Australian aviation safety: a systemic investigation and case study approach

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Additional Information:

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Metadata Record: https://dspace.lboro.ac.uk/2134/6881

Publisher: © Graham Robert Braithwaite

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Australian Aviation Safety: A Systemic Investigation and Case Study Approach

by

Graham Robert Braithwaite

A Doctoral Thesis

Submitted in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy of Loughborough University

April 1998

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Australian Aviation Safety:
A Systemic Investigation and Case Study Approach

Synopsis

Aviation represents a complex socio-technical system in which a strong emphasis is placed upon safe operation. Advances in this area have traditionally been reactive following particular incidents or accidents. As the traditional accident causes (predominantly technical engineering factors) have become better understood, the need for proactive solutions to counteract the increasing proportion of human performance related accidents has grown.

This thesis proposes and utilises case-study research methodology to examine the reasons behind Australia’s good record for airline safety. At the time of writing, no lives have been lost in an Australian jet passenger aircraft accident. The methodology is designed to advance the application of systemic safety investigation in order to avoid the traditional “primary-cause focussed safety investigations” which are generally used following accidents.

Having established the safety record for commercial jet RPT (regular public transport) operations to be above average, a number of factors which may have an effect on that record are reviewed. The analysis is divided into three main sections, namely the human, operational and natural environments. Evidence used comes from a variety of sources so as to ensure validity. Data collection methods included primary data obtained through expert witness interviews and attitude surveys of 2,600 Australian and British flight crew and air traffic controllers. Secondary data came from extensive literature reviews which have attempted to bring together existing micro-level research work in a systems context.

Initial conclusions point to the existence of a number of natural environment factors which are perceived to have a major effect on flight safety. However, deeper examination has suggested that there are a number of cultural factors within the human and operational environments which exist at professional, corporate, industry and national levels. These have contributed to the quality and quantity of risk countermeasures which have been instrumental in creating the good safety record. This thesis explores the importance of these influences and how they may be changing in the current and future aviation environment.

Graham Braithwaite
April 1998

Keywords; Aviation, Safety, Culture, Australia, Human Factors
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Acknowledgments

People say that the aviation industry is difficult to get into, yet I have found the help and friendship that I have been given during my research quite overwhelming. Perhaps I have been lucky, but since part of my thesis tries to discount the concept of luck, I had better put it down to something else! May be it comes down to the fact that we are involved in an industry that is so exciting that, if we had to, we would probably do it for nothing.

To thank everyone individually would be difficult so I will just mention a few and send out a heartfelt thank you to everyone, wherever you are in the world, for sharing your wisdom, experience, excitement and friendship:

To my parents for backing me all the way and keeping the bank manager off my back. I guess we showed the primary school teacher who reckoned I would be hard pushed to get on a Youth Training Scheme, never mind get O levels, that she was wrong. To my sister for setting the trend of doing PhD’s in this household and for showing that a pure science degree would have been much less fun than this was.

To all of the crew at Loughborough; David Gillingwater for being a constant source of inspiration; Bob Caves for your infectious enthusiasm; Norman Ashford for having enough faith to give me a studentship, Jim McGuirk for being the cynic I always fought to impress and to all of the other research students who made life at Loughborough such a pleasure; Matt, Phil, Adrian, Dave, Mandy and Mel.

To all of the wonderful people in Australia; my Rotary hosts, Bruce and Lois Cameron; my supervisor at RMIT, John Clements; my very patient boss at UNSW, Jason Middleton and all of the aviation industry. Especially thanks to Ken Lewis and Mike Innes at Qantas, Max McGregor and Trevor Jensen at Ansett, Paul Mayes and Claire Marrison at BASI, Lindsey Naylor and Mark Stallbaum at the RAAF, Brent Hayward, John Guselli, John Lane and of course, Top Gun.

Thanks also to Stu Grieve for believing in me from the start, to Ashleigh Merrit for being the greatest e-mail buddy in the world and to Ben Colson for being an inspiration. Sincere appreciation to all of the many people who filled in questionnaires; Qantas, Ansett, Britannia, RAAF, RAAF ATC, CAA ATC and Rotary. To my closest, dearest friends who have endured so many “...no, not yet’’s from me over the last couple of years; Lucy in particular for being a complete star and proof reading the monster, Andrew, Trav, Ben, Rob, Gill, Janine, Lindsey and Andrea. Finally, thanks to Rotary International and in particular, Desmond Carroll and Alan Williamson and the Blackburn and East Keilor clubs.

If this thesis helps save even one life, then I have achieved Rotary’s one overall aim;

Service Above Self
Roger wrote to me at the start of my work and in a few short sentences summed up the results that my research later confirmed. To all that knew Roger, he represented one of the cleverest minds in aviation safety, and above all he had an amazing ability to communicate his enthusiasm to any audience. He inspired me from the start and it was with very great sadness that I learned of his passing whilst I was attending the 1996 International Society of Air Safety Investigators Seminar in Auckland.

If I ever manage to learn half of what Roger knew of this subject, or be half as entertaining as his presentations were, then I will have achieved something beyond imagination.

Thank you Roger and please, keep an eye out for those psychiatrists...
1.0 Introduction

The research documented within this thesis represents the product of four years work through Loughborough University and also based at the Royal Melbourne Institute of Technology University and University of New South Wales. It represents an attempt to contribute to the pool of knowledge within a number of disciplines both within aviation and in the wider community. Using both primary and secondary data and a structured methodology, the research was designed, not to prove a particular point, but rather to promote a system level understanding of the factors behind aviation safety.

The thesis is designed to provide a reference text which can be used both by academia and industry and in other disciplines in addition to aviation. Many of the principles explored are unique to aviation, but conversely there are also a number of generic principles that are of use to other transport modes and indeed in any high-technology system. The structure of the case study aims to be readable by both the intellectual and the layman and is written in such a way as to serve as a quick reference text for anyone interested in a particular specialist area.

The decision to study Australian aviation safety was initially based upon anecdotal evidence and a considerable background search was conducted before the main research effort could be undertaken. This process is documented in chapter two and leads into the developed methodology which is detailed in chapter three.

The three ‘environments of analysis’ which cover the natural, human and operational environments make up the bulk of the thesis. Where areas of interaction exist, an ‘icon navigation’ feature has been included to allow ease of reference without disruption the flow of the thesis.

Conclusions are drawn in chapter seven and areas for future research are recommended so that this research effort may continue to achieve new potential.

The objectives on which this research is based are reproduced below. However, it should also be borne in mind that the underlying motivation behind the funding (by Loughborough University’s Air Transport Group and Rotary International Foundation) and efforts contained within is a desire to further the science of proactive aviation safety. This thesis aims to contribute to an area of knowledge which is concerned with saving lives as well as other aspects of organisational efficiency.
The main objective of this research was;

1.1 Main Objective

To examine how Australia has managed to achieve an apparently good record for commercial airline safety.

To achieve this objective, a number of subobjectives were developed as follows;

1.1.1 Subobjectives

1. To establish if the safety record is good.
2. To establish what factors contributed to the safety record.
3. To examine what threats exist to these factors.
4. To suggest how these factors can be replicated or maintained.
5. To suggest areas for future research which build upon this work.

In turn, the hypothesis is best summarised as;

1.2 Hypothesis

It is the hypothesis of this research that a good record for airline safety in Australia has been the result of a complex interaction of factors from within the natural, human and operational environments.
1.3 Assumptions

Two assumptions have been used to allow the thesis to concentrate on a reasonably homogeneous area;

What is meant by the term ‘Australian Commercial Aviation’?

For the purpose of this research, the operations considered as commercial aviation are those operating regular passenger transport (RPT) operations using jet turbofan powered aircraft. This includes Qantas International, Qantas Domestic (formerly Australian Airlines) and Ansett Australia (and former associated companies including East West Airlines and Ansett WA). It is recognised that this does not include the full spectrum of carriers as some of the smaller operators such as Kendell and Hazelton Airlines operate large propeller driven aircraft types (such as Saab 340 and Shorts 360) on scheduled RPT operations throughout Australia. The reasons for their exclusion relate to the operation of the ‘two-airline policy’ whereby RPT services were restricted by government to a duopoly in which Ansett-ANA and Australian Airlines operated as sole competitors between 1951 and 1992. Furthermore, airline safety statistics (see section 2.2) generally refer exclusively to jet aircraft operations and therefore prevent simple analysis of mixed fleet types, not least because of the different legislative requirements for smaller aircraft types.

What about operations into Australia?

The international nature of aviation means that there are many foreign carriers operating within Australian airspace and into Australian airports. They will be controlled by Australian ATC and use Australian facilities and may reasonably be involved in damaging Australia’s safety record if they are involved in an accident within its territory. Equally, Qantas and Ansett flights to international destinations will encounter the opposite set of risks.

For the purpose of this research, the examination of Australian carriers will cover all flights and international flights to Australia will also be considered for their duration within Australian airspace. This includes incidents involving military aircraft and civilian aircraft together.
Chapter Two

The State of the Art

A comprehensive literature review of work within the field of aviation safety was conducted before the case study could be examined. This provides the justification for embarking on this research and an explanation of its potential for the furtherance of aviation safety.
2.1 Why use Australia as a case study?

The International Society of Air Safety Investigators code of ethics (ISASI, 1983) states that it is the responsibility of air safety investigators to "...apply facts and analyses to develop findings and recommendations that will improve aviation safety." As such, one of their guiding principles is to "...identify from an investigation those cause and effect relationships about which something can be done reasonably to prevent similar accidents."

Although that particular professional body states within its title that its concern is air safety investigation, the terminology used to present the code of ethics lends itself particularly towards accident investigation and not safety investigation. This is not unusual and is a good example of where the historical emphasis towards safety advances have lain. Aviation, like most human activities has acquired learning through its own mistakes. Many lives have been lost, in accidents that would now seem unthinkable, in a pioneering sacrifice to progress. Accident investigators have become incredibly skillful in deducing 'what went wrong' from the remains of smouldering wreckage, but the price of progress using this method is incredibly high. The shift to proactive safety (accident prevention) has been a slow one and one that is far from complete. The ability to learn from best practice to avoid mishaps in the first place is a desirable goal for air safety investigation and an underlying aim of this research.

It is widely suggested within the aviation community that Australian airlines exhibit a level of safety that is well above average. The statistics presented below support that assertion for commercial jet regular public transport (RPT) operations and it is the aim of this thesis to use them as a baseline for proactive safety research. If it could be proven that there are controllable variables behind the situation then there is considerable merit in highlighting them and their relative contribution. Industrial Psychologist, James Reason of Manchester University writes, "Should we not be studying what makes organisations relatively safe rather than focussing upon their moments of unsafety? Would it not be a good idea to identify the safest carrier, the most reliable maintainer and the best ATC system and then try to find out what makes them good and whether or not these ingredients could be bottled and handed on?" (Reason, 1993).

There are those who will immediately raise their eyebrows at the prospect of Australia being described as being "the safest country in the world to fly in" or indeed Qantas being described as "the safest airline in the world." (None more so than the author of this thesis). This research is not concerned with either proving Australia to be the safest place to fly, or indeed its airlines to be the safest in the world - such an exercise is counterproductive and all but impossible to complete. The main objective is to establish what is good about the Australian system so that it could be maintained and passed on to others.
Geographical areas such as Europe or North America have excellent records for airline safety and 'benefit' (statistically) from the stability of a large sample of take-offs and landings, especially in the case of the USA which accounts for approximately half of the world's aviation. However, they were unsuitable for consideration in this research for a number of reasons including:

- Europe is covered by multiple regulatory / ATC authorities
- North America is covered by two separate regulatory / ATC authorities
- Europe represents an area of many diverse national cultures / languages
- Europe represents a wide variety of economic strengths
- Both represent a very large number of different airlines
- Both areas have a comparatively high turnover of airlines
- The majority of previous aviation safety work has focussed on these areas

Australia benefits from being a self contained continent of similar physical area to both the USA and Europe. The airlines contained within are relatively stable (the only large carrier which has not remained in one form or another being the short lived Compass MkI and MkII.) and all controlled under one regulatory and air traffic control authority. There is a single common language, one government and there are relatively few RPT carriers. While the consideration of an entire aviation system will involve the consideration of a very large number of variables, the above set of factors means that certain extraneous variables can be controlled to a degree.

In the light of a lack of previous research in this area and a desire to develop stronger links between the two countries, Rotary International Foundation decided to support the principal researcher in this project through the provision of an Ambassadorial Scholarship. This funding provided return travel and full expenses to carry out a year of field research in Australia based at the Royal Melbourne Institute of Technology University.

Proactive safety is a more skilled and complex science than 'management by hindsight' and therefore tends to have been overlooked in many areas, yet its value cannot be denied. This research project focuses on Australia's good safety record and is committed to both its preservation and aiding the emulation of its key factors elsewhere in the world. One of the benefits of this work being conducted by a non-Australian is in terms of its credibility to the rest of the aviation community and the ability for an outsider to see the 'big picture' better than someone who is established within the Australian aviation community and therefore has a preconceived set of views. While academic rigor should dictate that the latter two factors do not cause problems, the approach used in this work prevents that danger earlier in the process.
2.2  Is Australia’s Record for Airline Safety Good?

Before any research can commence which aims to examine how a ‘good safety record’ has been achieved, it is logical that ‘good’ can be defined. Immediately, any hopes of a simple answer are dashed by the relative nature of the term ‘good’. If a comparison were made between the hull loss rate of any modern day airline to that of, say, the early US Post Office aircraft then it will appear to be excellent. If a similar comparison was made between the hull loss rate of even modern aircraft to the catastrophic loss of nuclear reactors then suddenly the failure rate may appear to be quite poor.

There are many ways to compare the safety of airlines and at its most basic, this involves a direct comparison of accidents over a period of time. Such a simplistic measure could be highly misleading and of little practical value. Airlines vary in size, history, aircraft types, operating areas and so on. It would be impossible to find two operations with enough similarities to make a comparison feasible and so the most simplistic tool available to us comes in terms of the accident rate. For two or more operations, one may consider the number of accidents per million departures or sectors.

In 1984, Flight International attempted to compare the safety records of leading air transport countries. (Taylor, 1991) As the question ‘which are the safest airlines?’ proved difficult to answer, safety was expressed in terms of fatal events per million departures.

