3.6 Humidity levels

In the survey for this thesis cabin crew rated cabin humidity highly as an area to be addressed for both cabin crew and passengers for ULR flights. Low humidity is an area of concern – humidifiers could be installed into the aircraft, but aircraft manufacturers see problems with condensation, corrosion and fatigue on the airplane structure (IEH, 2001). One study of low humidity (Wyon, 2002) identified health effects on the skin and eyes as reduced tear film stability, increased blink frequency and increased skin dryness.

Cabin air is dry because air is low in water content at higher altitude and also engineering restraints precluding aircraft humidifying system (Rayman, 1997). The optimum range of comfort for relative humidity is 40 to 70%; the aircraft cabin is normally below 25% (U.S. House of Representatives, 2003). A range of cabin humidity levels have been reported (Signal et al, 2004) ranging from 2 to 23% but many show a range from 2 to 15%.

Complaints of dry air have been found to increase with longer flight durations. Cabin conditions can also vary in flight and in some ways be airline specific as was identified in a study that compared London-Johannesburg and London-Narita return flights (Nagada and Koontz, 2003).

In a survey of 500 British Airways flight crew one third listed low humidity as a factor that often or always led to sleep disturbance (Pascoe et al, 1994). Other studies also show that low humidity has effects on passengers and crew especially affecting in-flight sleep (Signal et al, 2004). There are limited studies on aircraft humidity levels resulting in the use of studies on humidity in office buildings to review impacts. Results of building intervention studies suggest that an increase of 10% in relative humidity can alleviate a variety of symptoms (Nagda and Hodgson, 2001). It is determined that in the aircraft cabin environment that only a 5-10% increase can be achieved thus lifting the levels from 14-19% to 22-24%. The U.S. House Subcommittee on Aviation report (2003) notes that setting the level to 35% would be equal to a comfortable home environment and benefit passengers. This poses practical problems noted by aircraft

manufacturers in that bacterium and fungi may grow more readily in a wetter environment.

Although low humidity has impacts on the human body including drying out eyes, nose, mouth and skin these have not been linked to long term health problems (The United Kingdom Parliament, 2000). This dehydration can be remedied by increasing water intake to balance the dehydration effects. Temperature is also a related factor with the cabin being set at a range of 22-24°C with individual passengers unable to adjust the airflow to regulate temperature at their seats; the flight crew can adjust cabin temperature from the flight deck. Temperature is also used by some airlines to regulate passenger behaviour. This regulating is evident with a rise in cabin air temperature after meal service to encourage passenger sleep.

The effect from the pressurised cabin and air circulation systems cause a drying out of the human body through the loss of water. This loss of water and essential minerals by evaporation results in visual effects of dehydration and dry skin. Rehydration can be assisted by the consumption of water but the replacement of essential minerals can take longer. This dehydration especially nasal irritation can increase susceptibility to colds and flu like symptoms. These effects are masked somewhat by time zone changes and the phenomenon called “jet lag”. These conditions will increase on ULR flights as the exposure time to low humidity is increased.

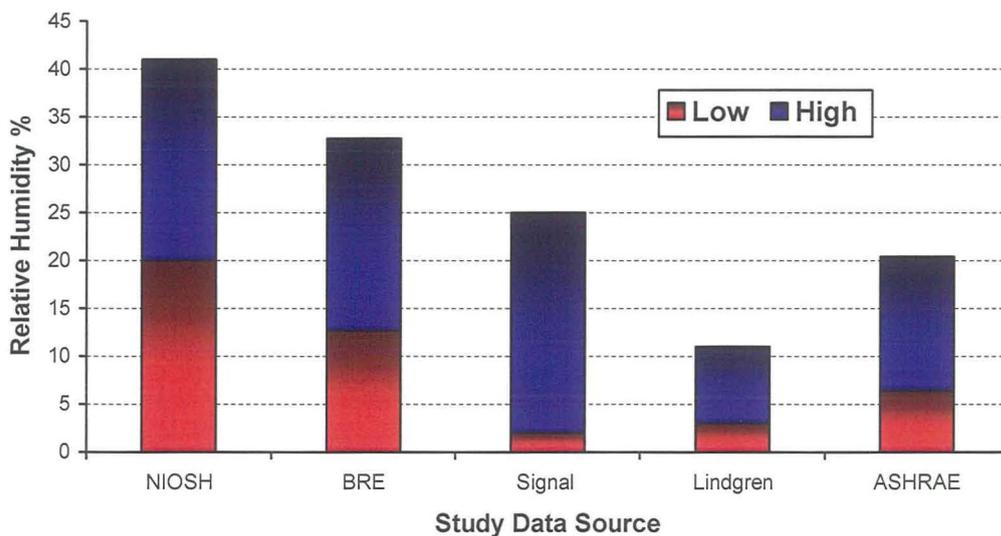


Figure 11 Comparison of findings on aircraft cabin Relative Humidity levels

What are the effects of cabin altitude pressure on susceptible cabin occupants, including infants, pregnant women, persons over 60 years of age, and people with cardiovascular disease?

Is there a linkage between humidity levels and person's health over extended periods in an aircraft cabin environment?

6.5.4 Ozone effects

FAR 25.832 was added by the FAA in January 1980 following a petition for rulemaking from passenger and cabin crew over the possible health effects of ozone in aircraft cabins. The FAR 25.832 requirement states that average ozone concentrations must not exceed 0.1 ppm above 27,000 ft and peak concentrations not to exceed 0.25 ppm above 32,000 ft. High quantities of ozone gas can be irritating to the respiratory tract and eyes. The level of discomfort is proportional to the level of activity of the person exposed and therefore cabin crew are the most likely to be affected (FAA, 2002). The FAR requirements are expected to assist in protecting passengers and crew members from hazardous exposure.

ASHRAE noted in their report on cabin environments that although ozone concentrations in their study on aircraft were not harmful that elevated ozone plumes can occur at high altitude Polar routes (ASHRAE, 1999). These elevated levels could place passengers and cabin crew who travel these routes at risk, more research on ozone exposure on Polar routes is needed.

The NRC Report recommendation is that the FAA should take measures to ensure compliance with FAR 25.832 requirements and should include the installation of ozone converters to ensure prescribed levels are not exceeded. The FAA report (FAA, 2002) noted that the installation of ozone converters on passenger transport aircraft may be the best method of governing ozone level. The FAA report also notes that the FAR 25.832 and Advisory Circular AC 120-38 requirements regarding ozone concentration were developed in the 1960s and 1970s. Since then the ozone content and distribution has changed significantly and recent research has identified changes in the atmosphere.

6.5.4.1 Impacts on flights

The advent of new longer range aircraft means that the flight may be conducted at higher levels or over extended periods of time in areas of the atmosphere where the

ozone concentrations are higher. Therefore there must be an increased risk of repeated crew exposure over a longer period with probable higher levels of ozone. This is particularly so on Polar routes and any future routing over the Antarctic region. The findings of the ASHRAE Report (1999) identified that of 287 five-minute mean periods tested when the aircraft was in flight, the 0.1 ppm figure was met or exceeded on nine occasions, the ozone sensor accuracy was plus or minus 0.1 ppm. The highest was 0.122 ppm on a flight from Washington to London. Therefore accurate analysis needs to be completed.

Further research and data is required to look at:

- What is the level and time of ozone exposure over ultra-long range flight routes?
- Is there an increased level of ozone exposure for aircraft operating over the Arctic and Antarctic regions?

6.5.5 Airborne disease

There are few studies specific to airborne transmission of diseases in an aircraft cabin and these mostly relate to Tuberculosis (TB).

6.5.5.1 SARS

In 2003 global aviation was rocked by the rapid spread of a communicable disease named SARS – severe acute respiratory syndrome. The aviation industry had been sure that the aircraft cabin was not an environment that disease would spread within. This was due to the arid cabin air that dries out droplets before it could be inhaled.

Additionally 80 percent of modern passenger aircraft (Sainarayan, 2005) are fitted with HEPA filters that should capture the virus droplets and the long cigar shape of the cabin means air circulation works transversally reducing the spread of disease through the cabin. The SARS situation questioned this confidence. The persons seated close to the infected person are at risk and also if the person moves through the cabin they may spread the disease.

ULR flights increase the incubation and exposure time of a disease thus increasing the possibility of increased disease spread on an aircraft. During the SARS outbreak the World Health Organisation (WHO) put in place screening methods and awareness programme coupled with airline onboard action programmes that virtually eliminated SARS in a short period of time. Following the SARS episode a combined contingency plan was developed involving ICAO, the WHO, IATA, and ACI.

This is now being reviewed and procedures updated amidst fears of a pandemic called “bird flu”.

6.5.5.2 ICAO Action

The 35th Session of the ICAO Assembly has declared that the health of passengers and crew members on international flights is an integral element of safe air travel (Sainarayan, 2005). The Assembly resolved to review standards relating to health issues, create new standards as appropriate, and support further research on the health consequences of air transport including communicable diseases. Article 14 of the Convention on International Civil Aviation obliges signatory states to take effective measures to prevent disease transmission and to consult closely with appropriate health agencies.

6.5.5.3 Risk

From the ASHRAE study and other research reviewed there appears to be little or no data supporting an increased risk of airborne disease producing bacteria and fungi in commercial air travel. These studies also support the fact that the recycled air system will not increase disease transfer. One report (ASHRAE, 1999) states that the likely spread of disease is from close proximity to other passengers rather than air circulation. Further research and data is required to look at:

- Verification studies that infectious disease agents are transmitted primarily between people in close proximity?
- Does recirculation of cabin air increase cabin occupant’s risk of exposure?

6.5.6 Seating

The survey to organisations rated seating as the most important area to address for ULR flights. The survey to cabin crew rated seating as the second most important area to address after cabin air quality.