<table>
<thead>
<tr>
<th>Major Nations</th>
<th>Fatal Events per 1m Flights</th>
<th>Fatalities per 1m Flights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>3.493</td>
<td>75.982</td>
</tr>
<tr>
<td>Australia</td>
<td>0.328</td>
<td>0.656</td>
</tr>
<tr>
<td>Belgium</td>
<td>1.938</td>
<td>203.488</td>
</tr>
<tr>
<td>Brazil</td>
<td>4.351</td>
<td>148.295</td>
</tr>
<tr>
<td>Canada</td>
<td>2.906</td>
<td>24.497</td>
</tr>
<tr>
<td>Colombia</td>
<td>27.464</td>
<td>509.2693</td>
</tr>
<tr>
<td>Egypt</td>
<td>13.423</td>
<td>362.416</td>
</tr>
<tr>
<td>France</td>
<td>1.232</td>
<td>2.156</td>
</tr>
<tr>
<td>West Germany</td>
<td>1.298</td>
<td>27.261</td>
</tr>
<tr>
<td>India</td>
<td>5.512</td>
<td>333.858</td>
</tr>
<tr>
<td>Italy</td>
<td>1.772</td>
<td>114.311</td>
</tr>
<tr>
<td>Japan</td>
<td>0.642</td>
<td>13.262</td>
</tr>
<tr>
<td>Netherlands</td>
<td>2.523</td>
<td>383.515</td>
</tr>
<tr>
<td>Scandinavia</td>
<td>0.455</td>
<td>8.417</td>
</tr>
<tr>
<td>Turkey</td>
<td>17.369</td>
<td>1717.121</td>
</tr>
<tr>
<td>UK</td>
<td>1.279</td>
<td>56.763</td>
</tr>
<tr>
<td>USA</td>
<td>1.179</td>
<td>36.593</td>
</tr>
<tr>
<td>Venezuela</td>
<td>4.082</td>
<td>161.632</td>
</tr>
</tbody>
</table>

Figure 2.2.1  Avition Safety Record for Major Nations 1973-84  Redrawn from Taylor, 1991
Ten years is a relatively short sampling frame in terms of statistical validity and yet it also covers a number of technological advances such as the widespread introduction of GPWS and TCAS equipment. Key events may be seen to hold loud statistical noise. For example, the statistic presented for Turkey places it second highest in terms of fatal events and highest (by a long way) in terms of fatalities per 1 million flights.

In 1974, a THY Turkish Airlines DC10-30 experienced explosive decompression near Ermenonville, France when its rear cargo-door blew out. Catastrophic damage to all of the aircraft’s control systems (which run together near to the tail) led to a total loss of handling and the loss of 346 lives. Other similar incidents involving the DC10 aircraft (e.g. American Airlines Flight 96 over Windsor, Ontario, 1972) demonstrated a poorly designed locking mechanism on the aircraft which could easily be forced into a danger-side failure position. The accident suffered by THY could have potentially befallen any DC10 operator and so could have easily skewed any number of the countries’ records on the above table.

![Prime Ranking 1973-1984](image)

Nevertheless, the progression of these measures into a ranking of countries produces an indicator of relative safety records which is at least a starting point for even the most cynical researcher.

Even this very basic analysis indicates a relationship between safety and economics as all of the top ten nations may be considered to be ‘first world’ and the only third world countries appear in the bottom third. However, the need for caution is also apparent. In 1985, a Japanese B747 crashed as a result of structural failure with the loss of 520 souls (the largest ever in a single aircraft accident). The third place held by Japan in Flight International’s analysis would have dropped dramatically if the table was extended to cover 11 years.

The temptation is therefore to ‘regionalise’ statistics in an attempt to smooth out statistical noise and form a larger base of statistics from which to work. The problem comes in attempting to define regions in a way that is both fair and meaningful. The simplest way is to use the geographic continents and this method has been used by both the International Air Transport Association - IATA (1993) and Boeing Commercial Airplane Group (1994).
IATA publish total loss* rates for the six IATA regions, namely:

- AFI - Africa
- CAR/SAM - Caribbean / South America
- EUR - Europe
- MID - Middle East
- NAT/NAM - North America / Atlantic
- AS/PAC - Asia / Pacific

Rates concern only Western built aircraft, principally through lack of available data from former Eastern Bloc states.

* - a total loss is not necessarily a fatal accident.

The shift in emphasis from ‘million flights’ to ‘million sectors’ takes account of multi-sectoral flights. A flight between two points may involved several sectors for one operator (i.e. several take offs and landings) and yet may be a single sector for another. As approximately 80% of accidents occur in the 18% of flight associated with take-off, initial climb, approach and landing (Boeing, 1996), the relevance of sectors becomes significant.

The six geographic areas cover many countries and therefore many regulators and operators. The question for the researcher is to understand the relevance of the categories used. The regions represent administrative regions for IATA - indeed, until 1994, Egypt and Cyprus were classified as the Middle East, but are now Africa and Europe respectively due to changes in administrative boundaries.
There are obvious differences in accident rates between continents; Africa's accident rate, for example, is near twenty times that of North America. However, it would be dangerous to take the inference that all of Africa's airlines have similar safety records any more so than North American airlines. Analysis of accidents demonstrates that geographical (physical) factors (terrain, weather etc.) account for a very low percentage of accidents. However, the tendency to use such regional statistics is quite common.

Boeing (1993) used seven regions to describe crew-caused and controlled flight into terrain (CFIT) accident rates in its publication "Crew Factor Accidents; Regional Perspective". For the period 1959 to 1992, the accident rates, described per million flights are as follows:

<table>
<thead>
<tr>
<th>Region</th>
<th>Crew-Caused Accidents Rate per million flights</th>
<th>CFIT Accidents Rate per million flights</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFI</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>CAR/SAM</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>EUR</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>MID</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>NAT/NAM</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>AS/PAC</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>AUS</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

![Figure 2.2.4](source: Boeing (1993))  
![Figure 2.2.5](source: Boeing (1993))

Boeing separate Australasia from Asia / Pacific and suggest that this region has the lowest accident rates for both types of accident (CFIT is the biggest single killer as accidents of this type are generally fatal. It is classified as a crew-caused accident by Boeing).

There is a significant difference in the accident rate for both causes between Australasia and the rest of the Asia Pacific Region. The crew caused accident rate is over six times higher in the latter region than in Australasia. Boeing hints at the role of culture in affecting these human factor accident rates and this effect of culture will be a main theme throughout this thesis. Even at this high level of grouping, the simple changing of groups can affect the apparent accident rates for particular countries. Further disaggregation is desirable if true cultural groups are to be established. For example, Cathay Pacific is principally a British Airline based in Asia. Most of its staff are from the UK and Australia and its only qualification for membership of the Asia / Pacific group is the geographical location of its home base.
Former American Airlines Senior Director of Safety, Mack Eastburn (1987) presented safety statistics in terms of hull losses as oppose to fatal accidents. His geographical distribution of airlines experiencing hull losses finds that as of January 1987:

<table>
<thead>
<tr>
<th>Geographic Area</th>
<th>Jet aircraft flying hours per hull loss:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia &amp; South Pacific</td>
<td>2,545,000</td>
</tr>
<tr>
<td>United States</td>
<td>968,000</td>
</tr>
<tr>
<td>Europe</td>
<td>447,000</td>
</tr>
<tr>
<td>Canada</td>
<td>582,000</td>
</tr>
<tr>
<td>Asia</td>
<td>259,000</td>
</tr>
<tr>
<td>Central &amp; South America</td>
<td>201,000</td>
</tr>
<tr>
<td>Africa</td>
<td>200,000</td>
</tr>
</tbody>
</table>

Figure 2.2.6 Jet Aircraft Hull Loss Rate Split by Regions Redrawn from Eastburn, 1987

These boundaries are once again different from those used by IATA and Boeing and appear to present Australia in a very favourable light compared to the rest of the world. Eastburn observes that Australia, the best group, is 12.7 times better (in terms of accident rate) than the worst group, Africa. Although he does not offer any sort of explanation of the reasons behind the disparity, he does point out that not only do we know where accidents are occurring, but also what is happening and in what phase of flight. His address was aimed at encouraging safety professionals to use the information available as “...our future success in the prevention of accidents lies in how well we... apply the lessons learned from our past accident experience”. A note of caution is relevant at this point. Although the accident record shows certain recurrent trends about the types and location of accidents, it is foolish to assume that a good safety record is also to be recurrent. A small number of accidents, especially involving hull loss even with a low number of fatalities, could easily move Australia & South Pacific significantly down the ranking.

There have been a number of attempts to formulate smaller and yet meaningful categories. Oster, Strong and Zorn (1992) created an eighth category in their review of fatal accidents between 1977 and 1989 when Eastern and Western Europe were split. During that period, the authors estimated that Western Europe experienced 1.15 fatal accidents per 1 million departures as opposed to Eastern Europe’s rate of 4.11 fatal accidents. As alterations in the membership of regional categories seems to have such a profound effect, there comes a point when countries appear to be the only fair measure of ‘different cultures’. This returns to Flight International’s first statistics and the problems already highlighted.
Oster et al.'s approach to regional fatality statistics covers not only the number of fatal accidents per million departures, but also attempts to estimate the risk of being killed on a scheduled passenger flight during the period 1977-1989. (The latter statistic being based on the number of accidents, fatalities and percentage of passengers killed in crashes.) The significance of the death risk seems quite pertinent, especially from the point of view of the passenger. The survivability of a crash may be expected to be a function of several factors including the secondary safety measures afforded by the aircraft (such as crashworthiness, evacuation systems etc.) or airline (emergency procedures) and crew (training for emergencies). If the fatal accident rates can be correlated against aircraft types, operators or regulatory regimes, then the death risk is able to reveal some significant conclusions. However, this exercise is not attempted by the authors, possibly due to the small size of the database available.

The percentage of passengers killed in a crash varies considerably between the eight regions from 60% in North America to 81% in Latin America and, rather surprisingly, Australia and New Zealand. However, caution is required as closer examination will reveal how misleading the statistics can be if taken solely on face value. The statistic for Australia / New Zealand reflects just five accidents and a total of 33 fatalities with the percentage of passengers killed being 81%. Even if all of the accidents shared the same fatality rate of 81% (which is unlikely), this means that each aircraft carried, on average, only eight persons. This is only the size of aircraft like the Britten-Norman Islander which are aircraft with lower secondary safety requirements and therefore must be expected to suffer a high fatality rate, on average, in the event of a crash. A single large aircraft accident that killed just one person would severely skew the statistics. For example, suppose an accident occurred such as the one on the 14th

<table>
<thead>
<tr>
<th>Region</th>
<th>No. of fatal accidents</th>
<th>Number of fatalities</th>
<th>% of pax killed in crash</th>
<th>Fatal acc's per 1 m departures</th>
<th>Death risk per 1 m departures</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America</td>
<td>63</td>
<td>1971</td>
<td>60</td>
<td>0.88</td>
<td>0.53</td>
</tr>
<tr>
<td>Latin America</td>
<td>64</td>
<td>2326</td>
<td>81</td>
<td>6.04</td>
<td>4.87</td>
</tr>
<tr>
<td>West Europe</td>
<td>30</td>
<td>1663</td>
<td>70</td>
<td>1.15</td>
<td>0.80</td>
</tr>
<tr>
<td>East Europe</td>
<td>33</td>
<td>1662</td>
<td>62</td>
<td>4.11</td>
<td>2.53</td>
</tr>
<tr>
<td>Asia</td>
<td>63</td>
<td>2439</td>
<td>64</td>
<td>4.66</td>
<td>2.97</td>
</tr>
<tr>
<td>Africa</td>
<td>31</td>
<td>1110</td>
<td>79</td>
<td>13.25</td>
<td>10.52</td>
</tr>
<tr>
<td>Middle East</td>
<td>17</td>
<td>1373</td>
<td>69</td>
<td>5.47</td>
<td>3.78</td>
</tr>
<tr>
<td>Australia / NZ</td>
<td>5</td>
<td>33</td>
<td>81</td>
<td>1.34</td>
<td>1.09</td>
</tr>
</tbody>
</table>

Figure 2.2.7 Fatal Accident Rates for Scheduled Operations by Region

Redrawn from Oster et al. (1992)
September 1993 at Warsaw Airport involving an A320-211 which overran in poor weather and killed 2 souls. The capacity of an Ansett A320 is 149 and supposing that it operated at 75% load factor, the effect on Figure 2.2.7, of an accident in which 2 persons died would be as follows:

| Ansett A320 Passenger Capacity: | 149 |
| A320 Crew: | 9 |
| Souls carried at 75% load factor: | 120 |
| Accidents recorded in Australian Statistics: | 5 |
| Fatalities recorded in Australian Statistics: | 33 |
| Fatality rate recorded in Australian Statistics: | 81% |
| New total fatalities: | 35 in 6 accidents |
| New fatality rate: | 22% |

Figure 2.2.8 Effect of Single Accident on Oster et al.'s Fatality Rate for Australia

What is also confusing is the fact that the authors claim that the table does not include regional and commuter operations and yet the accidents within Australia and New Zealand appear to reflect aircraft in that class (with an average of eight seats). The only accident involving a major Australian or New Zealand carrier within the time period 1977-1989 was the loss of an Air New Zealand DC-10 in the Antarctic in 1979 with the loss of 257 lives. This is not included in the author's analyses as it was classified as a charter flight*. Oster et al. also attempted to split the accident record into the fatality rate by carrier for the period 1977-1989. The airlines considered by the authors within the Australia-New Zealand region are as follows:

| Air New Zealand |
| Ansett |
| Australian *(now QF)* |
| East-West *(now AN)* |
| Qantas |
| Air NSW *(now AN)* |
| Ansett WA *(now AN)* |

Figure 2.2.9 Australasian Airlines Used in Oster et al.'s Study

*(There is no explanation offered for the exclusion of charter flights which has the effect of removing several large accidents from the record including the world's worst involving KLM and Pan-Am in 1977 at Tenerife. It can only be assumed that this is the case because charter-only carriers are not included in the national analyses as in some countries the safety standards required for charter flights are less than those for scheduled services.)*
Every one of the Australasian carriers listed has had zero accidents and therefore scores a zero death risk per million departures. The accidents that contributed to the previous regional table were obviously not suffered by any of these seven carriers. However, although the authors claim that "regional and commuter operations" are not included in this analysis, there are no other primary level carriers operating in this area, besides the listed seven. Without examining the raw data used for Figure 2.2.7, it is difficult to really trust the analysis for fear of misinterpretation of the definitions used.