Sixteen hours plus in an aircraft is a long period of time for the human body to spend mostly in a seated position without physical activity. Seat comfort and legroom are rated by passengers as two of the least satisfactory characteristics of air travel (Nagada and Koontz, 2003). There are several areas that passengers are not presently adequately catered for in relation to seating including:

Impaired mobility

Wheelchair users

The elderly

Disabled toilets

Tall people – Short people

Large people – Small people

Safety belts and seats for children and infants (Not helped by differing international standards)

6.5.6.1 Seat pitch

Seat pitch is the distance between the back of one seat to the same point on the seat in front. Airlines set their own seating arrangements and seat pitch but they must meet safety standards for seat spacing. These safety standards are mainly for emergency evacuation requirements rather than for passenger comfort. The United Kingdom Civil Aviation Authority requires a minimum 28 inch⁸ pitch. With air travel now a form of mass transportation the need has increased for airlines to maximise revenue per seat. The seat pitch is increasingly being reduced to increase available passenger seats per flight leading to more productivity per flight.

A Consumer's Association survey from 2000 (The United Kingdom Parliament, 2000) found seat pitch in short haul economy ranged from 28 to 32 inches, and seat width from 15.5 to 20 inches. In long haul economy class, seat pitch ranged from 28 to 34 inches, and seat width from 16.2 to 18 inches.

For ULR flights seat pitch is an important passenger health and comfort factor due to extended sitting requirements. Not only will the passengers be constrained for a longer period of time they also need to undertake several tasks in a seated position including sleep and eating meals. Singapore Airlines has reduced seating capacity and improved seating layout on its ULR flights.

In relation to ULR flights the effects of circadian rhythm and multiple crossing of time zones must be managed effectively. Sleep is an important component of this management, with passenger ability to have effective restorative sleep at a time that meets individual passenger needs. This involves having seats that will allow the passenger to be able to go to sleep, be in a suitable configuration for sleep, and be set for sleep when the passenger wants to sleep without unduly affecting other passengers.

⁸ Seat dimension information from airlines is normally in imperial measures not metric. For consistency in this Thesis all seating information is in imperial measures.

From studies in the late 1980s it appears that the greater the back angle with the vertical the better the sleep quality and that adequate sleep may be obtained in seats as long as the seat angle with the vertical approaches 40° (Nicholson, 1987). A more recent study (Aeschbach et al cited in Signal et al, 2004) found that the sitting position impaired objective and subjective sleep quality. Most modern passenger aircraft seats allow the back to recline thus setting a better sleep angle, but is it sufficient?

Will ULR flights have seats to not only recline but allow lumbar and side support for sleep?

Once again the extension from 14 hours to 20 hours is a large increase with sleep being an important added component.

Air New Zealand is an airline which operates some of the longest scheduled routes in the world. The airline presently operates Boeing 747 aircraft for its long haul routes to Europe. As part of a fleet upgrade all the airline's Boeing 747s have been remodelled including new upgraded seats.

The Air New Zealand 747s upgrade has resulted in:

A Business Premier class with seats that are 22 inches wide and that lay flat for sleeping to 6½ feet or 2 metres long.

The new Pacific Premier Economy class has seats that have a pitch of 39-40 inches – 6 inches more than industry standard.

The Pacific Economy class have a seat pitch of 34 inches.

6.5.6.2 Seats for all passengers?

The range of passenger heights and weights is not presently catered for on long haul flights. Seating for people less than 5½ feet (1.65 metres) and over 6 feet 3 inches (1.95 metres) does not seem to be adequately catered for.

Shorter people put up with seats that don't allow them to put their feet flat on the floor.

Taller people over 6 feet face cramped "knees up" conditions.

An internet web site dedicated to extra tall people details some interesting data although the accuracy cannot be confirmed but it is interesting to review.

(http://extratall.co.uk/news_cramped_seats_can_kill.htm).

The British Consumers Association recommends any person over 6 feet tall needs at least 31 inches of seat pitch.

Although seat pitch and width is constantly being addressed by airlines the focus is on seat pitch rather than additional ergonomic requirements. Proper ergonomic seats with

lumbar support and height adjustment for ULR flights need to be considered. Why can't airline seats be raised or lowered to improve leg length and comfort?

6.5.6.3 Seat pitch survey

Two surveys obtained from the internet are detailed below; neither detailed the date of survey nor provided details on sources of data. Although they cannot be validated in terms of method or procedure they do provide an interesting comparison.

Table 11 is by David Hiles a 6 foot 4 inch economist with the US Bureau of Labour Statistics.

Table 12 is a survey performed by the British news paper the Evening Standard.

Table 11

David Hiles Survey of Airline Seat Pitch

Airline	Aircraft Type	Seat Pitch (Inches)
Aeroflot	Airbus 310	31
Air France	Boeing 747	30
Austrian	Airbus 310	31
British Airways	Boeing 767	32
British Airways	Boeing 777	31
Iceland Air	Boeing 757	33
Lufthansa	Boeing 747	32
Northwest/KLM	DC 10	31
Swissair	Airbus 310	31
United	Boeing 777	31
United	Boeing 767	32

Table 12*Evening Standard Airline Seat Survey*

Airline	Seat Width (Inches)	Seat Pitch (Inches)
Air France	16.2-18	30-32
Air New Zealand	17.5	34
Air Tours International	16.2	28
Alitalia	17.8	33
British Airways	17.5	31
Cathay Pacific	17.15	32-33
Lufthansa	17.7	31.9
Malaysian Airlines	18.5	34
Qantas	17.21	31-32
Singapore Airlines	17.7	32
Sri Lankan Airline	17	32
Thai Air International	17	34
United Airlines	18	31
Virgin Atlantic	17.7	32

6.5.6.4 Singapore Airlines ULR aircraft seating

The Singapore Airlines A340-500 flight from Singapore to New York is configured with 181 seats, comprising 64 Business Class (Raffles Class) and 117 Economy (Executive Economy) class. This is a generous seating layout as the Airbus A340 can accommodate 300 or more passengers.

The Raffles class has lay flat beds, called the Spacebed, for added passenger comfort.

The Raffles Class cabin has 64 seats arranged in a 2-2-2 configuration with a pitch of 64 inches, bed width of 26 inches and bed length of 78 inches.

The Executive Economy Class offers 117 seats in a 2-3-2 configuration with seat width of 20 inches, pitch of 37 inches, and a back-seat recline of eight inches. Executive Economy Class does not have lay flat beds.

Will other airlines be so generous in seating layout especially those with a less healthy financial position than Singapore Airlines?

If low cost operators begin ULR flights they will be looking to maximise revenues and passengers, therefore an A340 would be configured with 300 or more passenger seats.

6.5.7 Section summary

- Cabin crew survey rated air quality and humidity as important areas to address. The organisation survey rated air quality as the least important area to address for cabin crew and passengers.
- The aircraft cabin environment has been shown to have an impact on passenger and cabin crew health.
- A wide range of studies have been performed with common factors of cabin air quality, Deep Vein Thrombosis, and infection risk.
- Cabin pressure has a range of impacts on passengers as the oxygen level in blood lowers.
- Air flow and air quality is related to the lessening of external air and increasing use of recirculated air.
- Low humidity increases skin dryness and adds to jet lag.
- The risk of airborne disease transmission was thought to be low in airliners until SARS and “bird flu”.
- ULR flights will extend the incubation and exposure levels of airborne diseases.
- Better and more effective air filtration systems for airliners should be looked at.
- Further research should be done on recycled air risk level for disease transmission.
- Passenger seating was identified in both surveys as an important passenger consideration to be addressed.
- Better seating required for ULR flights that cater to the range of individual heights and sizes.

6.6 Passengers – Customers or cargo?

6.6.1 General

Passengers were not surveyed as part of this study but represent a large group of people affected by ULR flight. Cabin crew have the most contact with and get the continual feedback from passengers, their rankings on passenger issues clearly identified issues

related to air quality and cabin humidity as very important. This contrasts to that of the organisations surveyed. Cabin crew also identified areas related to meals, toilets and exercise areas, in general these are areas that all of us as passengers would agree with. Airlines in general have focussed on in-flight entertainment and seating rather than toilets and exercise areas that would be more expensive to provide. So who protects the passenger and what issues are important?

6.6.2 Passenger health

The World Health Organisation has periodically published reports on the situation in relation to international travel and health. The 2005 report (World Health Organisation, 2005) notes that air travel, particularly over long distances, exposes passengers to a number of factors that may have an effect on their health and well being. These include hypoxia, ozone, cabin humidity, motion sickness and in particular prolonged immobility. Travel by air is also noted as not a natural activity for humans and that many people experience some degree of psychological difficulty when flying. In the pre-1980 era airlines provided passengers with high levels of comfort and spacious aircraft seating. Then the privatisation and the unregulated commercial environment put pressure on airlines to lower costs and increase profits, the result was more seating for more passengers with less legroom and closer seat spacing. Most aviation regulatory authorities worldwide did not address the impact on passenger health of cabin layout and seating. In recent times health and safety has become more important with increased legislation to protect people. In aviation regulatory authorities are only now reviewing the safety impacts on passengers. Unfortunately little solid research has been performed to back up the new legislation.

Many promises are made by airlines and aircraft manufacturers when new aircraft are being developed and introduced. Virgin Airlines had plans when introducing their new Airbus A340-600 of having double beds in private rooms on board with showers, along with exercise and massage areas. These ideas were scrubbed as the space to be used was in the forward and aft cargo areas which were needed for high revenue generating cargo. There is however a dedicated on-board massage area at the front of the cabin (Kingsley-Jones and Sobie, 2005).

6.6.2.1 ICAO Regulation

The core ICAO instrument for regulating international civil aviation is the Chicago Convention with the associated standards and recommended practices (SARPs) for ICAO Member States to adhere to. The ICAO SARPs contain little in regard to the health and comfort of air passengers. However ICAO has now taken up the topic of passenger health focussing on “from arrival at the airport to leaving at the end of journey” and is reviewing SARPS with this new focus. In 2003 an ICAO working group was established to look at passenger health issues. ICAO Assembly Resolution A35-12, *Protection of the health of passengers and crews*, was adopted in October 2004 (Curdt-Christiansen, 2005). It focuses mainly on communicable diseases and the spread of infection in aircraft.

The resolution states:

1. The protection of the health of passengers and crews on international flights is an integral element of safe air travel and that conditions should be in place to ensure the preservation in a timely and cost-effective manner.
2. To review existing and develop new SARPs related to health.
3. Develop SARPs to address contingency plans to prevent the spread of communicable diseases by air transport.
4. Urge States to implement all existing SARPs related to health.
5. Support research into the effects of flying on passengers and crew health.

In January 2005 ICAO issued official letters to contracting States urging them to implement existing SARPs related to passenger and crew health, and recommending States adopt a contingency phased response plan.

This action is in response to increasing international action on health and safety matters for both airline passengers and airline employees. However the nature of the structure and process requirements of ICAO means that action can be slow and thus it is up to individual aviation regulators to take action.

6.6.2.2 European action

The European Civil Aviation Conference (ECAC) is a European political organisation closely linked to ICAO which facilitates development of aviation issues. The ECAC identified in 2002 the need to address provisions for passenger health and established a

working group to review the pertinent issues (Evans, 2005). The result is a manual on air passenger health issues covering four areas:

1. Medical incident reporting/recording
2. Provision of services to the passenger
3. Legal issues
4. Information for the Passenger

The new European Aviation Safety Authority is further developing these issues to look at required regulatory action.

6.6.2.3 Passenger stress factors

Passengers are affected by a range of stresses as they travel on aircraft because they are placed in an artificially controlled, confined environment. These stressors need to be addressed by regulators, airlines, and airport operators. A range of factors have been identified (Rayman, 1997) including:

Airport Tumult: Crowded, congested terminals. Long walks to gates, multiple passenger screening points, and queuing (especially for check-in).

Barometric Pressure and Oxygen: Changes in barometric pressure occur during changes in the flight phase i.e. from departure to cruise to landing. These changes may affect people susceptible to air pressure changes – these include respiratory infections, allergies and sinus problems.

Immobility: The modern aircraft is a mass transportation mode with passengers having to endure hours in cramped and restrictive seats. The limited space in the cabin, and new security concerns, reduces passenger's ability to move around. This prolonged immobility puts passengers with heart disease, chronic venous problems and those susceptible to circulation disorders at risk. Deep Venous Thrombosis (DVT) is one highly publicised result of this inactivity impacting on susceptible people.

Jet Lag: Circadian desynchronosis, or jet lag, results from crossing multiple time zones in a matter of hours. Includes short term physiological effects that pass after several days. It is more apparent on east bound flights as opposed to west bound flights.

Vibration, noise, humidity: Vibration and noise have been greatly reduced in modern aircraft due to technological advances. But vibration due to turbulence has a major impact on passengers and can cause discomfort to passengers. As described earlier in this thesis, cabin relative humidity levels are below the optimal comfort level of

40-70%. The low humidity is due to low water content in the air at altitude with economic and engineering reasons precluding the fitting of an aircraft cabin humidifying system.

Radiation: The issue of radiation increases as commercial flights fly higher and longer. Radiation is carcinogenic and can cause genetic defects during pregnancy and cancer at very high levels. Radiation levels are highest at the poles and lowest at the equator. Therefore Polar flights do bring risks of increased exposure. Cosmic radiation is approximately 100 times higher at typical cruise altitude than at ground level (IEH, 2001).

Medical Considerations: In flight illness, medical care in-flight and the increased need for medical oxygen as more elderly passengers are carried.

Air humidification is one area that the cabin environment can be improved by the use of a ceramic evaporation (Lindgren, 2003), without any increase of micro-organisms in the cabin air. An increase of relative air humidity by 3-10% could produce increased tear film stability, increased nasal patency in the nose, and reduced headache and ocular, nasal, and dermal dryness symptoms.

All these factors can be addressed in better ways than present. For ULR flights it is essential for both passenger comfort and flight safety that these factors are mitigated.

6.6.2.4 Polar routes

Airlines should inform pregnant passengers and frequent fliers of the radiation risk associated with the Polar route (Crampton, 2001). Passengers flying the North Pole route are exposed to high levels of cosmic and solar radiation. Frequent passengers taking five round trips a year could exceed the maximum levels for annual radiation doses.

6.6.3 Ageing population

The world population is aging as the “baby boomers” generation gets older and as medicine develops people are living longer and arguably healthier lives. As such the average age of passengers is increasing as the older population have more leisure time and disposable income. Older people are more susceptible to the cabin environment effects detailed in this study. Areas important to older passengers include seating, medical assistance, and in flight exercise.

ULR flights may appeal to the older passenger as these flights reduce connections, airport stress and allow quicker access to distant locations. Airline operators cannot address the issue of the aging passenger but they can address impacts on these passengers from the cabin environment and flight operation. To do this analysis must be made of these passenger types, their needs and wants on ULR flights. To treat these older passengers like the general, younger passenger population may be dangerous both to the operation of ULR flights in general and the specific airline. It seems the cruise liner industry has successfully analysed the needs of the richer, older population and accommodated these needs to increase passenger numbers.

Solutions include more medical training for cabin crew, more on board medical equipment and possibly a return to the requirement that one cabin crew member be a trained nurse. Why was it ever removed?

6.6.4 Circadian rhythm

6.6.4.1 Circadian disruption

Long distance air travel involves a disruption to the circadian rhythm as changing time zones impact on the biological clock. Circadian rhythm is a process that affects many human physiological functions that establishes a body clock. The disruption of the body clock, poor in-flight sleep and the cabin environment are cumulative effects that impact on the person when they arrive at their destination requiring a period of time to recover. Jet lag is the colloquial term for the impact of these time zone changes. Jet lag is a temporary dissociation between environmental (local time) and body (internal clock) which results in a person trying to sleep when their body is still awake or the reverse (Waterhouse et al, 1997). This state is further influenced by external cues such as light, heat, food intake and surrounding activity. The symptoms are fatigue, headaches, irritability, loss of concentration, indigestion, loss of appetite and bowel irregularities (Waterhouse et al, 1997).

Circadian rhythm impacts are only in an east or west travel direction. Flights north or south have shown no impacts as time zone changes do not occur (Edwards, 1990), however air travel north or south does leave the person fatigued and this may be due to the cabin environment. It has been stated that a person needs one day to recover for every time zone crossed (O'Connell, 1997).

6.6.4.2 Sleep requirements

Given the importance of sleep in ensuring the reduction of fatigue and the adaptation of circadian rhythm little aviation research has been performed on passenger insomnia or sleep impacts at altitude. Recent research in conjunction with Boeing (Signal et al, 2004) on flight crew sleep is essentially the start of ULR flight sleep research. This research must be expanded to cabin crew and passengers as ULR flights become more common. The ability for circadian impacts to be minimised depends on the stage of the circadian cycle that the person's body is at, then the person must adjust their sleep patterns in the next period to align with their arrival time. The circadian cycle is slightly longer than 24 hours for most people.

Information on ULR sleep and impacts must be given to passengers to assist them in developing their own individual sleep strategies. The ability for a person to stay in step with the day/night cycle is influenced by the environment especially the effect of light, eating time of substantive meals, and activities of others. Added to this is the pattern of activity and sleep which assist in a person adapting to the time zone on arrival.

6.6.4.3 Circadian influences

The number of time zones and type are also key factors with less time zone changes the better and eastward direction flight easier to adapt to than westward (Signal et al, 2004). This builds on an earlier study that found that it takes 13 days to fully adjust circadian rhythm after six times zone changes in a easterly direction, but only 10 days to adjust after six time zone changes in a westerly direction (Costa, 1999).

Resynchronisation following flight can take up to 10 days with a range of effects:

- Fatigue
- Reduced alertness\concentration
- Impairment of mental performance, inc memory
- Reduced motivation
- Irritability
- Nausea\digestive problems

Detailed studies on circadian readjustment show varying degrees of realignment of the circadian rhythm dependant more on the environment rather than the person. For example, research has showed that a time shift of 6 hours required 2 days to return performance to pre-flight levels (Aschoff, 1976). Additionally the findings also showed

that re-entrainment of the sleep\wake cycle took 2-3 days, the body temperature took 5 days, and the cortisol excretion took up to 8 days for some individuals.

These are short term effects but if the travel period is doubled will the impacts last longer and have long term impacts?

6.6.5 Physical and psychological

What will be the effects of long periods of confinement both in physical and psychological terms? The increased length of confinement produces a range of effects particularly in terms of group interaction.

6.6.5.1 Deep Vein Thrombosis

Much has been made of the incidence of Deep Vein Thrombosis or “economy class syndrome” in aviation. The condition is when a blood clot forms in the vein deep in the body, it occurs mostly in the leg veins. The causes are normally attributed to older age, obesity, and a history of venous disease. Air travel has been linked to DVT, especially with the reduction in seat pitch and the increasing flight lengths. Several researchers believe that air travel increases the risk of DVT through:

- Decreased air pressure and the release of nitric oxide into the aircraft cabin.
- Dehydration as a result of low humidity in the cabin coupled with the consumption of alcohol and caffeine.
- Prolonged sitting and pressure on the calves by the passenger seat which can lead to stagnant blood flow in the veins.

A recent study (Schwartz et al, 2003) compared a control group to a group of people who had travelled on a flight lasting at least eight hours. The findings revealed that of those who travelled on the flights 2.1% were diagnosed with isolated calf muscle venous thrombosis (ICMVT), a precursor to DVT, compared to 0.8% in the control group. Of the group who travelled 0.7% were diagnosed with DVT compared to 0.2% in the control group. Overall the travelling group had a 2.8 fold increased risk of having a thrombotic event (4.4 fold for DVT and 2.5 fold for ICMVT). Most people who developed DVT had other risk factors such as an elevated Body Mass Index or being in the older age group.