Notwithstanding this crisis of confidence, the list of accident and fatality records by carrier provides some interesting statistics to support the view that the Australian carriers enjoy an above average safety record. Selected carriers are listed below for reference and comparison. As mentioned previously, the table does not include accidents which occurred on charter flights (even when operated by ‘scheduled' carriers). Although this caveat is acknowledged by the authors, they do not give an explanation of the rationale behind it. This is unfortunate as the mix of charter to scheduled traffic by different airlines is prone to significant variation. Dan Air, for example, flew predominantly in the charter market whereas an airline like Qantas or Australian flew solely on scheduled services. The effect of excluding charter services is the removal of some very significant accidents including the Pan-Am and KLM B747 collision at Tenerife (1977), the British Airways (- Airtours) B737 fire at Manchester (1985) and the Dan Air B727 CFIT accident at Tenerife (1980).

However, the statistics do provide a reasonable indication of relative safety performance for many of the airlines listed. Ideally, the greater the number of departures made, the more significant the estimate of death risk can be. However even this ideal is affected somewhat by the time-series nature of the data and safety improvements that may occur within the period of study. Outliers in the data occur when death risk is calculated from the safety record of an airline that has completed a low number of departures and suffered an accident. For example, the single fatal accident which occurred to a TAAG (Angola) flight within their 5000 flights puts the death risk of flying at 217.39 per million departures. While such a fact may be statistically sound for the period 1977-1989, caution must be applied to using it in the predictive sense of measuring safety health of an airline.
### Safety Records for 35 International Carriers Between 1977-1989

<table>
<thead>
<tr>
<th>Carrier</th>
<th>1977/1989 Departures (Millions)</th>
<th>Fatal Accidents</th>
<th>Fatal Adjusted Accidents</th>
<th>Fatal Accidents per 1 Million Departures</th>
<th>Death Risk per 1 Million Departures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>North America</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delta</td>
<td>7.626</td>
<td>2</td>
<td>0.96</td>
<td>0.26</td>
<td>0.13</td>
</tr>
<tr>
<td>United</td>
<td>6.852</td>
<td>4</td>
<td>1.46</td>
<td>0.58</td>
<td>0.21</td>
</tr>
<tr>
<td>American</td>
<td>6.035</td>
<td>2</td>
<td>1.32</td>
<td>0.33</td>
<td>0.22</td>
</tr>
<tr>
<td>USAir</td>
<td>4.774</td>
<td>4</td>
<td>1.13</td>
<td>0.84</td>
<td>0.24</td>
</tr>
<tr>
<td>TWA</td>
<td>3.515</td>
<td>1</td>
<td>0.03</td>
<td>0.28</td>
<td>0.01</td>
</tr>
<tr>
<td>Northwest</td>
<td>3.243</td>
<td>2</td>
<td>1.47</td>
<td>0.62</td>
<td>0.45</td>
</tr>
<tr>
<td>Continental</td>
<td>3.174</td>
<td>3</td>
<td>0.87</td>
<td>0.95</td>
<td>0.27</td>
</tr>
<tr>
<td>Pan-Am</td>
<td>1.646</td>
<td>4</td>
<td>2.52</td>
<td>2.43</td>
<td>1.53</td>
</tr>
<tr>
<td><strong>Australasia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air New Zealand</td>
<td>0.914</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Ansett</td>
<td>0.903</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Australian</td>
<td>0.414</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>East-West</td>
<td>0.300</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Qantas</td>
<td>0.248</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Air NSW</td>
<td>0.190</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Ansett WA</td>
<td>0.183</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>European</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lufthansa</td>
<td>2.778</td>
<td>1</td>
<td>0.05</td>
<td>0.36</td>
<td>0.02</td>
</tr>
<tr>
<td>British Airways</td>
<td>2.674</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>KLM</td>
<td>0.860</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Olympic</td>
<td>0.844</td>
<td>1</td>
<td>1.00</td>
<td>1.19</td>
<td>1.19</td>
</tr>
<tr>
<td>British Midland</td>
<td>0.448</td>
<td>1</td>
<td>0.37</td>
<td>2.23</td>
<td>0.83</td>
</tr>
<tr>
<td>Dan Air</td>
<td>0.382</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Asia</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANA</td>
<td>2.204</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>MAS</td>
<td>1.194</td>
<td>1</td>
<td>1.00</td>
<td>0.84</td>
<td>0.84</td>
</tr>
<tr>
<td>JAL</td>
<td>1.029</td>
<td>3</td>
<td>1.55</td>
<td>2.92</td>
<td>1.50</td>
</tr>
<tr>
<td>PIA</td>
<td>0.611</td>
<td>3</td>
<td>2.24</td>
<td>4.91</td>
<td>3.67</td>
</tr>
<tr>
<td>SIA</td>
<td>0.410</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Thai</td>
<td>0.309</td>
<td>3</td>
<td>2.78</td>
<td>9.71</td>
<td>9.00</td>
</tr>
<tr>
<td><strong>Africa</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAA</td>
<td>0.732</td>
<td>1</td>
<td>1.00</td>
<td>1.37</td>
<td>1.37</td>
</tr>
<tr>
<td>Nigeria Airways</td>
<td>0.372</td>
<td>2</td>
<td>1.80</td>
<td>5.37</td>
<td>4.83</td>
</tr>
<tr>
<td>Ethiopian</td>
<td>0.179</td>
<td>2</td>
<td>1.82</td>
<td>11.17</td>
<td>10.18</td>
</tr>
<tr>
<td>TAAG (Angola)</td>
<td>0.005</td>
<td>1</td>
<td>1.00</td>
<td>217.39</td>
<td>217.39</td>
</tr>
<tr>
<td><strong>Middle East</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saudia</td>
<td>1.134</td>
<td>2</td>
<td>1.02</td>
<td>1.76</td>
<td>0.90</td>
</tr>
<tr>
<td>Gulf Air</td>
<td>0.176</td>
<td>1</td>
<td>1.00</td>
<td>5.67</td>
<td>5.67</td>
</tr>
<tr>
<td>El Al</td>
<td>0.141</td>
<td>1</td>
<td>0.01</td>
<td>7.11</td>
<td>0.04</td>
</tr>
<tr>
<td>Yemen Airways</td>
<td>0.065</td>
<td>1</td>
<td>1.00</td>
<td>15.41</td>
<td>15.8</td>
</tr>
</tbody>
</table>

Figure 2.2.10 Redrawn from Oster, Strong and Zorn (1992)
Even if the variations of national culture, which appear to be so significant in crafting a safety record, are equalised, a deeper investigation of different airline safety records indicates that other factors besides nationality are also highly significant. Barnett, Abraham and Schimmel (1979) of MIT considered the fatal accident records of 58 major world airlines including 18 US domestic carriers and 40 major flag carriers. Their authoritative text attempted to tackle some of the hazards which had affected previous attempts at classifying safety records. Five of their major concerns were that:

- Different airlines fly routes of different lengths
- Different airlines fly into different airports through different airspace
- Different airlines use different aircraft
- Some airlines have been flying longer than others
- Some of an airline’s accidents are probably not its own fault

To consider each in turn:

a) Different airlines fly routes of different lengths.

The authors refer to previous texts as having assumed that accident risk of a particular flight is proportional to its length. As mentioned earlier, the fact that the majority of accidents occur during take-off and landing discounts such a relationship. However, the dangers of low arousal of flight crew following flights of great length, leading to poor performance during landing, is acknowledged as a possible relationship. An analysis of 18 major US Carriers between 1957-76 (accounting for 54 accidents) revealed no significant relationship between flight time and fatal accident risk. No consideration is therefore given to airlines with unusually long routes.

b) Different airlines fly into different airports through different airspace.

Although the authors recognise the existence of certain airports with inadequate equipment, hazardous approaches and frequently poor weather, they do not subscribe to the notion of airlines being “hapless victims of airport conditions beyond their control”. Airlines have the ability to choose their routes and crew members will, arguably, be more alert when approaching an airport they consider to be marginal. Different routes are therefore not considered to be part of their analysis.
c) Different airlines use different aircraft.

Barnett et al. refer to the possibility that certain new types of aircraft contain design flaws which are unknown to the manufacturer or operators. An accident occurring because of such a flaw may unnecessarily affect the safety record of a particular operator. The authors claim that because this issue has arisen so infrequently, it is not worth considering. Wing breakages on Lockheed Electra aircraft due to resonance are mentioned although the early DH Comet losses due to metal fatigue are not. The early losses of DC10 aircraft are also discounted on grounds of ‘questionable maintenance’ although the loss of THY DC10 at Ermenonville was clearly the result of poor design of the rear cargo door locking system.

d) Some airlines have been flying longer than others.

Air travel has become safer over time, especially in the years following the mass introduction of jet aircraft. Boeing’s annual rates for hull loss accidents per million departures for all aircraft is shown below.

![Worldwide Commercial Jet Fleet Fatal Accidents](image)

The text recognises the problems of comparing airlines which have been operating throughout the period with newer airlines which commenced operations during the ‘flatter’ rates from the mid 1970’s. The problem is solved by examining airline safety records within several shorter periods of time.
Some of an airline's accidents are probably not its own fault.

There are several circumstances where an airline may be seen to have no control over the occurrence of a particular accident. These may be the result of unpredicted severe weather conditions, midair collisions or sabotage. Barnett et al. refer to these as 'bad luck' and argue that such bad luck is, by definition, randomly distributed amongst airlines. (Luck is a difficult concept to justify in academic research work and will be covered in greater detail later).

In an attempt to rate the airlines' safety records over a particular time frame the authors developed a measure of total involvement in disasters to be measured against the number of flights completed. Although a commonly used measure of accidents is fatalities (for example, Boeing use fatalities to demonstrate the importance of loss of control and CFIT accidents as the most prolific killers in aviation.), such a measure does not take account of the difference between one crash in which 150 die as oppose to three crashes where 50 die in each. Another measure is the proportion of an airline's flights which suffered fatal accidents. However, this ignores factors such as passenger load and how many survived as a result of airline-controlled factors such as the quality of emergency procedures.

The solution was to produce an alternative safety measure called the "cumulative fatality quotient" (CFQ). The fatality quotient (FQ) is defined as the fraction of passengers who do not survive any given flight and the CFQ incorporates the total number of flights studied. From this figure, the authors derive the "average fatality quotient" (AFQ) as a measure of overall safety performance or in other words, the probability that a person would die on any flight during the studied period chosen at random.

The 18 US domestic carriers were considered first and these results are considered to be outside the remit of this thesis. However, a good demonstration of the dangers of regionalising statistics is provided by the authors which is worth consideration. By converting the calculated AFQ values, the odds of being killed on a US domestic flight are shown;

<table>
<thead>
<tr>
<th>Period</th>
<th>Odds of Being Killed on a Flight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1957-61</td>
<td>1 in 988,000</td>
</tr>
<tr>
<td>1962-66</td>
<td>1 in 1,087,000</td>
</tr>
<tr>
<td>1967-71</td>
<td>1 in 2,064,000</td>
</tr>
<tr>
<td>1972-76</td>
<td>1 in 2,599,000</td>
</tr>
</tbody>
</table>

These results clearly demonstrate the considerable improvement in aviation safety over the 20 year period and yet also show a clear disparity between the US and the rest of the world;
Notwithstanding the constraints stated at the outset, Barnett et al. produced a table of accident records for 40 major international airlines between 1960-1975 which is presented below;

Safety Records for 40 International Carriers Between 1960-1975

<table>
<thead>
<tr>
<th>Airline</th>
<th>Number of Flights (000's)</th>
<th>Expected CFQ (under model)</th>
<th>Actual CFQ</th>
<th>Death Risk per Flight (AFQ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aer Lingus (Ireland)</td>
<td>430</td>
<td>1.62</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Aeromexico</td>
<td>74</td>
<td>0.23</td>
<td>1.05</td>
<td>14</td>
</tr>
<tr>
<td>Air Canada</td>
<td>600</td>
<td>2.23</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Air France</td>
<td>1379</td>
<td>5.01</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Air India</td>
<td>132</td>
<td>0.47</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Alitalia</td>
<td>883</td>
<td>3.04</td>
<td>1.86</td>
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Figure 2.2.14 Redrawn from Barnett, Abraham and Schimmel (1979)
Death risk can be seen to vary between zero and 88 (per million flights) with Qantas being rated as zero. Closer examination by the authors revealed an apparent size dichotomy where larger airlines experienced significantly fewer than predicted accidents and smaller airlines, the opposite. However, even though Qantas and El Al (Israel) are classified as small airlines, they stand out as exceptions to the rule. Barnett et al. speculate that this may be that the key safety factor is not the size of an airline but the level of “technological development of the mother country”.

In 1993, the International Airline Passengers Association (IAPA, 1993) completed a safety rating exercise using ten years of data in an attempt to “...predict the future risk of a particular airline having a fatal accident”. Six months of research led to the formation of a method to rate the relative safety of the world’s airlines. This included both the more easily quantifiable factors such as accidents per million flights or deaths per million passengers and more difficult factors such as the quality of pilot training and maintenance. Unusually, it also considered other factors such as value of fleet, age of aircraft, its country’s air traffic infrastructure and government commitment to safety. Although IAPA conceded that they rated certain airlines as safe, they could not guarantee that they would not have a fatal accident in the future. There was also scant explanation of the methodology or the criteria used to assess the qualitative factors.

Airlines were classified by size in the following way:

**Group A: The Best of the Biggest**

*Qualifications - Over the past ten years:*

1. At least 2,000,000 flights.
2. Less than one accident per 2,500,000 flights.
3. Less than one fatality per 4,000,000 passengers.
4. Fleet age under 12 years.