DVT is not limited to aviation and can in fact be linked back to the 1940s when medical conditions were linked to being seated for long periods of time in bomb shelters (BRE, 2001). DVT is also not limited to “economy class seating” it affects all passengers

including business and first class, although their seating is better arranged. There is no doubt that prolonged immobility and cramped seating are associated with DVT and these factors are both present in long distance flight. A range of research on DVT shows that sufferers tend to have deposition to DVT due to the health factors detailed above. A hospital study from the United Kingdom (DeHart, 2003) reviewed 1250 cases of DVT finding that 3.8% of the patients had made a journey of 100 miles or more within four weeks of diagnosis. Of the travellers 60% were by air and 36% by road, with nearly all the travellers having at least one medical risk factor for Thrombosis present.

The United Kingdom Parliament in 2000 following several reports on air travel and health made several recommendations (The United Kingdom Parliament, 2000) to address concerns. These recommendations included more research on specific issues and better information to passengers on health related areas. One such recommendation was that every ticket sale point should have a card asking intending passengers “Are you fit to fly?” and another that there should be a health briefing before take off to compliment the safety briefing.

6.6.6 In-flight entertainment

The increasing approach to long range operations in relation to passengers is to keep them entertained. This will also be the case for ULR flights. The survey to organisations reflected this with in-flight boredom rated second in importance as an area to be addressed but ahead of other cabin environmental areas. Airlines in the 1980s and 1990s had a single large screen in-flight movie system to cater for a section of passenger seats. This is now replaced or supplemented by individual entertainment systems for each seat offering on demand movies, games and a range of interactive activities. This is also being extended to email and internet access.

The cost of in flight entertainment is high both in cost of hardware purchase and installation as well as extra wiring and weight. The additional weight and complex wiring system comes at the cost of other aircraft systems, passenger related services, additional fuel burn, and increased maintenance requirements. Many low cost operators do not offer in flight entertainment due to the costs of providing these systems.

Passenger boredom is an issue being addressed with in flight entertainment systems.

What about passenger health?

Could not a compromise be a less complex system to meet passenger needs with the saved money being spent on passenger comfort levels?

Would not the weight and money invested be better spent on adjustable seats, better air quality, or increased cabin humidity levels?

6.6.7 Section summary

- Passengers are an integral component of ULR operations and issues that may impact them need to be identified and addressed.
- Long distance air travel is not a natural human activity and passenger health is growing in importance internationally.
- Airlines have reduced passenger comfort and space items to improve profitability.
- An aging population presents more problems in relation to medical problems and stress on ULR flights.
- Passengers should be more aware of specific impacts from Polar flight.
- Passenger stress is an invisible but real element of air travel.
- Identified stress factors need more research and be addressed better by regulators, airlines, and air operators.
- Circadian rhythms have a major impact on passengers and these impacts must be managed effectively.
- DVT has a high profile as a long flight health problem but there are other passenger health issues which need addressing for ULR flights.
- In flight entertainment is used to relieve passenger boredom but more needs to be spent on passenger health especially on ULR flights.
- Increased emphasis is needed on ULR flight briefing for passengers including DVT, exercise, sleep patterns and managing circadian rhythm.

6.7 Chapter Summary

This chapter has expanded on the findings of the surveys to organisations and cabin crew. It has reviewed and analysed specific issues to identify actions already taken along with areas to be addressed. From the review of ETOPS and LROPS it can be seen that these operations are increasing and the aircraft technology is assisting in pushing the operational boundaries. Diversion airports are integral components of these extended operations. The review performed shows that requirements for diversion airports especially their adequacy to handle large aircraft with hundreds of passengers has not matched that of the aircraft systems and better facilities at ULR alternate aerodromes is needed.

Cabin crew perform an important safety role and value safety aspects of their duties. The review does show that better regulation on licensing and training for cabin crew is needed. CRM training and integration with flight crew needs improving. In the main cabin crew research has been found wanting with a lack of specific research especially on the cabin environment and cabin crew health. Cabin crew are regularly exposed to poor air quality and low humidity in their workplace. Cabin crew health and safety needs more research and analysis to ensure fatigue and rest issues are addressed. The cabin environment for both cabin crew and passengers needs to be addressed and improved. Passengers are exposed this environment and are confined to seats in which physical activity is limited. Airlines who are to operate ULR flights need to provide passengers with better physical facilities and the ability to exercise or else the incidence of in-flight medical conditions such as DVT will increase.

Chapter 7 Findings and Recommendations

7.1 Findings

ULR flight brings a new dimension to air travel not only for airlines and flight crew but as importantly cabin crew and passengers. This thesis has provided a background to ULR flights in relation to operational aspects, the aircraft, flight routes and diversions. New ULR aircraft have an operational range of more than 9,000 nautical miles with a single flight being able to connect nearly any two points on the planet. These flight routes use new Polar routes and can be operated by two, three, or four engine airliners. Singapore Airlines presently operates 18 hour plus flights and in the near future several other airlines intend to start similar operations. Aviation regulators need to ensure these new ULR flights are conducted safely and they are presently reviewing operational procedures under ETOPS and new LROPS criteria. Beyond operational requirements it has been identified that aviation regulators need to address cabin crew and passenger health and safety. Internationally ULR flight preparation has focussed on the aircraft, routes and flight crew without appropriate consideration of the impacts on cabin crew and passengers.

Surveys were undertaken to organisations and cabin crew to get empirical data on the current situation in long haul and perceived impact areas with ULR flights.

The organisational survey was responded to by seven airlines with a mix of current and potential ULR operators. The survey identified operational factors as important to organisations in particular regulatory requirements and aircraft performance. In relation to cabin crew and ULR operations the organisations rated rest facilities and cabin crew duties as areas to be addressed. Conversely cabin air quality and cabin humidity were rated lowest. Additional areas involving cabin crew were crew training, fatigue, and crew resource management. Organisations rated seating and in-flight boredom as the major passenger areas to be addressed.

The cabin crew survey was responded to by 119 cabin crew ranging from new entrants to those with 36 years experience. They identified several areas related to health and safety not only of themselves but also of passengers. Most of these issues relate to the cabin environment, and the impact of long hours in an aircraft. Cabin crew rated cabin safety as the extremely important role of their job, twice as important as the in-flight service role. Cabin crew believed that airlines did not value their safety role. Although nearly all cabin crew respondents are provided with CRM training, 25% of respondent's emergency training did not involve flight crew. Fatigue, sleep, and dehydration were the top impacts identified from long haul flight with 97% of respondents believing these impacts will increase with ULR flight. A majority of cabin crew believe the Civil Aviation Authority should regulate flight and duty times, with over 60% wanting the aviation regulator to issue cabin crew licences. In-flight rest and the rest facilities currently provided for cabin crew are viewed by the majority as inadequate, especially cabin crew with ten years or less experience. There was a significant statistical relationship between the adequacy of on-board rest facilities and cabin crew rest adequacy. Cabin crew respondents believe rest and fatigue need to be addressed for ULR flights, including the type and location of rest facilities. One area noted by cabin crew was in relation to in-flight meals and their diet, an area not previously identified in studies. No statistically significant difference was found between the results of responses from cabin crew with 10 years experience or less experience and those with more than 10 years experience. This was also the case when responses were compared between cabin crew who performed less than five flights per month and those who performed five or more flights.

From the survey results several areas were reviewed and discussed in more depth identifying more details. The number of ETOPS flights and routes flown has increased exponentially in the last 10 years with operational limits increased steadily from 90 to

120 to 180 and now 207 minutes. Although diversion airports must meet minimum criteria some ETOPS flights rely on aerodromes with limited facilities. Polar and Pacific region diversion aerodromes have adequate runways but most have no passenger accommodation, basic medical facilities and limited technical support. The plane may be able to land but the passengers may not be able to be accommodated and there not be appropriate medical assistance available. In relation to diversion airports a number of questions need to be addressed including suitability, facilities, medical services and passenger related services.

Cabin crew have an important safety role for the flight particularly in regard to emergency evacuation and passenger safety. The cabin crew safety role is detailed by ICAO but unlike other aircraft crew members cabin crew are not licensed or covered by ICAO standards, cabin crew would like to see action in this area. Training is important and cabin crew must be fully included in CRM programmes especially technical training and joint emergency training. Cabin crew are important flight safety personnel, aviation regulators and air operators must recognise this. Air operators must place more importance on the role of the cabin crew and ensure they are able to adequately perform their safety role. Aviation regulators must back this up with appropriate licensing, regulation and oversight of cabin personnel. This includes regulating flight and duty time requirements.

The cabin environmental impacts on cabin crew include respiratory symptoms, skin dryness, fatigue and neurological effects such as dizziness. With Polar routes cosmic radiation adds a new impact that increases with altitude and latitude. Increased radiation exposure has a range of bodily impacts that are cumulative and cabin crew are particularly susceptible to these higher radiation levels. Cabin crew rest is influenced by the length of rest, when it is taken and the location of rest facilities. Aircraft manufacturers need to note the location of crew rest facilities and airline operators need to place more importance on rest periods and locations. Cabin crew fatigue is influenced by circadian rhythm, work load and type of in-flight rest. Increased fatigue issues mean there is a need for systems to identify and manage fatigue such as FRMS.

In relation to ULR flights not only is the level of research between the two types of crew different but standards are focussed more on flight crew. It has been identified from this study that cabin crew are exposed on a repetitive basis to a range of cabin environment impacts on their health and welfare. It is also identified that there is a lack of research on these cabin impact on the cabin crew role, duties, and health. This lack

of research is highlighted when compared to the research on flight crew and the investment in flight deck equipment and systems.

A number of studies have identified specific problem areas that need to be addressed in relation to the cabin environmental and passengers. These areas include air quality, low humidity, airborne diseases, extended periods of physical confinement and cabin pressure variations. Many of these studies have been initiated by government agencies, including aviation regulators, with specific recommendations for action. However action has been slow or deferred whilst the impacts on cabin crew and passengers continue.

Cabin environment influences passenger health particularly elderly travellers. An aging population presents more problems in relation to medical problems and passenger stress on ULR flights. Airlines have reduced several passenger comfort and space items to improve profitability including fresh air quantity and passenger seating. For ULR flights airlines need to take better care of their passengers and review passenger related health and safety measures. The passenger will be impacted by ULR flights and unlike cargo their impacts could result in litigation and financial penalty to operators.

Aircraft manufacturers and air operators have spent time and money to push the boundaries of aircraft. They must also spend time and money addressing issues related to the pushing of the boundaries of the people onboard.

7.2 Recommendations

ULR flights are currently in operation and are set to increase in number and types of operators. The aircraft, the routes and the flight crew have been thoroughly researched and operationally these ULR flights are operating successfully as a result of the research and preparation done. But much needs to be done to ensure the long term success of ULR flights in relation to cabin crew and passengers.

From the research completed in this thesis it is recommended that:

ULR Operations

- Aviation regulators implement improved regulations on ETOPS and LROPS flights as soon as possible. They cannot continue to rely on the present Advisory Circulars and Exemptions.
- Specific aviation regulator requirements needed for Polar routes especially cabin impacts, diversion requirements and diversion airport specifications.

- Need for extensive pre-flight briefing of the entire crew, flight and cabin, before the ULR flight including flight route specific procedures and diversion requirements.
- Medical incidents in-flight should be reported and recorded in a central database to analyse data to establish trends and actions required.
- Aviation regulators need stringent standards for diversions airports to ensure the aircraft can land safely and that the airport has adequate facilities for passengers and crew.
- Airlines should be required to have a detailed plan for diversions including Standard Operating Procedures for diversions and passenger safety plans.
- Specific ULR pre-flight briefing for passengers on DVT, exercise, sleep patterns and managing circadian rhythm including any specific precautions for passengers.

Cabin Crew

- Extensive research is required on cabin crew in relation to the impacts of ULR flights on health and their cabin duties. This research should also analyse specific strategies to address these impacts.
- For ULR flights better application of Crew Resource Management is required with combined training for cabin and flight crew particularly in relation to emergency and evacuation training.
- Aviation regulators and airlines should ensure cabin crew training and ongoing competency has the same integrity as that of ICAO Annex 1 licences.
- There is a need for aviation regulators to set specific cabin crew flight and duty times for ULR flights including specified rest period requirements.
- Mandated use of systems to identify and manage fatigue such as FRMS.
- Need for research and scientific analysis on cabin crew rest and sleep requirements including the relationship between rest facilities and adequacy of rest.
- With new aircraft and ULR flight the role of cabin crew is changing. Regulators and airlines must research and identify these changes and address them.

Passengers

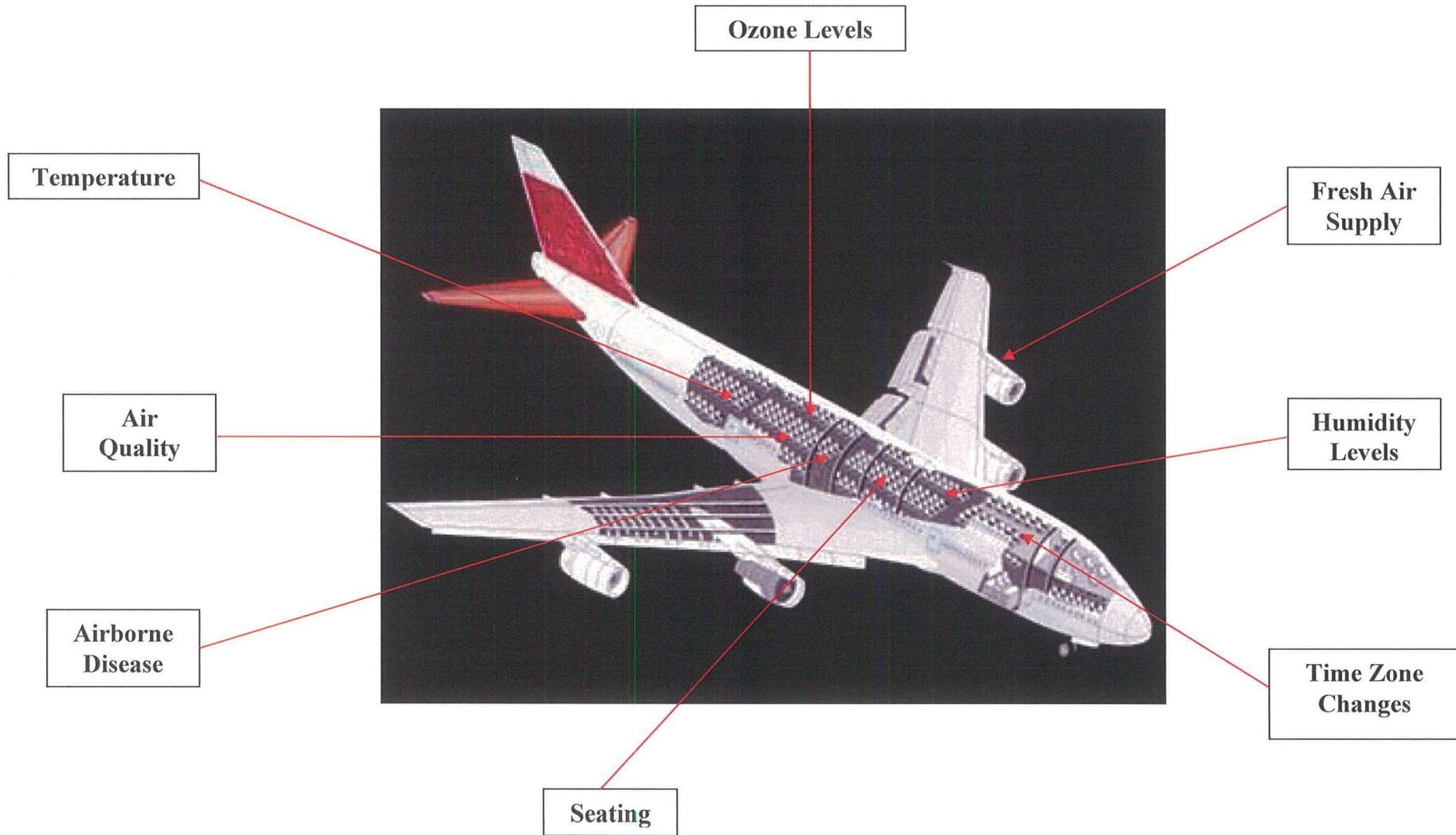
- Passenger information should be improved with better information on cabin environment health impacts and strategies to address these impacts. This information includes partial pressure altitude, low humidity levels, changes in circadian rhythm and, on affected routes, cosmic radiation.
- Airlines and aircraft manufacturers should look at better and more effective air filtration systems for passenger airliners. This includes further research on recycled air risk for disease transmission.
- Research is required on the specific impacts of ULR flights on passenger health. This research should also analyse specific strategies to address these impacts.
- Airlines should look at better seating for ULR flights to assist passenger health and sleep including lumbar support and improved seat adjustability.
- Identified passenger stress factors need more research and be addressed better by aviation regulators, airlines, and air operators.

Passenger flights in general

- Aviation regulators and airlines need to raise emphasis on passenger health and safety.

APPENDIX 1

Schematic view of cabin impacts



APPENDIX 2

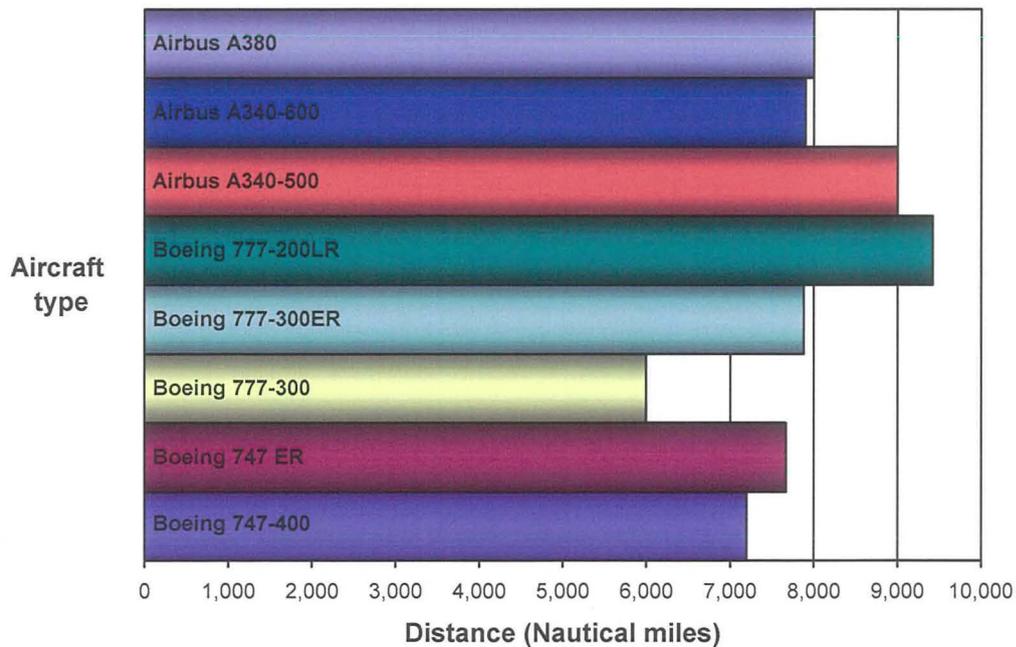
Aircraft data

Table of maximum aircraft range

(Data from the official websites of Boeing www.boeing.com and Airbus www.airbus.com)

Aircraft	Maximum Distance (Nautical miles)
Boeing 747-400	7,200
Boeing 747 ER	7,670
Boeing 777-300	5,995
Boeing 777-300ER	7,880
Boeing 777-200LR	9,420
Airbus A340-500	9,000
Airbus A340-600	7,900
Airbus A380	8,000

Comparison of ultra long range aircraft range



APPENDIX 3

Survey to organisations

The following block of questions require a ranking. Rank 1 being the most important, Rank 2 being the next most important, and so on.