**American Airlines** (over 9,000,000 sectors without loss)
**British Airways** (one accident in 3,000,000 flights.)
**Delta** (one accident per 4,000,000 flights.)
**Lufthansa** (one fatality per 20,000,000 passengers.)
**Scandinavian** (SAS) (accident free for over 24 years.)
**Southwest** (largest airline in the world never to have an accident.)

Figure 2.2.15 IAPA Safest Airlines Group A Redrawn from IAPA (1993)
**Group B: The Best of the Mid-Sized Airlines**

*Qualifications - Over the past ten years:*

1. 1,000,000 to 2,000,000 flights.
2. Zero accidents.
3. Fleet age under 12 years.

**All Nippon Airways** (ANA) (No accidents in 22 years.)
**America West** (No fatalities.)
**Ansett Australia** (No jet crashes in over 25 years)
**Canadian Airlines International** (Only accident with more than one fatality in last 25 years.)
**Saudia** (12 years since last accident.)

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**Group C: The Best of the Medium-Small Airlines**

*Qualifications - Over the past ten years:*

1. 600,000 to 1,000,000 flights.
2. Zero accidents.
3. Fleet age under 12 years.

**Alaska Airlines** (One fatality 17 years ago.)
**Finnair** (No jet crashes ever.)
**KLM** (No accidents in 16 years.)
**Malaysian** (No fatalities in 15 years.)
**Swissair**

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A month after the original list was published in August 1993, IAPA added to the list the four small airlines it considered to be the safest. In alphabetical order, these were Cathay Pacific, Qantas, Sabena and Singapore Airlines. All four “...are in politically stable countries, have a long history of excellent management and take their airline’s safety very seriously” (IAPA, 1993b).

Although Ansett and Qantas are mentioned as being among the safest, such a statement should only be seen as corroborating the work of Barnett *et al.* and not a standalone judgment. The
lack of explanation regarding either the selection of classifications or the quantification of qualitative data do little to add to the credibility of the statistics. There are a number of apparent oversights which deserved further investigation.

For example, the statement concerning SAS being accident free for over 24 years seemed to ignore the occasion in 1991 when an MD-80 aircraft suffered a double engine failure on climb and crashed in a nearby field. Although the aircraft broke into three parts and was a total hull loss, there were no fatalities, largely on account of a nearby wood which dissipated some of the energy of the aircraft before it touched down. IAPA argued that its definition of an accident required there to be a fatality (contrary to the ICAO and IATA definitions) because “...IAPA feels that what passengers care about most is fatalities.” (Burchill, 1994). Although IAPA eventually conceded that the accident was “…100% avoidable and a disgrace to modern aviation” (Margolis, 1994), the fact that such an accident had no different a set of causal factors than a fatal accident casts a shadow on the reliability of such statistics for assessing the true safety health of an airline.

As there were no fatalities in this accident, should it affect the safety record?

All of these statistics demonstrate a similar theme which is that, although it would be unwise to take the rating of airlines as being a guarantee as to the future safety of particular operators (indeed, the loss of an American Airlines B757 near to Cali at the end of 1995 reset the airline’s 9 million sectors without loss record.), they do give some indication of safety performance. What is also true is that the principle Australian carriers (Qantas, Ansett and Australian Airlines) consistently appear as ‘above average’. It would be quite pointless and rather foolish to try and prove (or even suggest) that the Australian carriers are the safest in the world. Movie watchers may have delighted in the spectacle of the autistic Raymond from the film Rain Man refusing to fly on any airline other than Qantas as “Qantas never crash...” but such an assertion is not open to scientific proof and neither should it be.
The fact is, as David Learmount (1987) put it, that; "...anybody in the air transport business will recognise that Qantas is operationally excellent", but as soon as anyone tries to prove that they, or indeed any other operator, are the safest then they enter the realms of pure speculation. Statistics allow researchers to see that the safety record is above average and offer lessons for operators all around the world.

This analysis confirm the difficulties of using statistics to examine both safety records and the safety health of any airline or country. Nevertheless, they also seem to agree that the record for Australian carriers is above average by virtue of zero hull losses in commercial jet RPT aircraft. Detractors of the record would point out that should Australia lose a large aircraft such as a B747, then the statistics for Australia’s safety record would change significantly due to the comparatively low number of sectors flown and the current zero loss score. While this may be true in the pure statistical sense, such logic would seem to suggest that the only way to measure the safety record accurately was if there was a crash to divide the number of sectors flown by. In other words, ‘zero’ hull losses is not a good number for statisticians to work with! Even if such an accident occurred tomorrow then the important question to answer is, would such an incident negate the value of this research project. The answer is most likely no as this work can only hope to cover what has created a good safety record so far. It can also advocate strengths that can be maintained and weaknesses that must be addressed but it cannot guarantee a continued good safety record.

Flight International (Taylor, 1991), Boeing (1993), Eastburn (1987), Oster, Strong and Zorn (1992), Barnett, Abraham and Schimmel (1979) and IAPA (1993) all produce evidence which puts Australian aviation or its main airlines (Qantas, Australian and Ansett) at the top of the list in terms of safety record. Even though some of Oster, Strong and Zorn’s (1992) data seems to suggest the Australasian rate is worse than North America, they do not present sufficient data to explain this relative to their list of seven carriers from the region, all who have a fatal accident rate of 0.00 per one million departures. ICAO refuse to release comparative safety statistics and the IATA statistics are not useful for this research project by virtue of Australia being included into the diverse ‘Asia Pacific Region’.

It is the contention of this thesis that none of the statistical techniques that are currently available are sufficient to be used exclusively to answer the question “Is Australia’s Safety Record Good?” However, as they all seem to say similar things about the Australian record, it seems fair to assume for the purposes of this thesis that Australia’s record for jet RPT operations is above average or ‘good’. This is not to suggest that it is the best or will continue to be above average in the future, but it does provide sufficient support to use Australia as a case study to examine the reasons behind safe aircraft operations.
2.3 How Do We Define Safety?

There is a strong relationship between aviation and safety. This is possibly because aviation has the potential to be so dangerous or conversely, because it is so statistically safe as a mode of transport. Either way, the condition of 'safe' is something that all aspects of aviation strive towards, but does anyone really know what 'safety' actually is? In the absence of a universal description, it is entirely possible that everyone is aiming towards a different goal.

2.3.1 The Definition of Safety

The Collins English Dictionary defines safe as being "the quality or state of being free from danger", but such a loose description allows many interpretations. If 'safe' is used in the absolute form of meaning free from any danger then it can only really be directed towards a simple cause and effect relationship. For example, if a baby and dog are kept together in the same room then there is a danger that the baby could be attacked by the dog. By removing the animal from the room, the baby may be considered to be free from that danger and therefore safe. However, this does not account for the fact that there are other dangers in the room such as falling furniture or electrical appliances. In the wider sense, the removal of a particular risk is rarely a guarantee of absolute safety. Real life situations will be prone to a variety of risks - the absolute definition of safety would suggest that if this is true then it is all but impossible to achieve safety.

Safety is not measurable; risks are measured. Safety may be judged relative to its level of risk versus the acceptable level of risk. To determine safety therefore, involves two quite separate activities; measuring risk and judging safety i.e. the acceptability of risks. It is therefore vital to reconcile the term safety with risk.

A deeper investigation of the meaning of safety is not a new thing. Lowrance (1976) remarked on the "...widespread confusion about the nature of safety" adding that "...for a concept so deeply rooted in both technical and popular usage, safety has remained dismaying ill-defined". His chosen definition of safety - "a thing is safe if its risks are judged to be acceptable" acknowledges the impossibility of eliminating all risk and adds the relativity and judgmental nature of safety. Safety is a state which may be defined by individuals and is therefore potentially variable in its definition. Some definitions of safety refer solely to human life. Jones-Lee's (1989) exploration of safety and decision making refers exclusively to "the safety of human life and the degree of protection from physical risk". The Royal Society (1992) clearly states its understanding of the concept of safety as:

"Safety relates to the freedom from risks that are harmful to a person or a group of persons, either local to the hazard, nationally or even worldwide. It is implied that for the consequences of an event to be defined as a hazard, i.e. a potential for causing harm, there is some
risk to the human population and therefore safety could not be guaranteed, even if the risk is accepted when judged against some criterion of acceptability”.

Safety is a delicate balance - an ideal state and yet one where the true condition can only be known in retrospect. Experience and experimentation lead to a level which may be labelled as ‘safe’ and yet there is no guarantee that safety is to be achieved. This is a function of two things - the problem of defining an ‘acceptable’ level to be labelled ‘safe’ and the variability or unpredictability of certain risks.

Before it is possible to understand these problems, it is necessary to explore the concept of risk in more detail.

2.3.2 The Definition of Risk

Risk is a word of many meanings: Although it is relatively simply defined by the dictionary as "chance of bad consequences of loss", it is a word that is used in different contexts to mean different things. It is therefore important to develop a working definition of risk for use in the context of this thesis.

Solomon (1993) points to three quite different contexts in which the concept of risk occurs;

1. In a decision-analytical sense, risk refers to the fact that the consequences of choosing an alternative are not known with certainty, but instead can be expressed as a probabilistic outcomes. In this sense, no reference needs to be made about the positive or negative effect of the consequence.

2. The popular view of risk emphasises the probability of a potential harm and focuses on the probability of that harm without regard to the (negative) magnitude. The benefits in this sense are completely ignored.

3. Between these two viewpoints lies a third definition of risk - the probability of an event times the consequence of an event summed over all events.

The Royal Society’s (1992) definition is closest to the third of Solomon’s statements, reading “risk is a combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence”. Both definitions clearly indicate the components of magnitude and probability as being critical to any risk.

Previous to the Royal Society, the Council for Science and Society (CSS 1977) also explained the concept of risk relative to hazards. A hazard describes a situation with "the potential to cause harm (to people, property or the environment)" and risk in turn refers to "the probability that the potential hazard will be realised". This definition accepts that the consequence of a hazard (and realised risks) can be more than the human loss that is so often referred to.
All of these definitions suggest that some measure of risk is possible in the form of an objective quantitative probability. In its absolute sense then this may be true, but the wide use and misuse of the term 'risk' raises the possibility of it being used to mean rather different things.

Risk may be considered as the possibility of misfortune or loss and is based on probability (whether calculated or perceived). "All activities have an inherent risk and risks can never be removed completely from any activity." (Solomon, 1993) In common usage, the word 'risk' is generally associated with 'high risk'. Phrases which describe an activity as being 'open to some risk' or an individual's actions being 'risky' suggest that the risk is higher than normal. All activities, by definition, carry some element of risk. The confusion appears to lie in discriminating between risk and safety. Activities which are deemed to be safe still carry an element of risk. The presence of risk does not necessarily equate with a lack of safety.

There is no unique measure of risk because there are so many different types of exposure to risk. For example, whereas all the population are exposed to cosmic radiation and therefore, the risk of malignant neoplasms can be calculated per group of population, only a limited number of people are exposed to, say, the risks of a motorcycle accident by virtue of the fact that only a small population ride motorcycles.

The measure of "accidents" can also be quite different. While fatalities may seem to be a reasonable and easily defined measure, it can also give a false impression. For example, as Solomon points out, one hundred car accidents each with a single fatality is not perceived to be equivalent to a single accident that kills one hundred people. Even classification of accidents by fatal, serious and minor injuries may be misleading as it ignores the 'quality of life' issue. As human life can not be readily valued (except by arbitrary figures for cost benefit analysis), it is even more difficult to try and suggest a value for a serious injury than for a fatality. For example, the following diagram suggests a possible distribution of accidents for two industries.

![Figure 2.3.1 Frequency versus Severity of Accidents](image-url)
The fatality rate for paper mills may be low compared to that of air travel but there may be a significantly higher number of maimings and less serious injuries. Therefore, fatalities as a stand alone measure may prove to be misleading as a measure of overall ‘risk’.

The risk measure must therefore be sensitive to the nature of the particular risk it is designed to represent. If the risk relates to catastrophic events such as dam bursts or ferries lost at sea, it is sensible to measure the probability that more than a given number of people are killed in an accident in a particular time period. According to Solomon, this provides a useful measure of distribution for comparing the way they are perceived psychologically.

An alternate measure is the expected number of fatalities within a particular group over a specified time (e.g. airline passenger fatalities per n hours flown.)

Lowerance (1976) suggests evidence regarding hazards may be gathered from a multiple of sources such as:

- Traditional or folk knowledge
- Common-sense assessment
- Analogy to well known cases
- Experiments on human subjects
- Review of inadvertent and occupational exposure
- Epidemiological surveys
- Experiments on non-human organisms
- Tests of product performance

Johnson and Covello (1987) discuss the social construction of risk highlighting the issues behind “...the claim that risk is a social construct stemming primarily or wholly from social and cultural factors”. One perspective is that this implies “...that people are incapable of perceiving what is really dangerous since there are no actual or objective risks in the world.” Risk perception research sees the convergence (and even divergence) of psychology, sociology and politics in an attempt to explain a process that is governed by “...knowledge, values and feelings and is considerably dependent on the cultural / societal context.” (Rohrmann, 1995)

2.3.3 Risk as a Societal Construct

Rohrmann (1995) observes that the concept of risk has become ever more topical during the last decade. In particular, the hazards perceived to be posed by large-scale technologies such as nuclear power and chemical industries have led to an increased awareness of accidents (acute threat) and longer term environmental or health damage (chronic threat). Add to this an increased awareness of the human sciences of psychology, physiology and sociology and the result is an increasingly complex societal decision making process.
It is the subjective nature of 'risk' which demonstrates the role of society in creating and enhancing the concept. Regardless of the efforts of international human rights activists, the fact remains that the price of human life still varies significantly around the world.

The implications of this for aviation safety will be discussed in greater detail elsewhere in the text, but it is important to precede this with an explanation of the concept of risk acceptability as this represents the link between risk and safety.

2.3.4 Risk Acceptability

"The term risk acceptability conveys the impression that society purposely accepts risks as the reasonable price for some beneficial technology or activity." (Kasperson and Kasperson, 1984) Logically this is exactly right; society does accept risk and yet, as a result of confused usage of the term, there is a perception that risk is not acceptable in any form. Kasperson and Kasperon continue to suggest that in respect to the above statement; "...For some special cases this may approach reality. Hang-gliding, race-car driving, mountain climbing, and even adultery, divorce, and midlife career changes are all high-risk activities in which the benefits are intrinsically entwined with the risks. These activities are exhilarating because they are dangerous. But most risks of concern are the undesired and oft unforeseen by-products of otherwise beneficial activities or technologies." (Kasperson and Kasperson, 1984).