Question 1 – Operations

In relation to ULR operations, rank the following in order of operational importance:

	Sum	Average	1	2	3	4	5
Regulatory requirements	14	2.8	28.6%	57.1%	0.0%	14.3%	0.0%
Aircraft performance	19	3.8	42.9%	14.3%	0.0%	14.3%	28.6%
Optimum flight route	19	3.8	14.3%	0.0%	85.7%	0.0%	0.0%
Diversion airport facilities	23	4.6	0.0%	28.6%	14.3%	57.1%	0.0%
Flight duration	30	6	14.3%	0.0%	0.0%	14.3%	71.4%

Question 2 – Cabin Crew

In relation to ULR operations and cabin crew, rank the following items in order of importance to be addressed:

	Sum	Average	1	2	3	4	5
Cabin crew rest facilities	15	3	28.6%	28.6%	42.9%	0.0%	0.0%
Impacts on Cabin Crew duties	16	3.2	42.9%	28.6%	0.0%	14.3%	14.3%
In-flight rest scheduling	18	3.6	14.3%	42.9%	14.3%	28.6%	0.0%
In-flight emergencies	27	5.4	14.3%	0.0%	14.3%	28.6%	42.9%
Impacts from cabin air quality and humidity	29	5.8	0.0%	0.0%	28.6%	28.6%	42.9%

Question 3 – Passengers

In relation to ULR operations and passengers, rank the following impacts in order of importance to be addressed:

	Sum	Average	1	2	3	4	5
Seating	10	2	57.1%	42.9%	0.0%	0.0%	0.0%
In-flight Boredom	14	2.8	42.9%	14.3%	42.9%	0.0%	0.0%
Cabin humidity	23	4.6	0.0%	28.6%	28.6%	28.6%	14.3%
Circadian rhythm	28	5.6	0.0%	14.3%	28.6%	0.0%	57.1%
Cabin air quality	30	6.0	0.0%	0.0%	0.0%	71.4%	28.6%

ULR – Organisational Specific

Question 4

Does your organisation currently operate ULR flights?

Yes (Answer Questions 5 to 7 and 12 & 13) - 50% (3)

No (Answer Question 8 to 13) - 50% (3)

Question 5

What type of aircraft/s is operated on ULR flights?

Airbus A340-500

Airbus A340-600

Question 6

What ULR flight routes and flight times are operated?

Hong Kong to JFK

Singapore to New York

Singapore to Los Angeles

Question 7

Name the top three areas that need to be addressed in relation to ULR flights from your organisation's experience with ULR flights.

1. Crew Training
2. Rest facilities
3. Crew Resource Management

Question 8

From your organisation's experience with ULR flights, name the top three benefits to your organisation from operating ULR flights.

1. Corporate image
2. Passenger convenience
3. Commercial benefit of non-stop services

Question 9

From your organisation's experience with ULR flights, name the top three benefits to your passengers from operating ULR flights.

1. Better flight connections
2. Convenience
3. Time savings

Question 10

Does your organisation intend to conduct ULR flights in the next 5 years?

Yes - 66% (2)

No (Go to question 12) - 33% (1)

Question 11

What type of aircraft/s is intended to be operated on ULR flights?

Airbus A340-500
Boeing 777 LR

Question 12

What ULR flight routes and flight times are likely to be operated?

Asia to West Coast USA 18hr+
Asia to South America

Question 13

Name the top three areas that need to be addressed before operating ULR flights.

1. Crew complement
2. Emergencies
3. Customer comfort

Question 14

Name the top three benefits to your organisation from operating ULR flights.

1. Efficiency
2. Airline profile
3. New markets and routes

Question 15

Name the top three benefits to your passengers from operating ULR flights.

1. Time savings
2. Comfort
3. Convenience

Question 7 – Training - Initial (109)

Assess the quality of initial cabin crew training provided by your airline:

Excellent	Very Good	Good	Fair	Inadequate
27.5%	40.4%	20.2%	11%	0.9%

Question 8 – Training - Ongoing (109)

Assess the quality of ongoing cabin crew training provided by your airline:

Excellent	Very Good	Good	Fair	Inadequate
14.7%	43.1%	26.6%	10.1%	5.5%

Question 9 – Crew Resource Management (109)

Does your airline provide Crew Resource Management (CRM) training for cabin crew?

Yes 95.4%
No 4.6%

Question 10 – Crew Resource Management - Effectiveness (109)

To what extent do you believe CRM helps improve communication and teamwork between flight and cabin crew?

Improves Significantly	Improves Somewhat	Stays the Same	Deteriorates Somewhat	Deteriorates Significantly
25.5%	47.1%	25.5%	2.0%	0.0%

Question 11 – Emergency Training (109)

Does your airline’s cabin crew emergency training involve flight crew?

Yes 74.3%
No 25.7%

Question 12 – Cabin crew health on long haul flights (92)

Name the top three health impacts on cabin crew from long haul flights.

1. Fatigue
2. Sleep
3. Dehydration

Question 13 – Cabin crew health improvements (92)

Name the top three improvements in relation to cabin crew health you would like to see for long haul flights.

1. More rest at stopover
2. Increased crew numbers
3. Improved in-flight cabin crew meals

Question 14 – Cabin crew rest (92)

On long haul flights what rest periods does your airline provide and where are these rests taken (seat, bunk etc)?

Mostly 2-3 hours.

Boeing 767 and Airbus A330 taken in passenger seats.

Boeing 777 bunks in centre section of aircraft.

Boeing 747 bunks in rear of aircraft.

Question 15 – Cabin crew rest required (92)

Do you believe these rest periods are adequate? If no briefly state why.

Yes 62.0%

No 38.0%

Sleep not long enough.

Night flight has major impact on sleep.

More crew needed.

Flight Service Manager dictates rest periods.

Meal service has bearing on amount of sleep.

Question 16 – Cabin crew rest facilities (92)

Do you believe the rest facilities provided are adequate? If no briefly state why.

Yes 29.3%

No 70.7%

Lie down sleep needed.

Rest area is confined, noisy, unclean and needs more ventilation.

Facilities should be the same as flight crew.

Question 17 – Cabin crew regulation (92)

Do you believe the Civil Aviation Authority should regulate cabin crew flight and duty times including rest periods?

Yes 80.4%

No 19.6%

Question 18 – Cabin crew licensing (92)

Do you believe the Civil Aviation Authority should issue cabin crew licences as they do for pilots and engineers?

Yes 60.9%

No 39.1%

The next set of questions is about ULR in relation to cabin attendants and passengers.

Question 19 – Cabin crew health on ULR flights (74)

Do you believe the health impacts you identified for long haul flights will be increased with ULR flights?

Yes 97.3%

No 2.7%

Question 20 – Cabin crew & ULR flights (74)

ULR operations will affect cabin crew in the following areas. Please rank these in order of personal importance to be addressed: Use a ranking from 1 to 5 with 1 being the most important and 5 the least important.

	Sum	Average	1	2	3	4	5
In-flight rest facilities	198	39.6	23.0%	25.7%	23.0%	17.6%	10.8%
Cabin Crew duties	215	43	24.3%	20.3%	20.3%	10.8%	24.3%
Cabin air quality and humidity	228	45.6	13.5%	24.3%	20.3%	24.3%	17.6%
In-flight rest scheduling	231	46.2	14.9%	20.3%	21.6%	24.3%	18.9%
Emergency training	238	47.6	24.3%	9.5%	14.9%	23.0%	28.4%

Question 21 – Cabin Crew & ULR Flight Improvements (74)

Question 20 identified five areas that need to be addressed by airlines in relation to cabin crew before operating ULR flights. If there are additional areas not listed above please detail. You may list up to three.

1. Rest at destination
2. Crew numbers
3. Meals

Question 22 – Passengers & ULR flights (74)

ULR operations will affect passengers in the following areas. Please rank these in order of personal importance to be addressed: *Use a ranking from 1 to 5 with 1 being the most important and 5 the least important.*

	Sum	Average	1	2	3	4	5
Cabin air quality	188	37.6	17.6%	33.8%	28.4%	17.6%	2.7%
Seating	196	39.2	35.1%	16.2%	10.8%	24.3%	13.5%
Cabin humidity	216	43.2	8.1%	31.1%	29.7%	23.0%	8.1%
Circadian rhythm	243	48.6	23.0%	8.1%	24.3%	6.8%	37.8%
In-flight Boredom	267	53.4	16.2%	10.8%	6.8%	28.4%	37.8%

Question 23 – Passengers & ULR Flight

Question 22 identified five areas that need to be addressed by airlines in relation to passengers before operating ULR flights. If there are additional areas not listed above please detail. You may list up to three.

1. Meals
2. Toilet – numbers and hygiene
3. Seating and exercise area

Comments – Details

Research on cancer cases in cabin crew.
Research on cabin crew issues in general.
Money dictates importance of cabin crew role.
Technology has outpaced human component.
Duties, rest and humidity collectively have a huge impact.
Double crew numbers instead of 20 hour duties.
Research on health issues especially circadian rhythm.
Rest important for crew to be at best performance.
Airlines need to address toilets, fresh food, alcohol intake.
ULR needs more crew comfort, ability to move around cabin, legroom, DVT.
ULR passengers – personal space, comfortable seats, entertainment.
Airline industry tough – reducing costs include crew costs with aircraft bigger and flying further.
Quick turnarounds and minimum crew – very fatiguing.
Hotels okay but only if quiet and noise levels low.
Cabin crew seen as an expense by management not an asset.
CAA don't care and medical profession ignore cabin crew.
After 12 years cabin crew finally covered by Health and Safety in Employment Act.
Cabin crew role not valued.
Glamour and in-flight service pushed not cabin crew safety aspect and duties.
CAA must set rest and duty minimums as management ignore these issues.
Airlines will push cabin crew on ULR flights and reduce conditions.
How many normal people do a 15 hour day in poor work conditions.
Management ignores unique sickness from fatigue, erratic night shift, aircraft environment.
Not covered by Holidays Act.
Lack of work\life balance
First generation of pure jet flying new things are being discovered.
Research needed.
Increase crew numbers.
High incidents of cancers especially breast cancer.
On Time Performance affecting safety and security checks.
Lie flat beds and more toilets needed for ULR flights.
ULR flights should not be rostered back to back.
Cabin humidity needs to be addressed.
Radiation levels need to be monitored and regulated.

Link between cancers and arduous hours?

Legislation on days off for long haul and ULR flights.

Cabin crew suffer from eczema, acne, irregular or no periods.

Cabin crew conditions – duty hours, credit system. Block to block hours.

Not paid until cabin door closed.

Rest periods differ between airlines.

Fatigue has safety consequences.

Passenger control is a problem on Boeing 747.

Pilots given better in-flight rest facilities, food, hotels and allowances.

Pilots want company after flights where cabin crew want peace and quiet away from people.

Mix of flights not just ULR for variety.

APPENDIX 5

FAA ETOPS Regulations before and after proposed ETOPS rule changes published 14 November 2003

Proposed ETOPS requirement	Under current advisory circulars and policy			Under the proposed regulation		
	Twins	More than two engines	Part 135 operations	Twins	More than two engines	Part 135 operations
Applicability	More than 60 minutes from an adequate airport	Does not apply to turbine engine airplanes.	Does not apply	More than 60 minutes from an adequate airport	More than 180 minutes from an adequate airport	More than 180 minutes from an adequate airport
Terminology	ETOPS (Extended Operations for Two Engine Airplanes)	ETOPS does not currently apply to turbine engine airplanes with more than two engines	ETOPS does not currently apply to part 135 operations	ETOPS (Extended Operations)	ETOPS (Extended Operations)	ETOPS (Extended Operations)
Maximum permissible distance from an adequate airport	207 minutes	Not regulated	180 minutes	240 minutes with certificate holder approval, beyond 240 minutes with route specific approval	To maximum system limitation	240 minutes
Cargo fire suppression	Diversion limit plus 15 minutes	Not required	Not required	Diversion limit plus 15 minutes.	Diversion limit plus 15 minutes (6 year compliance period)	Not required
Rescue and fire fighting service capability	ICAO category 4	Not required	Not required	ICAO category 4 up to 180 min, ICAO category 7 beyond 180 min	ICAO category 7	Not required
Passenger recovery plan	Required for polar operations	Required for polar operations	Required for polar operations	Required	Required	Required
Engine reliability standards	IFSD rates: 0.02/1000 hrs for 180 min, 0.19/1000 hrs for 207 min	None	None	IFSD rates: 0.05/1000 hrs for 120 min, 0.02/1000 hrs for 180 min, 0.01/1000 hrs for > 180 min	IFSD rates: 0.2/1000 hrs for 3 engine airplanes, 0.1/1000 hrs for 4 engine airplanes	Not specified
Areas of designated ETOPS applicability	Polar	Polar	Polar	Applies	Applies	Applies
Time-limited systems	Per type design approval limit for the airplane (up to 207 min).	No requirement	No requirement	Specified in part 25, Appendix L	Specified in part 25, Appendix L	Specified in part 25, Appendix L
Dispatch weather requirements for alternate	Applies	No requirement	No requirement	Applies	Applies	Applies
ETOPS maintenance program	Required	No requirement	No requirement	Required	Required	Required
Communication capabilities	SATCOM required for 207 min ETOPS	No requirement	No requirement	Additional com required. SATCOM beyond 180 min..	Additional com required. SATCOM beyond 180 min..	Additional com required. SATCOM beyond 180 min..

APPENDIX 6

FAA Polar routes regulatory requirements

United States Federal Aviation Authority (FAA) regulations specify additional requirements for North Polar air operations in Operational Specifications B055 (FAA, 2005) including:

1. Specific North Polar flight approval.
2. Fuel freeze specifications and monitoring.
3. Required communication capability for all portions of the flight. This includes voice and data link using High Frequency, Very High Frequency and Satellite Communication.
4. Additional items on the Minimum Equipment List.
5. Additional training programme for flight crew, maintenance and dispatch personnel.
6. Long-range flight crew requirements include rest plan and proficiency tests.
7. Requirements during Solar Flare activity.
8. Specific North Polar operations equipment. Medical Kit and cold weather anti-exposure suits.
9. En Route Polar Diversion Alternate Airport requirements. Safe offloading of passengers, provide accommodation for the passengers\flightcrew before evacuation, and safe extraction of passenger\flightcrew within 12 to 48 hours.
10. Recovery plan for passengers at polar diversion airport.
11. Validation flight with FAA to review operations before approval.
12. Program Tracking and Reporting Subsystem.

Bibliography

- American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc. (ASHRAE). (1999). *Relate Air Quality and Other factors to Symptoms Reported by passengers and Crew on Commercial Transport Category Aircraft*. Project 957-RP, Final Report, February 1999.
- Aschoff, J. (1976). Circadian systems in man and their implications. *Hospital Practice*, 11, 51-57. May 1976.
- Bachtel, C.M. (2005). *ETOPS, Extended Operations, and En Route Alternate Airports*. Boeing Commercial Airplanes.
- Boeing Corporation. (1999). *ETOPS: Expansion in the North Pacific Market*. Boeing Aero Magazine 1999. Boeing Commercial Airplanes Group.
- Boeing Corporation. (2003). *Boeing 777 Systems Manual*. June 2003. Boeing Commercial Airplanes Group.
- Boeing Corporation. (2004). *Boeing's ETOPS Quarterly Report for the 3rd Quarter 2004*. September 2004. Boeing Commercial Airplanes Group.
- Boeing Corporation. (2005). Polar routes offer new opportunities. *Boeing Aero Magazine*, 16. Boeing Commercial Airplanes Group.
Retrieved 3 August, 2005, from
http://www.boeing.com/commercial/aeromagazine/aero_16/polar_route_opportunities.html
- British Airline Pilots Association. (2002). *BALPA draft cosmic radiation guidance material*. Discussion paper presented to the IFALPA Human Performance Committee Meeting, 19-21 November 2002, Auckland, New Zealand.

- Brown, T.P., Shuker, L.K., Rushton, L., Warren, F. and Stevens, J. (2001). The possible effects on health, comfort and safety of aircraft cabin environments. *Journal of the Royal Society of Health*, 122(3), 177-184.
- Building Research Establishment Limited. (2001). *Study of possible effects on health of aircraft cabin environments - Stage 2*. September 2001.
- Building Research Establishment Limited. (2004). *Building Research Establishment study of air quality in the aircraft cabin: Final Report*. 3 March 2004.
- Commonwealth of Australia. (2005). *Civil Aviation Legislation Amendment (Mutual Recognition with New Zealand) Bill 2005*. Rural and regional affairs and transport legislation committee. Proof Committee Hansard. Australian Senate. Monday, 29 August 2005. Canberra.
- Costa, G. (1999). Fatigue and Biological Rhythms. In D.J Garland, J.A. Wise, and V.D Hopkins (Eds.), *Handbook of Aviation Human Factors*. pp 235-255. Mahwah, New Jersey: Lawrence Erlbaum Associates.
- Crampton, T. (2001). Flying on top of the world – a radiation risk. *International Herald Tribune*, 24 May 2001. New York.
- Curdt-Christiansen, C. (2005). *Health of Passengers and Crews: Resolution A35-12*. Paper presented to the ICAO regional meeting on personnel licensing and aviation medicine. Bangkok. July 2005.
- DeHart, R.L. (2003). Health issues of air travel. *Annual review of Public Health*, 24, 133-151. January 2003.
- DeJohn, C.A., Veronneau, S.J.H., and Hordinsky, J.R. (1997). *The status of in-flight medical care aboard selected U.S. air carriers*. DOT/FAA/AM-97/2. Office of Aviation Medicine, Washington D.C.

- DeJohn, C.A., Veronneau, S.J.H., Wolbrink, A.M., Larcher, J.G., Smith, D.W., and Garrett, J. (2000). *The evaluation of in-flight medical care aboard selected U.S. air carriers: 1996 to 1997*. DOT/FAA/AM-00/13. May 2000. Office of Aviation Medicine, Washington D.C.
- Dowdall, N. (2000). "Is there a doctor on the aircraft?" Top 10 in-flight medical emergencies – Education and Debate. *British Medical Journal*, 321, 1336-1337.
- Dunbar, M.G., Chute, R.D., and Jordan, K. (1997). *Evaluation of Cabin Crew Technical Knowledge*. Published in the Proceedings of the 9th International Symposium on Aviation Psychology (1997); pp 527-531. Columbus, Ohio.
- Edwards, E. (1972). *Man and machine: Systems for safety*. British Airline Pilots Associations, pages 21-36. In Proceedings of British Airline Pilots Associations Technical Symposium, London, 1972.
- Edwards, D.C. (1990). *Pilot: Mental and physical performance*. Ames: Iowa State University Press.
- Evans, Dr T. (2005). *Air Passenger Health Issues*. Paper presented to the ICAO regional meeting on personnel licensing and aviation medicine. Bangkok. July 2005.
- Extra Tall website. *Cramped seats can kill!* Retrieved 15 July 2005 from http://extratall.co.uk/news_cramped_seats_can_kill.htm
- Federal Aviation Administration. (2002). *Report to the Administrator on the National Research Council Report, "The Airliner Cabin Environment and the Health of Passengers and Crew"*. Prepared by the Airliner Cabin Environment Report Response Team. February 6, 2002. FAA. Washington.
- Federal Aviation Administration. (2003). *Notice of Proposed Rulemaking - Extended Operations of Multi Engine Aircraft*. FAA Document 1999-6717-61. November 14, 2003. FAA. Washington D.C.