The Norwegian safety society, Det Norske Veritas, provides a clear explanation of the process of risk acceptability;

The criteria for the acceptance of risk in relation to the safety of human life spring from each person's attitude towards safety and also from social conditions and the attitudes of the mass media and politicians. We are here faced with a spectrum of attitudes. Some of these may serve as starting points for rational evaluations and decisions: other attitudes are too 'narrow' or emotional to provide general norms." (Det Norske Veritas, 1979)

"The acceptable level of risk is not the ideal risk. Ideally, the risks should be zero. The acceptable level is a level that is 'good enough,' where 'good enough' means you think that the advantages of increased safety are not worth the costs of reducing risk by restricting or otherwise altering the activity." (Slovic, Fischoff and Lichtenstein, 1980)

2.3.5 Is Acceptability the same as Affordability?

The notion of 'affordable safety' seems to bring shivers to the collective spines of professional aviators throughout Australia. This is largely a function of the man who first popularised the phrase and his interpretation of it. During his time as Chairman of the Civil Aviation Authority (Australia) Board, Dick Smith was responsible for a wide-scale restructuring and down-sizing of the authority which was very unpopular with a large cross-section of the aviation industry. "Those who object to the term 'affordable safety' saw it as a key feature of the
period they considered to be the 'dark ages' of aviation safety regulation in Australia or the 'slash and burn' period of safety regulation. This was the period when Smith was chairman of the CAA" (House of Representatives Standing Committee, 1995)

The House of Representatives Standing Committee explains affordable safety as being a concept with two separate parts:

a) Changes and standards are market driven and if the costs of regulatory changes are too high, excessive ticket prices will result in fewer people flying and more people using less safe road transport.

b) There is a finite 'safety dollar' which, in the case of the CAA meant reallocating resources to maximise lives saved.

The House of Representatives Standing Committee concluded that there was nothing objectionable about affordable safety although they conceded that this was not a term they would use. In fact, the whole concept of safety is based upon affordability, that is the point at which we consider certain risks to be acceptable. i.e. where we consider resources allocated to risk countermeasures to have reached the reasonable limit. Nevertheless, the concept of affordable safety as defined above is worth deeper consideration.

The concept of the market regulating aviation safety is based on the economic forces which balance the cost of risk countermeasures against the risk and cost of accidental consequences. However, Smith's argument seems based on the actions of the end user i.e. the passenger - the very section of the community who are the least informed about aviation safety matters. Chalk (1987) suggests that "...although consumers lack the technical expertise to measure the inputs to safety provision, they can measure the output - fewer accidents. If consumers are informed about accidents for which an airline or an aircraft manufacturer is considered culpable, they can avoid riskier airlines and aircraft and manufacturers." The crucial question is who is responsible for the communication of critical safety related information and how is its integrity assured?

The mass media is the principal conduit for information with the great variations in reliability that is associated with a communication method whose success is measured in sales or viewing figures. A recent example of the variations would be the stories that have been published regarding the cause behind the loss of TWA800 off Long Island in June 1996. Stories have circulated and been aired which talk about terrorist devices, a 'friendly-fire' missile or an explosion in the centre wing fuel tank. Passengers could easily come to the conclusion that airport security in the USA was deficient, US airspace unsafe, or the Boeing 747 a defective aircraft. Even on the single issue of the aircraft suffering a catastrophic in-flight failure, will the average passenger be provided with enough facts to decide whether the failure was a result of poor maintenance on the part of Trans World Airways, a design fault on the aircraft or a result of the aircraft being 25 years old. Indeed, if they decided that the problem was a
design fault on the Boeing 747 then how many passengers would know the difference between the Classic (-100, -200 and -300 series) and Advanced (-400) series aircraft? As the Boeing 747 is the mainstay of international operations is it reasonable to believe that such a process is affecting modal choice?

The acceptability of risk is not the same as the elimination of it. Everyone accepts risks in one form or another as part of daily life and if this was not the case then people would probably soon die of dehydration or starvation (drinking water or eating food also includes a risk taking decision). The crucial factors that set skydiving grandmothers apart from those who sit darning socks and, moreover, those which appear to separate ‘right stuff’ aviators from the average airline pilots, seem to be the level of acceptable risk. What is most important to the integrity of the aviation industry is that the decision makers, at whatever level, are armed with an accurate perception of risk acceptability. Slovic, Fischhoff and Lichtenstein (1980) note that “people respond to the hazards they perceive” and consequently if these “…perceptions are faulty, efforts at public and environmental protection are likely to be misdirected.”

Safety, based upon the concept of risk acceptability is perhaps best explained in the form of a very simple diagram;

![Figure 2.3.2](image)

Absolute safety is achieved when risk exposure is balanced perfectly with safety measures. This is a Utopian system that can never be achieved as it relies on complete knowledge, not only of the full set of risks which may occur, but also the full properties of safety measures. The accident record shows that accidents are occurring because of risks that were unforeseen (e.g. metal fatigue in the early Comet aircraft) or the full effect of safety measures were unknown (danger-side failures such as the role of assistant bosun on P & O’s ‘Herald’ Ro-Ro ferries to inform the bridge if bow doors were not closed before the ship set sail).
Figure 2.3.2 represents a perfect economic system where the amount spent on risk-countermeasures is precisely balanced by the savings on accidental losses. It has never and will never be achieved in any system that has a human involvement, such is the inherent nature of human error. 

In accepting that this ideal is a point to aim for, safety professionals attempt to create a system where the balance is as close to perfect as possible. This process is an attempt to achieve the ‘point’ of risk acceptability - an area of balance where the wastage is minimised.

One interpretation of acceptable risk is presented schematically above (Figure 2.3.3) where the level of risk exposure is slightly greater than the level of safety measures. If all of the risks were to present themselves then accidents would still occur, but as this is unlikely, the above schematic demonstrates a situation where the safety measures which are selected represent the best guesses or most effective measures. The safety system will cover the most common events or most dangerous events, but this may still mean that some accidents will occur. The clever science is in predicting the risk exposure profile accurately and preparing a set of countermeasures which adequately caters for it.

If the level of risk exposure is allowed to become too great then the balance will tip towards unsafety. Conversely, if the safety measures are excessive then the balance will tip towards a condition of ‘over-safety’ where economic efficiency is lost. In the greater scheme of things this may mean new safety problems for other systems elsewhere. For example, if aviation became so expensive for this reason, then travellers may switch to cheaper modes such as car travel with inferior safety records which are cheaper to use.
It is, however, worth considering that there is a point on the safety balance where acceptable safety and 'oversafety' start to meet where resource allocation affects the margin of safety that is often afforded in complex systems. The 'extra safety' that is often included in a system 'for a rainy day' or to 'round up' safety calculations may be responsible for catching some of the outlier accidents which would have occurred if the balance of acceptable safety had been more strictly enforced. It is possible that part of Australia's good safety record is as a result of this additional safety margin - decisions that may have appeared uneconomic at the time but in retrospect have been useful and necessary measures.

Too much risk is undesirable; as is too much in the way of safety measures. Economic inefficiency leads to the substitution of resources - a grand version of what Smith (House of Representatives Standing Committee, 1995) refers to as the finite safety dollar.

These schematic balances represent various processes which act to influence the level of safety in a particular system. This may be in the formal sense of cost-benefit analysis or quantitative risk assessment (QRA) where the risk exposure is quantified (in financial cost, human life and so on) and measured against the cost of safety measures, or may be in the less formal sense of an individual's attitude towards risk taking or the power of market forces to decide what it considers to be an acceptable balance.
2.3.6 Getting the Balance Right...

There are many interpretations of what is safe. If it is assumed that safety is the condition where risk is controlled to an acceptable level, then the problem of defining the term safety is shifted to that of defining the level of risk which is acceptable. This concept will be explored in more detail throughout this thesis, but is important that the reader understands the difference between safety and risk at an early stage.

It is suggested that Australian aviation may possess a different perception of acceptable risk than other countries / authorities / airlines around the world and it is important that these differences are examined, if they do in fact exist. In simple terms, the following issues will be considered:

- Do Australians possess a lower acceptance of risk?
- Does Australian aviation possess a lower acceptance of risk?
- Do Australia’s airlines possess a lower acceptance of risk?
- Does aviation recruit individuals who possess a lower acceptance of risk?
- Does Australia have the same risk acceptability but lower exposure?
2.4 How Do We Measure Safety?

Although it has already been suggested that safety cannot be measured (only risk can be measured), as safety is an outcome and not a state, it is important to make a distinction between attempting to measure safety (as a state) and measuring safety records. A number of attempts have been made to do the latter (which is valid when used to look at a historical outcome) and most attempts to do the former have ended up being a disguised version of the latter!

Measuring safety records gives important safety trend information, but can also be misleading. Two methodologies of measuring safety (used by academia and industry, and the consumer) are discussed below;

2.4.1 Statistical Measures of Safety

The production of ‘safety statistics’ is a prolific industry by itself, based upon the premise that a record of accidents or incidences is the measure of how ‘safe’ a particular activity was. The most commonly used measures are in terms of fatalities or simply ‘events’ over time.

Fatalities, (or often fatalities per 100,000 persons per year) is a favoured measure because of the requirement to report such occurrences, usually through the coroner’s office. This allows reliable statistics to be collated for analysis on an international level. Deaths are classified by an ISO (International Standards Organisation) code which cover all but the most bizarre causes of death. Such records exist for a number of years and often in computerised form to demonstrate data trends and smooth out statistical noise.

Mortality rates for the general public that include death from ‘natural causes’ (disease and natural disasters) put the risk from accidents into perspective. Solomon (1993) documents statistics on mortality from the Universal Almanacs as follows;

<table>
<thead>
<tr>
<th>Typical Mortality Rate for the General Public in the USA averaged from 1965-1992.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Fatalities per 100,000 persons per year)</td>
</tr>
<tr>
<td>Total risk</td>
</tr>
<tr>
<td>Death from disease</td>
</tr>
<tr>
<td>Death from all accidents</td>
</tr>
<tr>
<td>Death from natural events</td>
</tr>
</tbody>
</table>

Figure 2.4.1 Typical Mortality Rate for the General Public in the USA Solomon (1993)
Heart disease accounts for well over a third of all deaths (360 per 100,000 persons pa) or well over six times as many as from all accidents. However, safety statistics are rarely grouped in such a way as to bring the full spectrum of hazards together. Accidental deaths are grouped together and then often split into occupational hazards, transport, sport etc. Some would argue that accidents should be separated because they are, by definition, preventable. However, many of the deaths due to disease are also preventable (e.g. some heart and lung diseases due to smoking) as are some of the deaths from natural events (e.g. those living on flood plains).

The problem with comparing safety records between different modes of transport is finding a fair measurement to use. Some modes are used more than others, cover greater distances and operate at different speeds. Further, the level and severity of injury experienced from certain transport modes is highly variable e.g. slow speed modes like bicycles attract more injury accidents than fatalities in contrast to, say, aircraft travel. To compare air travel with bicycle travel over a fixed mileage would favour air travel unless modes were compared solely on the basis of fatal injuries.

Solomon observes the level of accidental deaths between transport modes in the USA to conclude that flying is very much safer than car travel in terms of accident rate per one hundred million passenger miles.

![Accidental Transportation Deaths per 100 Million Passenger Miles](image)
Reason (1993) however, provides a compelling warning to those accepting this apparently 'safe' situation at face value. If the average failure accident rate for commercial aviation is taken to be approximately one per million flying hours, this is a mortality rate 2-3 times worse than the UK accident risk in cars since wearing seat belts became mandatory. In turn, aviation has a mortality rate sixty times that of passenger trains. Car journeys are generally short in nature (compared to air travel) and accidents are often non-fatal. Railway accidents are relatively infrequent and have a higher degree of survivability than air accidents.

Woodhouse and Woodhouse (1997) argue that the most reliable indicator of risk in aviation is accident rate (accidents per million sectors). They suggest that, “Accidents are a more appropriate numerator than either fatal accidents or fatalities because the survivability of accidents is so much a matter of chance.” However, they also add a cautionary note regarding the existing databases of aircraft accident statistics. “Until 1993, notification of accidents to ICAO was a recommended practice rather than a standard. ICAO data is therefore incomplete, particularly for ‘serious damage’ accidents”.

Waldock (1992) wryly observes the problems of observing 'safety' in aviation even through the collection of accident statistics; “...they are rare events; they don’t happen frequently enough to generate a large enough population to be valid. One bad accident can skew the statistics drastically. If we had more accidents to work with, we could probably do a better job of measuring safety by statistical analysis”.

2.4.2 Reporting of Occurrences

The integrity of statistics is fundamentally controlled by the quality of the data from which they are sourced. In other words, safety statistics are only of any real use if they represent the full picture. This is one of the reasons why transportation safety statistics tend to use only fatalities to compare records between modes. While fatal accidents must, by law, be reported to the coroner in most countries, serious injury or minor injury accidents do not need reporting. Therefore statistics which claim to describe ‘all accidents’ may be incomplete because of this reason.

Although ICAO Annexe 13 requires the reporting of all aircraft accidents, it is apparent that certain member states have not followed this directive. Accidents within former Soviet states and China are known to have occurred and not reported. For example, in one accident a Chinese B737 was lost and the airframe written off by the insurance company although is still yet to be reported as an accident to ICAO. For this reason, aviation safety statistics tend to exclude losses from these areas and to ‘Eastern built’ aircraft types.

Incident reporting is a safety measurement tool which is being increasingly used around the world. However, it remains a source of confusion as a result of the way such reporting systems are set up. Incidents may mean a very near accident - this may be a spectacular event with lots of witnesses such as a near-miss in mid-air or a go-around executed to avoid a runway
incursion, or they may mean an ‘invisible’ event such as flight crew falling asleep in flight or a single GA pilot nearly colliding with terrain outside controlled airspace. Although some countries such as Australia do have a mandatory incident reporting system, many do not and therefore depend on voluntary reports by flight crew or air traffic controllers and this is why databases tend to be incomplete. Whether the reporting system is mandatory or voluntary, the crew or controllers involved need to recognise that they have had an incident and then, in the case of voluntary systems need to believe it important enough for them to fill in the required paperwork. This is often at the end of a long trip when crew members would rather go home if they can get away with it. Individuals may also wish to consider their legal position in filing a report. Although airline and national systems such as Australia’s CAIR system or NASA’s ASRS systems are run as confidential and non-punitive systems, there is a growing concern that any safety critical information which is recorded may be subpoenaed in a court of law. This is because although agreements exist between the aviation regulators, airlines, unions and crews, they can still be overruled by Federal courts. While this is a issue that has yet to develop into a real problem, its threat has been enough to cause incomplete reporting of incidents. Further to these reasons, there is also the simple fact that individuals may choose not to admit to an incident because they are embarrassed or ashamed that something has happened to them and no-one else needs to know.

As the ways to report incidents improve such as through better access to, or better designed reporting forms so too the number of incident reports will rise. This has caused some consternation in organisations which have successfully encouraged incident reporting as incidents appear to escalate. The crucial distinction is that it is generally only the number of reported incidents that have increased which is actually a good thing in terms of organisational safety. British Airways is proud to report an average of 2000 reports a year for its BASIS confidential reporting system and contrast this against a certain US major airline which claims to have ‘no incidents’ to report (Hunt, 1994). Unless complete incident reporting can be guaranteed (which is unlikely), the number of incidents is only a very rough safety measurement tool. Even if the absolute number of incidents is ignored for the reasons stated above, and analysis is restricted to the proportion of incident types, this is still prone to a level of error. It assumes that those reporting the incidents are able to accurately spot and assess the severity of incident types. It may be that the most dangerous proportion of incidents are those that remain unrecognised and therefore invisible in published incident statistics.

2.4.3 The Customer and Measures of Safety

Although accident statistics are collected and prepared by a number of agencies, it is important to recognise the potential for these figures to be misquoted or used selectively outside of aviation. The customer’s measures of safety do not follow rigid rules of academic rigor and can be influenced by a number of subtle processes. One of the strongest influences comes from the media which is a point that must be borne in mind when tackling the subject of safety measurement.
2.4.4 Measures of Safety and the Media

Safety is generally negatively reported. In other words, it is only mentioned in times of unsafet. This is especially so in the mass media where accidents sell newspapers and increase television ratings. Coverage of accidents appears to be proportionate to the 'visibility' of the event. Large railway accidents in which only a single person dies often command far more coverage than small car accidents where two or three die. For example, in 1985, two passenger trains collided at Colwich Junction near Stafford with the loss of one of the drivers. The crash scene was spectacular and the story covered most of the first six pages of the tabloid Liverpool Echo (the destination of one of the trains). On the seventh page of the newspaper, a story about the death of two locals in a car crash filled three inches of single column space.

Aircraft accidents in particular seem to attract a disproportionate amount of attention because they often involve a high number of fatalities in a short period of time and leave a large amount of wreckage. The presence of explosions and fire only heighten the visibility of such events. The relative novelty of mass travel by air means that many generations still retain a mystified view of aviation which both propagates and in turn is propagated by the mass media.

The media's prime task is to bring fast and up to date information to its customers which is often contrary to the objectives of safety investigators who are trying to ensure integrity of information over speed. In the first hours and days following an aircraft accident, there is often a mass of speculation which can mislead the public. By the time accident investigators have done their job and produced a complete accident investigation report, the public interest has often waned. Hence, misconceptions formed at the speculative phase tend to live on in the public's perceptions. Once an airline has become 'unsafe' in the eyes of the public then the restoration of trust is a difficult task. For example, early accidents to Dan Air aircraft left a legacy of jokes regarding the integrity of the airline until its take-over by British Airways. The notion that the airline suddenly became that much safer once a new livery was applied is a little ironic when it was British Airways that operated an older short range fleet and who took over Dan-Air's expertise in crew resource management.

The crucial point is that although the media is capable of leaving the public with a misdirected perception of safety matters, it is that perception that ultimately influences their decision making. Curtis (1996) observed the way aircraft accidents were reported in the New York Times between 1978 and 1994 to examine the nature of media bias. The conclusions were that jet aircraft events were more likely to be reported than corresponding propeller aircraft events ( categorised by fatalities) and that although fatal accidents were reported with a greater magnitude, the more fatalities involved, there was no clear relationship between the amount of coverage and the number of fatalities. More specifically, Curtis suggests that the reporting of deaths caused by hijack, sabotage or military action is disproportionate enough to leave readers with a distorted view of the hazard.
The influence of the mass media can also work in reverse albeit with less regularity in practice than a negative effect. The 1987 film *Rain Man*, starring Tom Cruise and Dustin Hoffman, left the public with a rose tinted view of the integrity of Qantas over other international airlines which continues today. During the course of this research, much comment has been made by non-experts about the subject. Most people have heard of Qantas as being the safest airline in the world and then quote the source of knowledge as the film. If Hollywood says that “Qantas never crash”, then it seems, that this is good enough for the man in the street.

However, it is also worth noting that the influence of the media can also be positive. Disproportionately high levels of attention on aviation safety heighten consciousness and awareness. As such this is not always a bad thing for future progress. Funding for safety measures, research or additional safety staff is often much more forthcoming following a serious accident. The proportion of research money spent on evacuation trials at Cranfield in the UK in the aftermath of the British Airtours accident at Manchester in 1985 is one example. As one senior airline manager commented during this research, “...you should see the safety budget grow in any airline following an accident” (anon.).

The effect of biased reporting of aviation accidents and incidents may be one of the reasons that it is such a safe mode of transport. The inaccurate communication of risk may be one of the reasons that funding has been available to elevate aviation safety to such a prominent position. As risk taking decisions always incorporate a level of perception, the role of the media in crafting perceptions should not be underestimated, either as a positive or negative concept.
2.5 Why Do Accidents Happen?

2.5.1 The Definition of an Accident

The Collins English Dictionary (1993) defines an accident in three different ways as;

1. an unforeseen event or one without an apparent cause
2. anything that occurs unintentionally or by chance
3. a misfortune or mishap, especially one causing injury or death

Such definitions need some alteration before they can be applied to the aviation environment. For example, there are few accidents which cannot be assigned "...an apparent cause". One such definition would be that used by Boeing (1996) in the preparation of its annual accident summary;

"Aircraft accident means an occurrence associated with the operation of an aircraft that takes place between the time any person boards the aircraft with the intention of flight until such time as all persons have disembarked, in which any person suffers death or serious injury as a result of being in or upon the aircraft or by direct contact with the aircraft or anything attached thereto*, or the aircraft receives substantial damage."

* Includes the effects of jet blast but not of wake turbulence.

2.5.2 Accidents as System Failures

In the context of this work, an accident will be considered to be an unforeseen system failure and an incident, a partial system failure. The aviation system is far more than just a physical set up and is best classified as a sociotechnical system. A pipework failure study conducted by Technica (HSE, 1992) demonstrated a sociotechnical system to be comprised of five levels. The pyramid of components show increasingly remote causes of accidents demonstrating the deep rooted nature of many accidents. The principles are easily applied to aviation;

Level 1 - Engineering Reliability. The design of the hardware and software involved in operating aircraft and the limits within which it may operate. This includes airframes, engines, navigation aids and air traffic control. It does not include the man-machine interface which is a function of the reliability of the operator. It does include automatic safety devices (ASDs) and systems designed to operate in emergencies such as ram air turbines. It is the easiest of the five components to quantify and the most often quoted, in terms of failure rate or mean time to failure (MTTF). The reliability of the aviation system is often quoted in terms of engineering reliability for this reason.
Level 2 - Operator Reliability. This category encompasses all human factors which can influence the reliability of the operator such as training levels, experience, job design, workplace design and support systems. The amount of variation in operator reliability is a function of Levels 4 and 5 which set the standards for recruitment, training etc.

Level 3 - Communication. This level is concerned with the dissemination of and feedback from information through documentation, briefings, log books and reporting systems etc. It is the vital linkage between all levels of the sociotechnical system without which a level of coordination and safety is unachievable.

Level 4 - Organisation and Management. Style of management and the structure of an organisation will strongly affect the management of safety through the setting of standards, priorities and targets. Management must fit personnel and processes to meet the requirements of the system if it is to perform in the way they anticipate.

Level 5 - System Climate. The widest of the five levels linking the organisation and its management with other systems such as the regulator. Influences result from economic pressures, public opinion, regulations and the state of the technology available. The inclusion of this level is especially important for comparing how similar organisations (e.g. airlines) may operate in different parts of the world or under different types of regulation.
Understanding of the various levels of a system and their importance in terms of accident prevention diminishes inversely to the relative importance of each level in preventing a major accident in the future. For example, if the system climate is one of economic strife and slack regulation and management is more intent on ‘keeping aircraft flying’ then the doubling of mean time to failure of, say, an engine component will have little affect on the overall safety of the system. If poorly trained crews are forced to fly an unfamiliar aircraft in marginal conditions then the extra reliability of such a component will probably have little or no bearing on the likelihood of them having an accident. However, if regulation is tight and economic pressure at an acceptable level then the increase in reliability of the component may not even be necessary to maintain a safe operation.

2.5.3 What is a Systems Approach?

For any accident to occur, there need to be a number of causal factors or conditions that combine in a particular way. No accidents occur solely as a result of a single factor. In aviation, accidents result from “collective mistakes rather than individual errors” (Reason, 1992) where collective mistakes are the result of a number of individual errors interacting together. An accident may be represented diagrammatically using a fault tree as follows:

![Fault Tree Diagram]

Figure 2.5.2 Example Fault Tree Redrawn from VRJ, 1994

The above fault tree is part of a model of collision risk to aircraft under air traffic control.

Each box represents an error of omission (e.g. failure to fit ACAS equipment) or an error of commission (e.g. aircraft sees but makes error). Individual errors are not enough to cause an accident. The reader must be careful not to interpret errors late in the chain as being accident causing by themselves. For example, if a collision occurred following the error made by the first aircraft after spotting the second, traditional accident investigation may have deemed that the accident would not have happened if this error had not taken place and therefore this is the causal factor. Although the former statement bears some truth, the accident could have also been avoided through the fitment of ACAS alert systems or transponders. Further, the
reasons behind the first crew’s inability to successfully avoid the other aircraft, such as poor
airmanship, may not have been significant if a collision pair had not been created.

Aviation represents a complex system of multiple interactions that is highly sensitive to both
the physical environment and the passage of time. It requires the close interaction of both a
technical and human component in a situation where both are highly dependant upon and sig-
nificantly affected by each other.

Professor James Reason’s text ‘Human Error’ (1990) has become a reference point for all
human factors practitioners involved in safety. The underlying theme is that, “...in consider-
ing the human contribution to systems disasters, it is important to distinguish two types of
error: Active errors, whose effects are felt almost immediately, and latent errors whose
adverse consequences may lie dormant within the system for a long time, only becoming evi-
dent when they combine with others to breach the system’s defences”.

In simple terms, the work of Reason illustrates that accidents are the end result of a number
of failures to the safety system. Therefore, if any given accident is assigned a single causal
factor, it ignores the safety systems that had been built to prevent the last (failed) defence
from ever needing to be used. Traditional accident investigation has tended to focus on the
active failures which occurred immediately prior to the accident. These failures may include
‘pilot errors’ such a failing to execute a stabilised approach, or controlled flight into terrain or
other errors such as the failure of ATC to assure separation. However, in all of these cases,
there are a number of safety systems (or at least opportunities for safety systems) which need
to have failed prior to the event. These are what Reason refers to as ‘latent defects’ and may
include the failure of a crew member to cross-check, the failure of training staff to educate
individuals correctly in how to deal with a particular situation, an economic decision not to fit
a particular item of safety equipment and so on.

This is best described using what is now commonly referred to as Reason’s ‘Swiss Cheese
Diagram’ which is presented overleaf. The barriers or walls represent the safety systems (or
opportunities for safety systems) which all exhibit a number of holes or latent defects. This is
a normal situation for most, if not all, complex systems and these defects are not enough to
cause an accident by themselves. It is only when a number of latent defects ‘line up’ and
interact that at a particular moment, which combines with an active failure which may, for
example, be bad weather or the performance of an individual, that an accident occurs.
Therefore it is possible for 9 out of 10 safety measures to fail or 999 out of a 1000, both with-
out an accident, but when the final ‘missing’ failure occurs, so an accident will also occur.
A good example of such an accident occurred in 1987 when the Herald of Free Enterprise Ro-Ro ferry sank outside Zeebrugge harbour, the blame was initially placed upon the Assistant Bosun who was responsible for ensuring that the Bow Doors were closed for sailing. He was asleep in his cabin when the ship set sail and did not telephone the bridge to inform them that the door were still open on departure. Deeper examination of the accident demonstrates how the Assistant Bosun’s actions were one of a few active failures or circumstances (which included a swell in the North Sea) which had combined with a particular set of latent defects that had been within the ‘Free Enterprise’ class of vessels since they were commissioned. The failure of the Assistant Bosun represented a danger-side failure which in turn is a function of poor system design. Other latent defects in the system previous to the incident include a management decision not to install a safety warning light (fallible decisions), poor crew scheduling (which had contributed to the Assistant Bosun’s fatigue)(line management deficiencies) and the setting of precedence in allowing Ro-Ro ships to leave port with the bow doors open in spite of previous occurrences (psychological precursors of unsafe acts).
In 1988, The World Bank held a workshop "...to develop a multi-sectoral/multi-disciplinary research programme to determine critical management and organisational failures that may lead to a catastrophic failure." This provided a simple, yet effective diagram to demonstrate the inverse relationship between the level of understanding in accident prevention and the relative importance. The diagram is easily related to Technica’s sociotechnical pyramid.

As the World Bank pyramid clearly shows, the need for understanding is opposite to the areas of current knowledge, namely the engineered and clearly defined world of automated safety devices and similar equipment. It is here that a systems approach to aviation safety is vital if it is to advance to any degree in the near future. A systems approach grasps the concept of accident chains and the existence of multiple causes in accidents. It acknowledges the potential of organisations and their culture have upon the ‘health’ of a system and in doing so attempts to redress the imbalance towards the more tangible end of science i.e. engineering.