- Federal Aviation Administration. (2004). *Flight Attendant Certification*. FAA Order 8400.10. Bulletin FSAT 04-07. FAA. Washington D.C.
- Federal Aviation Administration. (2005). *OPSPEC B055 – North Polar Operations*. FAA Order 8400. Volume 3, Air Operator Technical Administration. Chapter 1, Operations Specification. Section 4. Part B Operations Specifications – En Route Authorizations and Limitations. Washington D.C.
- Fennell, P.J. and Muir, H.C. (1993). *The influence of hatch weight and seating configuration on the operation of a Type III hatch*. CAA. Paper 93015. London.
- Fewings, R. (2005). *Alternative Airports in Polar Regions*. Retrieved from Airport International July 6 2005. <http://www.airport-int.com/article>
- Flight Safety Australia. (2002). *Long haul rule changes in the wind*. Civil Aviation Safety Authority. January-February, 2002.
- Flight Safety Foundation. (1999). Strategies for enhancing safety in the 21st Century Highlight 1999 International Aviation Meeting. *Flight Safety Foundation News*. November 11, 1999. Alexandria, Virginia.
- Flight Safety Foundation. (2003). Consensus emerges from international focus on crew alertness in Ultra-Long-Range Operations. *Flight Safety Digest*, 22(5-6). May-June 2003.
- Flight Safety Foundation. (2005a). Fourth workshop yields insights into early Ultra-long-range Flight Experience. *Flight Safety Digest*, 24(8-9), 1-15. August-September 2005.
- Flight Safety Foundation. (2005b). The Singapore Experience: Task Force Studies Scientific Data to Assess Flights. *Flight Safety Digest*, 24(8-9), 20-39. August-September 2005.

- Flight Safety Foundation, (2005c). Cabin crews adapt readily to challenges of Ultra-long-range flight. *Flight Safety Digest*, 24(8-9), 41-45. August-September 2005.
- Goodwin, T. (2000). In-flight emergencies: an overview – Education and Debate. *British Medical Journal*, 321, 1338-41. November 25, 2000.
- Hawkins, F.H. (1987). *Human Factors in Flight*. Gower Technical Press, Aldershot, United Kingdom.
- Hocking, M.B. (2000). Passenger aircraft cabin air quality: trends, effects, societal costs, proposals. *Chemosphere*, 41, 603-615.
- Hocking, M.B. (2002). Trends in cabin air quality of commercial aircraft: industry and passenger perspectives. *Reviews on Environmental Health*. 17(1), 1-49.
- IEH. (2001). A consultation on the possible effects on health, comfort and safety of aircraft cabin environments. *Institute for Environmental and Health*. (Web report W5), Leicester, United Kingdom. Posted March 2001 to the internet. Retrieved 22 August, 2005, from <http://www.le.ac.uk/ieh/webpub.html>.
- International Civil Aviation Organisation. (1996). *Training Manual, Part E-1 – Cabin Attendants Safety Training*. Document 7192. 2nd Edition. 1996. Montreal, Canada.
- International Civil Aviation Organisation. (2001). *Annex 6 to the Convention on International Civil Aviation*. November 1, 2001. Montreal, Canada.
- International Civil Aviation Organisation. (2003). *Human Factors Digest No. 15*. Circular 300. November 2003. Montreal, Canada.
- International Federation of Airline Pilots Associations. (2002). *Effects of cosmic radiation on aircrew*. Medical Information Sheet – Cosmic Radiation. IFALPA Human Performance Committee Meeting, 19-21 November 2002, Auckland, New Zealand.

- Irrgang, M. (1997). Airline irregular operations. In D. Jenkins (Ed.), *Handbook of Airline Economics*, New York, NY. McGraw-Hill.
- Jenkins, D. & Cotton, B. (2002). *Improving airline profitability through better estimated times of arrival and terminal area flight information – A benefit analysis of PASSUR*. January 2002. Retrieved 15 November 2005 from www.passur.com/report/report_toc.htm
- Jones, C. (2003). Epic Journey. *Flight Safety Australia*. September/October 2003.
- Kingsley-Jones, M., & Sobie, B. (2005). The Long Hello. *Flight International*. May 3-9, 2005. London.
- Klopfenstein, M. & Smith, P. (1999). *RTO-37 En route User Deviation Assessment*. November, 1999.
- Kolander, C. (2002). *Ultra Long-Range Operations – Cabin Crew Perspective*. Presentation to the Ultra Long Range Task Force. Paris.
- Kraus, J.F. (1985). *Epidemiological studies of health effects in commercial pilots and flight attendants: A review*. School of Public Health, University of California., Los Angeles.
- Lindgren, T. (2003). *Cabin air quality in commercial aircraft – Exposure, Symptoms and Signs*. Comprehensive Summaries of Dissertations from the Faculty of Medicine. MEDFARM 2003/564. Uppsala
- Mortazavi, A., Eisenberg, M.J., Langleben, D., Ernst, P., & Schiff, R. (2003). Altitude related hypoxia: Risk assessment and management for passengers on commercial aircraft. *Aviation, Space, and Environmental Medicine*, 74(9), 922-927. September 2003.

- Muir, H., and Cobbett, A.M. (1996). *Influences of cabin crew during emergency evacuations at floor level exits*. Civil Aviation Authority. Paper 95006, Part A; FAA No. DOT/FAA/AR-95/52. London.
- Muir, H., Marrison, C., and Evans, A. (1989). *Aircraft Evacuations: The effect of passenger motivation and cabin configuration adjacent to the exit*. Civil Aviation Authority. Paper 89019. London.
- Nagada, N. L. & Hodgson, M. (2001). Low relative humidity and aircraft cabin air quality. *Indoor Air 2001*, 11, 200-14.
- Nagada, N. L. & Koontz, M.D. (2003). Review of studies on flight attendant health and comfort in airliners cabins. *Aviation, Space, & Environmental Medicine*, 74(2), 101-9.
- National Institute for Occupational Safety and Health (NIOSH). (1993). *HETA 90-266-2281, Alaska Airlines, Seattle, Washington*. Health Hazard Evaluation Report, January 1993. U.S. Department of Health and Human Services, Public Health Service, Centres for Disease Control.
- National Transportation Safety Board. (2000). *Emergency Evacuation of Commercial Airplanes*. NTSB Safety Study NTSB/SS-00/01. Washington DC.
- Nav Canada. (2000). *Polar Routes – A direct link between America and Asia*. Nav Canada presentation to Aviation 2000. December 4, 2000.
- Nicholson, A.N. (1987). Influence of back angle on the quality of sleep in seats. *Ergonomics*. 30(7), 1033-41.
- O'Connell, D. (1997). *Jetlag – How to Beat It*. London, United Kingdom, Ascendant Publishing.

- Pascoe, P.A., Johnson, M.K., Montgomery, J.M., Robertson, K.A., and Spencer, M.B. (1994). *Sleep in Rest Facilities Onboard Aircraft: Questionnaire Studies*. Farnborough, U.K, DERA: DERA/CHS/A&N/CR/95/002.
- Printup, M.B. (2001). *The effects of fatigue on performance and safety*. Retrieved 3 August, 2005, from www.avweb.com/articles/fatigue.
- Rayman, R. B. (1997). Passenger Safety, Health, and Comfort: A Review. *Aviation Space Environmental Medicine*, 68(5), 432-440. May 1997.
- Reason, J. (1990). *Human Error*. Cambridge University Press. New York.
- Rosekind, M.R., Gregory, K.B., Co, E.L., Miller, D.L., and Dinges, D.F. (2000). *Crew Factors in flight operations XII: A survey of sleep quantity and quality in on-board crew rest facilities*. National Aeronautical and Space Administration. September 2000. Ames Research Center, Moffett Field, California.
- Ross, D., Hadi, M., Palmer, J. et al. (2000). *Cabin air quality monitoring in Boeing 777s*. Centre for Safety, Health, and Environment. Report 201543. December 2000. United Kingdom.
- Sainarayan, I. (2005). Preventing the spread of disease is critical to the industry's own health. *ICAO Journal*, Number 3, 2005, 11-13. Montreal, Canada.
- Schwartz, T., Siegert, G., Oettler, W., Halbritter, K., Beyer, J., Frommhold, R., Gehrisch, S., Lenz, F., Kuhlisch, E., Schroeder, H., and Schellong, S. (2003). *Venous Thrombosis after long-haul flights*. *Archives of internal medicine*. December 8, 2003; Volume 163, Number 22: 2759-2764.
- Signal, L., MacDonald, C. and Gander, P. (2004). *Factors affecting the sleep of economy class passengers during long haul flights*. August, 2004. Report for the Boeing Commercial Airplane Group prepared by the Sleep/Wake Research Centre, Massey University, Wellington, New Zealand.

- Sirven, J.I., Claypool, D.W., Sahs, K.L., Wingerchuk, D.M., Bortz, J.J., Drazkowski, J., Caselli, R. and Zanick, D. (2002). Is there a neurologist on this flight? *Neurology*, 58, 1739-1744. June 2002.
- The United Kingdom Parliament. (2000). *Air Travel and Health: Fifth Report*. House of Lords Select Committee on Science and Technology. 15 November 2000. United Kingdom.
- Thomas, G. (2005a). Ultra Long-Haul Specialist – Boeing rolls out the 777-200LR to serve niche markets. *Air Transport World*, 39. March 2005.
- Transport Safety Board of Canada. (1995). *A safety study of evacuations of large, passenger carrying aircraft*. TSB report SA9501. Quebec, Ontario.
- U.S. Department of Transportation. (2005). *Review of costs of the airfield on Midway Island*. Office of the Secretary of Transportation. Report Number: FI-2005-079. Issued September 30, 2005.
- U.S House of Representatives Committee on Transportation and Infrastructure: Subcommittee on Aviation. (2003). *Hearing on the Aircraft Cabin Environment*. Washington D.C. House of Representatives Committee on Transportation and Infrastructure: Subcommittee on Aviation.
- Van den Bergh, R. (2005). Boeing preparing for long haul. *The Dominion Post*. Friday July 29, 2005. Wellington, NZ.
- Waterhouse, J., Reilly, T., and Atkinson, G. (1997). Jet Lag. *The Lancet*, 350 (991), 1611-1616.
- World Health Organisation. (2005). *International travel and health; Situation as on 1 January 2005*. World Health Organisation 2005. Switzerland.
- Wyon, D.P. Pr. (2002). *Proceedings 9th International Conference on indoor air quality and climate*. Indoor Air 2002. Monterey, California.