Speaking at the 1997 Ohio State University Aviation Psychology Symposium in Columbus, Ohio, ICAO’s Head of Human Factors, Captain Dan Maurino (1997) warned that "...human error is a symptom of system failure and not a cause of it." This was a move aimed at challenging the new found temptation of the industry to shrug its collective shoulders and assign accidents to human error, which is then classified as being ‘too hard’ to tackle. The belief that human error is specific to individuals, such that following an incident or accident it is sufficient to just remove that individual from the system to regain safety, is both outdated and fundamentally flawed.

Knowledge of accidents and the multiple causes that lay behind all of them reveals that human error is present in 100% of cases (Faulkner, 1996). Such errors may reveal themselves as decisions far away from the accident face (such as in the certification process of a particu-
lar component or aircraft type) or may present themselves as active failures immediately prior to the event. There may be multiple human failures or a mixture of human and technical or environmental factors, but it is impossible for any accident involving a system as complex as aviation to be totally absent from an example of human error as a contributory factor. Once this fact is accepted, efforts can be better directed towards detecting human error (as a symptom of system failure) and preventing accidents by strengthening or adding defences.

2.5.4 The Use of a Systems Approach for this Research

The fact that human error is present in 100% of aviation accidents is logical and supported by Reason's theory of organisational accidents. However, it is not a view that is generally held by the aviation community at large for a number of reasons including;

- insufficient information
- machismo or ego
- incomplete accident investigation
- a need to avoid blame / punishment / litigation

However, the case-study design utilised in this research takes account of the importance of human error. If it is present in 100% of accident, then it seems logical that safe systems are such because of the control of human error. It is for this reason that the focus of this research is tilted particularly towards this area.

The understanding of all of the complex interactions of high technology systems such as aviation is limited by what is termed 'system opacity'. In other words, the high complexity of the system makes it difficult to understand how some actions may influence other areas of the system and in turn, this is often why accidents occur. Even moves aimed at increasing safety in a particular area can have a negative effect that is not immediately obvious. A very simple example is that of domestic smoke alarms. Fire Brigade data support the view that people who own smoke detectors are liable to become less cautious because they know they have a safety device. In many cases this has led to deaths where householders have allowed the alarm's battery to run flat and are then killed in a fire which burns undetected. In other words although the introduction of smoke alarms has undoubtedly saved many lives, they have also resulted in extra deaths through a new cause. As long as the latter figure is outweighed by the former and its set up costs then they will be seen as a useful device.

One of the reasons for looking at Australia's safety from a systems outlook is so that positive safety concepts which may be cancelled out elsewhere in the system are not overlooked. For example, if the weather is shown to be better than average for flying, it may be that more accidents occur in bad weather because of insufficient experience, Australian pilots are less able to cope with inclement weather overseas or pilots become blasé about the hazards. Although the contribution of good weather to the safety record would still stand, the negatives must also be presented to prevent the onset of complacency.
2.6 Review of accident types

Although accident investigation has started to move to a situation where accidents are recorded by multiple causal factors or contributory factors, statistics used to describe accident types generally still focus on a single primary cause. This is due in no small part to the fact that historical accident investigations have tended to settle for a single primary cause and the US NTSB is still required to determine the primary cause of an accident even if they do now include other significant causal factors.

While some of the more progressive investigative bodies such as Australia’s BASI and Canada’s CTSB (Canadian Transportation Safety Board) now refuse to specify a primary cause in their accident report, it will take a number of years before accident cause statistics start to reflect this way of thinking. In fact, even though these accidents are classified in the official accident report as having numerous causal factors, they are still graded into a single causal factor by insurance companies who produce their own sets of statistics. There are advantages for some of the publishers of accidents statistics to keep to the old system of single primary causes, not least the ease of compilation. An aircraft manufacturer, for example, may not appear much under the category of ‘aircraft design deficiencies’ as a primary cause, but this may be a contributory cause to poor human performance which would then be rated as the primary cause. If all contributory factors were included then the number of accidents where aircraft design deficiencies were a factor may be a much higher proportion.

The real danger from looking too closely at accident causation statistics (as with many forms of statistics) is taking them out of context to support or refute a particular argument. Each classification of factors attract interest from different sectors of the industry and tend to be extensively reviewed at the micro-level. The objective of this section is to introduce the current statistics which are available in this area and the relative importance that they place upon different areas. In examining a particular operating system, this research has to take account of varying perceptions of the relative importance of individual causal factors or threats. For example, this can be a function of the amount of work done in a particular area rather than its relative importance.

Boeing’s annual statistics (1996) separate primary cause factors into six distinct categories as shown below. (The occurrence of acts of aggression and injury through turbulence and evacuation are removed.) The category of ‘flightcrew’ is a somewhat controversial one, not least because it represents such a large component of the data. The fact that the statistics are prepared by an aircraft manufacturer require an air of caution to be applied to the true meaning of such a statistic. A senior airline official (anon) suggests that one “...should treat Boeing’s statistics with the same caution you would the words of a second hand car salesman”. The suggestion is that an aircraft manufacturer is unlikely to admit that flightcrew errors that cause an accident are partly the result of the aircraft design or equipment levels not compensating for their actions.
However, statistics produced by IATA (1993) demonstrate a similar picture of the proportion of accident classification types. The classification system used by IATA distinguishes between human, technical and environmental factors. Therefore, Boeing’s six categories would be matched as follows:

<table>
<thead>
<tr>
<th>Boeing Classification</th>
<th>IATA Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flightcrew</td>
<td>Human Factors</td>
</tr>
<tr>
<td>Airplane</td>
<td>Technical</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Technical (and HF)</td>
</tr>
<tr>
<td>Weather</td>
<td>Environmental</td>
</tr>
<tr>
<td>Airport/ATC</td>
<td>Environmental (and HF)</td>
</tr>
<tr>
<td>Miscellaneous/other</td>
<td>Insufficient Information</td>
</tr>
</tbody>
</table>

For a ten year period (Boeing 1986-95; IATA 1984-91), IATA’s Human Factors category actually rated the human factors category as accounting for 66.9% of accidents as oppose to Boeing’s 59.8%. This is presumably a function of using the wider ‘human factors’ category rather than the controversial ‘flightcrew’ label which tends to suggest that human error is the exclusive domain of the aircraft’s crew. The legend ‘human factors’ will encompass maintenance and ATC errors. The technical category equated to 16.5% (Boeing = 17%) and the environmental category, 16.5% (Boeing = 9%). Assuming some variability for the different ten year periods used, low sample and different classification methods, the two sets of data appear to bear out similar conclusions about the types of accidents encountered. In particular, the high percentage of human factor primary cause accidents is significant as being the greatest challenge for aviation safety advances.
### Accident Causal Factors for 219 Accidents

<table>
<thead>
<tr>
<th>Group</th>
<th>Factor</th>
<th>Number of Accidents where factor occurs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Aircraft systems</td>
<td>1.1 Non-fitment of currently available safety equipment (GPWS, TCAS, windshear warning)</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>1.2 Failure / Inadequacy of safety equipment</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>1.3 System failure - reduced controllability</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>1.4 System failure - other</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>1.5 Non-fitment of potential new equip (enhanced GPWS)</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>2.1 Incorrect or inadequate instruction/advice</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>2.2 Failure to provide separation</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>2.3 Lack of ground aids</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>2.4 Wake Turbulence - aircraft spacing</td>
<td>1</td>
</tr>
<tr>
<td>2. ATC / Ground aids</td>
<td>3.1 Structural overload</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3.2 Wind shear / upset / turbulence</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>3.3 Poor visibility</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>3.4 Runway condition (ice, standing water etc.)</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>3.5 Icing</td>
<td>5</td>
</tr>
<tr>
<td>3. Atmospheric</td>
<td>4.1 Lack of situational awareness</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>4.2 Incorrect selection on instrument / navaid</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>4.3 Action on wrong control / instrument</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>4.4 Slow / delayed action</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>4.5 Omission of action / inappropriate action</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>4.6 Failure to cross-check / co-ordinate</td>
<td>118</td>
</tr>
<tr>
<td></td>
<td>4.7 Fatigue</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>4.8 State of mind</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>4.9 Fast / high on approach</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>4.10 Slow / low on approach</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>4.11 Loading error</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>4.12 Flight handling</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>4.13 Lack of qualification / training</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>4.14 Incapacitation</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>4.15 Failure to look-out</td>
<td>4</td>
</tr>
<tr>
<td>4. Crew</td>
<td>5.1 Engine failure</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>5.2 Damage due to non-containment</td>
<td>5</td>
</tr>
<tr>
<td>5. Engine</td>
<td>6.1 Fire due to engine failure</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>6.2 Fire due to aircraft systems</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>6.3 Fire - other causes</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>6.4 Post crash fire</td>
<td>24</td>
</tr>
<tr>
<td>6. Fire</td>
<td>7.1 Failure to complete due maintenance</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>7.2 Maintenance or repair error / inadequacy</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>7.3 Ground staff struck by aircraft</td>
<td>2</td>
</tr>
<tr>
<td>7. Maintenance</td>
<td>8.1 Corrosion, fatigue</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>8.2 Structural failure</td>
<td>7</td>
</tr>
<tr>
<td>8. Structure</td>
<td>9.1 Collision with high ground</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>9.2 Collision with level ground / airport</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>9.3 Impact with obstacle / obstruction</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>9.4 Mid-air collision</td>
<td>8</td>
</tr>
</tbody>
</table>

NB  Terrorism and sabotage, test and military-type operations are excluded. Also fatalities to third-parties who were not concerned with the operation of the aircraft are excluded.

Figure 2.6.2 Redrawn from Ashford, 1994
Deeper examination of accidents gives a clearer picture of the significance of human factors in accident causes. Ashford (1994) examined 219 accidents (to aircraft about 5700kg MTOW) documented within the UK CAA’s World Aircraft Accident Summary and ICAO’s ADREP database to highlight causal factors. The use of causal factors over primary causes is highly significant and separates this analysis from those of Boeing and IATA listed above.

A quick glance of the above chart demonstrates the prevalence of human factor problems in aircraft accidents. The three most common deficiencies are:

<table>
<thead>
<tr>
<th>4.6</th>
<th>Failure to cross-check / co-ordinate</th>
<th>(118 accidents)</th>
<th>(54%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Lack of Situational Awareness</td>
<td>(75 accidents)</td>
<td>(34%)</td>
</tr>
<tr>
<td>4.12</td>
<td>Flight Handling</td>
<td>(60 accidents)</td>
<td>(27%)</td>
</tr>
</tbody>
</table>

However, it should be noted that such error types are often combined with other failure types for accidents to occur. For example, lack of situational awareness may combine with collision with high ground or the non-fitment of safety equipment such as GPWS or TCAS (i.e. lack of situational awareness by itself is not enough to cause an accident - neither is lack of GPWS or TCAS equipment).

The advantage of Ashford’s multiple cause approach is that it allows the researcher to work on multiple prevention approaches. In other words, one approach may eliminate a particular hazard at a cost of $n$ dollars whereas another may eliminate two particular hazards at $2n$ dollars. More research might then discover a third approach which could counteract three hazards at only $n$ dollars. The latter solution is the optimal choice but might not have been selected if individual causal factors were considered in isolation. For example, while collision with high ground (9.1) may be prevented through the use of GPWS equipment, it may also be prevented through improving situational awareness through human factors training (4.1), ensuring cross-checking of the flying pilot by other crew members through CRM training (4.6), the use of improved ground aids through infrastructure investment (2.3) and so on. In turn, by ensuring cross-checking of the flying pilot (4.6) this could also counteract the following accident causal factors;

<table>
<thead>
<tr>
<th>4.2</th>
<th>Incorrect selection on instrument / navaid</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.3</td>
<td>Action on wrong control / instrument</td>
</tr>
<tr>
<td>4.4</td>
<td>Slow / delayed action</td>
</tr>
<tr>
<td>4.5</td>
<td>Omission of action / inappropriate action</td>
</tr>
<tr>
<td>4.9</td>
<td>Fast / high on approach</td>
</tr>
<tr>
<td>4.10</td>
<td>Slow / low on approach</td>
</tr>
<tr>
<td>4.12</td>
<td>Flight handling</td>
</tr>
<tr>
<td>4.14</td>
<td>Incapacitation</td>
</tr>
<tr>
<td>4.15</td>
<td>Failure to look-out</td>
</tr>
</tbody>
</table>
Sears (1986) examined 93 major accidents from a selection of 126 which occurred between 1977-1984 for significant causal factors. In order to select only those causes which were significant, the following criteria were required to be met:

- The accident might reasonably have been prevented had the factor not been present
- A definitive solution or remedy can be envisioned for the elimination of the factor

The product was a list of significant accident causal factors as they appeared in the 93 accidents. Of these, only 28% exhibited a single causal factor, 54% had two factors and 18% represented three or more causal factors. It is hard, if not impossible to believe that any accident involving a complex, high technology system such as aviation can be attributed to a single cause. It must therefore be assumed that Sears’ data accurately reflects the product of an accident investigation process which has failed to document the complete set of causes. The list is presented below:

<table>
<thead>
<tr>
<th>Significant Accident Causes and their Percentage of Presence</th>
</tr>
</thead>
<tbody>
<tr>
<td>33%</td>
</tr>
<tr>
<td>26%</td>
</tr>
<tr>
<td>13%</td>
</tr>
<tr>
<td>12%</td>
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<tr>
<td>10%</td>
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<td>6%</td>
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<td>6%</td>
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<tr>
<td>5%</td>
</tr>
<tr>
<td>5%</td>
</tr>
<tr>
<td>4%</td>
</tr>
<tr>
<td>4%</td>
</tr>
</tbody>
</table>

Figure 2.6.3 Redrawn from Sears, 1986

What Sears, Ashford, Boeing and IATA's analyses all have in common is the high proportion of human factor failures. Whether they are incorrectly labelled as flightcrew causes or at least biased towards 'the last person to touch the controls', the fact is that the high proportion of human factors causes is even now underestimated. Although researchers appear to have settled on human error or pilot error (the terms are often misused interchangeably) as accounting for 60 - 70% of accidents, with even industry leaders such as Ohio State University Aviation's
Richard Jensen (1982) stating that "...aviation accident statistics have found that 80-85% can be assigned broadly to 'pilot error...', there is a new movement gathering pace which suggests that 100% of aircraft accidents are the result of some human error. Students on the University of New South Wales' Bachelor of Aviation program (Faulkner, 1996) are challenged to find an accident that does not have a human factors causal factor behind it. So far, no-one has managed to rise to the challenge. This is because aviation is a systemic process which is designed to operate within the known boundaries of the physical environment. It is only when operations exceed those known boundaries that accidents occur and the decision to exceed is always a human one; either consciously or subconsciously.

To illustrate this point, the following table uses the selection of factors used by Sears alongside their human factors failures:

<table>
<thead>
<tr>
<th>Significant Accident Causes</th>
<th>Human Factors Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot deviated from basic operational procedure</td>
<td>Individual / Training</td>
</tr>
<tr>
<td>Inadequate crosscheck by second crew member</td>
<td>Individual / Training</td>
</tr>
<tr>
<td>Design faults</td>
<td>Design / Certification Engineers</td>
</tr>
<tr>
<td>Maintenance and inspection deficiencies</td>
<td>Individual / Training / Process Design</td>
</tr>
<tr>
<td>Complete absence of approach guidance</td>
<td>Airport Mgt / Regulator / Airline Mgt / Individual</td>
</tr>
<tr>
<td>Captain did not respond to crew input</td>
<td>Individual / Training</td>
</tr>
<tr>
<td>ATC failures or errors</td>
<td>Individual / Training / Expenditure Mgt</td>
</tr>
<tr>
<td>Crews not conditioned for proper response to abnormal conditions</td>
<td>Individual / Training / Certification</td>
</tr>
<tr>
<td>Other</td>
<td>(N/A)</td>
</tr>
<tr>
<td>Weather information insufficient or in error</td>
<td>Individual / Training / Expenditure Mgt</td>
</tr>
<tr>
<td>Runway hazards</td>
<td>Airport Mgt / Regulator / Airline Mgt / Individual</td>
</tr>
<tr>
<td>ATC/crew communication deficiencies</td>
<td>Individual / Training / Expenditure Mgt</td>
</tr>
<tr>
<td>Pilot did not recognise the need for go-around</td>
<td>Individual / Training</td>
</tr>
<tr>
<td>No GPWS installed</td>
<td>Individual / Training / Expenditure Mgt</td>
</tr>
<tr>
<td>Weight or centre-of-gravity in error</td>
<td>Individual (ground and flight crew) / Training</td>
</tr>
<tr>
<td>Deficiencies in accepted navigation procedures</td>
<td>Individual / Training / Regulator</td>
</tr>
<tr>
<td>Pilot incapacitation</td>
<td>Individual / Training / Company Medical / Regulator</td>
</tr>
</tbody>
</table>

Figure 2.6.4 Human Factors Failures Behind Sears’ Table of Significant Accident Causes
Once the aviation community accepts the human error component as being present in 100% of accidents, it is then able to move on to the systemic solutions rather than trying to find someone to blame. Complex systems will always be hampered by deficiencies in human performance whether these be errors, mistakes or aspects of physical endurance. It is for this reason that the design of that system to be 'human tolerant' is a priority.

By examining the accident and incident record, it is possible to get a reasonable idea about the areas that most need remedial action. However, existing knowledge of systems also issues its own warning that in attempting to fix one problem, there is a risk of causing others. For example, whereas glass-cockpit fly-by-wire technology has been able to reduce avionics failures and reduce crew workload, this has brought with it other problems such as reduced crew experience or reliance on automation, boredom and problems of type conversion from traditional style aircraft. Another example comes in the form of the increased accuracy of navigational systems. Whereas two aircraft who had been given opposing direction flight paths along the same route may have narrowly missed as a result of instrument error in the past, more accurate technology has reduced this margin of error;

![Figure 2.6.5](image)

There are no new accidents, only variations on a recurring theme. The use of a systemic approach to safety management is designed to prevent advances in one area from causing old accident causes from developing in new areas. Experience of accident investigation has demonstrated that human error was traditionally most important away from the accident face as latent defects within aircraft design, construction and flight planning. As these problems were confronted, accident investigation focussed more on the role of human performance in operation in the aircraft or air traffic control tower. Finally, investigation has entered into the new era of recognising the contribution of organisational (human) error which supplements the other two areas. This is summarised in the table shown overleaf;
What is most important to note that although the causal factors behind many accidents are in fact the same (which will be discussed later), differences in perception caused by differences in thinking throughout the development of aviation have created a legacy of misinformation. The perception that many accident causes have been conquered brings with it a danger of complacency or at least an honest misdirection of efforts. Early incidents involving the fly-by-wire A320 aircraft were swiftly blamed on the advanced technology when in fact the aircraft had behaved exactly as it was designed to. Poor type-conversion training resulted in handling accidents with the A320 the same way pilots had been caught out by the conversion from piston and turboprops to early jets such as the B707 and B727 series. One of the causal factors behind the infamous Mulhouse-Habsheim Airshow crash was the pilot attempting to execute a manoeuvre which was outside the capability of the aircraft which he had helped to program the fly-by-wire software for.
2.7 Why Do This Study?

From the day a child is born, it learns from its mistakes. As it becomes older and wiser it will begin to learn not just from its own mistakes but those of others to avoid unnecessary suffering. As aviation developed in the early twentieth century, mistakes were one of the greatest sources of learning. Man's new found ability to fly was in an area where there were no experts and learning came at a price. The knowledge acquired through mishaps and accidents crafted the way aviation developed. For example, the frequency that control cables snapped led to their duplication and the problems of increased workload led to the advent of multiple crewing.

Accident prevention relied upon accident investigation and so the science of picking up the pieces and deducing what went wrong developed alongside aviation. Even as early as 1915, the Royal Flying Corps had appointed an “Inspector of Accidents” in the UK. In more recent years the skills of the aircraft accident investigator have ranked amongst the finest of their professions - engineers, forensic scientists, pathologists, sound engineers etc. When Pan Am Flight 103 was brought down by a terrorist bomb over Lockerbie in 1988, the wreckage trail was some 180 miles long. From this, the Air Accidents Investigation Branch was able to piece together not only the baggage container in which the device was planted, but also the suitcase and radio-cassette player it was hidden within. There are few unsolved large aircraft accidents which pays great testimony to the ability of accident investigators.

However, just as the child becomes wiser by learning from other people's mistakes, so too the aviation industry needed to make this transition. Unfortunately, the accident record shows numerous examples of recurrent accidents before lessons were learned. Even now, the prevalence of Controlled Flight Into Terrain accidents (Between 1988 and 1993 for aircraft over 60,000lb, CFIT accounted for 53% of fatalities.) demonstrates how serviceable aircraft, even with comparatively state of the art equipment, are still being flown into the ground.

There are a number of key problems associated with relying upon accident investigation for advances in aviation safety:

a) Their reactive nature

By definition, accident investigation requires an accident to have taken place.

This often means;

- expensive damage to equipment
- third party property damage
- serious injury, trauma or loss of life
Investigation of the accident is mandated by certain articles of ICAO Annexe 13. Each member state is required to investigate accidents that occur within their airspace or involve their aircraft and report the findings via ICAO. However, the depth of investigation varies considerably between states for various reasons including the interpretation of ICAO recommended practices by the legislating authority and the availability of resources for the investigation. As a result, accidents with similar causes may be investigated with differing outcomes or findings. In turn, this means that some of the opportunity for future prevention is lost and contributes to incomplete databases of accident causal factors. As the schematic below demonstrates, investigations and the communication of findings may drift away from the optimal path and opportunities for accident prevention lost.

**The Dangers of Incomplete Investigation Techniques**

![Diagram showing the dangers of incomplete investigation techniques](Figure 2.7.1)
All accident investigation authorities do not have the same level of resources available to them or indeed the same priorities as to what information is required from an accident. The latter disparity may range from the ‘who did it?’ style of investigation to those that explore deeper organisational issues behind accident causes (for example, see BASI, 1996). Even within the ‘first world’ investigative authorities such as the British Air Accidents Investigation Branch (AAIB) and the Australian Bureau of Air Safety Investigation (BASI) there are different priorities in investigation that are reflected in the staff positions. The AAIB, for example have no human factors specialists or psychologists on their staff, but BASI have several.

Technically oriented investigations have been the traditional mainstay of aviation, discovering what went wrong on the day of the accident and highlighting a single primary cause. Recommendations promulgated from such investigations are usually concerned with technical engineering or operational aspects to remedy existing deficiencies. There is a shift towards examining deeper human factors issues, but this seems to be a slow process.

b) Their relative infrequency

Although aircraft accidents are high profile events and are therefore perceived to be relatively frequent events, they are still relatively rare events. In the ‘jet-age’ period 1959 - 1995, Boeing (1996) estimate a total of 304 million departures by western built aircraft (over 60,000 lb MGTW) of which there were 1063 accidents.

Of these accidents, 850 were during passenger operations, 120 during all-cargo flights and 93 during test, training, demonstration or ferry. The 1063 accidents can also be split between nine manufacturers which covers 32 significant types of aircraft. (i.e. this does not even split by series so a B737-100 would be classified alongside the more advanced B737-400 aircraft.)
Add to this mix the issues mentioned above regarding the investigative approaches of different states and the opportunities for trend analysis of accident causal factors becomes quite limited.

c) **The effect of time**

Strongly related to the above category is the passage of time and its effect on the value of accident investigation results for the promotion of flight safety. The infrequency of accidents dictates that the compilation of any sort of trend statistics will cover a significant period of time. During that time period, it is reasonable to assume that a number of changes will have occurred in some or all of the following areas:

- **Aircraft technology;**
  - new aircraft types
  - new aircraft series
  - existing aircraft modification (e.g. through AD's)
  - retrofitted equipment (e.g. GPWS, TCAS etc.)

- **Crew training;**
  - airline training methods. (e.g. CRM)
  - training technology (e.g. use of simulators)
  - background of recruits (e.g. ex-combat pilots)
  - use of on-condition monitoring (e.g. QARs)

- **Air traffic services;**
  - training of controllers
  - new technology (e.g radar coverage)

- **Accident investigation;**
  - new technology (e.g. DFDR's, CVR's)
  - change of focus (e.g. systemic investigations)

Although there are considerable negatives to accident investigation, there are alternatives available which are more proactive in nature;

i) **Incident Investigation**

Accidents represent the catastrophic breakdown of any safety system and yet there are many more occasions where safety systems fail either partially or without serious consequence. Such events are termed as incidents and are significantly more prevalent than accidents. The analysis of incidents may initially seem to provided similar opportunities for the prevention to the investigation of accidents, as the causal factors are often similar. Indeed, Pidgeon (1991)
observes that near misses differ from disasters "...only by the absence of the final trigger event and the intervention of chance." While this may be the case, the nature of incidents mean that the reporting mechanisms aren’t anywhere near as effective as they are for accidents. As mentioned earlier, incident reporting tends to be voluntary and depend upon individual’s not only taking the time and effort to report incidents but also recognising incidents in the first place. For example, although failure to cross-check or loss of situational awareness are found to be present in a high percentage of accidents, they are rarely reported in incident reporting systems because either they are not detected or the crew member involved is either too embarrassed or in fear of punishment to report it.

If a complete profile of incidents could be collected then the usefulness of this type of data would be significantly enhanced. Improvements in reporting forms and feedback processes have helped to improve quality and response rate although, as many systems are run at company level and are confidential, databases tend to be somewhat fragmented. The biggest collections of incident reports in Australia is BASI’s OASIS database which may be interrogated only through the data analysis officer. Although BASI were able to supply some valuable information which is presented elsewhere in this thesis, there are limitations on the amount of resources that they are able to devote to the searching of the archive and indeed the amount of data which is actually recorded. The OASIS database, like other similar systems such as British Airways’ BASIS, has only been in place for a few years and so currently has limitations on the scope for trend analysis.

As the various databases of incidents fill up, so the opportunities to learn more from trend analysis will develop. However, this will take some time and will require great caution. Just because a particular reported incident type appears to represent a high proportion, does not mean that it is in fact the most serious problem. At its very simplest, the fact that a large proportion of individuals recognise and report a problem type may mean that they are already modifying their behaviour to take account of it. Conversely, this may also mean that the poorly reported incident types are the ones that are of the greatest concern to the safety profession. However, this is not to say that there is a pareto relationship and will need further research.

At a higher level, there is significant potential for accident investigative techniques to be applied to incidents on a larger scale than simply collecting voluntary incident reports. At present, few authorities have the resources available to investigate incidents as well as accidents although there is a laudable move towards looking at some major incidents. For example, the Australian BASI investigated a significant near miss at Sydney Airport when a DC10 and A320 nearly collided during SIMOPS operations. There are also procedures in many organisations to conduct their own investigations, although by their very nature, the results of the investigations tend to remain exclusively in-house and not available to the research community.
ii) Case Study Research

If accident investigations can be seen to be an in depth case study of a failure to a safety system, it seems most reasonable that 'safe' normal operations provide a case study of a successful safety system. As mentioned earlier, Reason (1993) suggested; “Should we not be studying what makes organisations relatively safe rather than focussing upon their moments of unsafety? Would it not be a good idea to identify the safest carrier, the most reliable maintainer and the best ATC system and then try to find out what makes them good and whether or not these ingredients could be bottled and handed on?”.

By examining healthy operations, researchers are not hampered by the problems which often occur following accidents. These include injured or dead witnesses and those who wish to cover up their mistakes. In extreme circumstances, accidents remain unsolved in the absence of witnesses (such as the Colorado Springs and Pittsburg B737 accidents) or are prone to the distortion of facts which mayor may not be discovered. In the case of the 1979 Mount Erebus Disaster, the subsequent Royal Commission was forced to make the following damning conclusion about the airline management’s contribution to the inquiry;

“No judicial officer ever wishes to be compelled to say that he has listened to evidence which is false. He prefers to say, as I hope the hundreds of judgements which I have written will illustrate, that he cannot accept the relevant explanation, or he prefers a contrary version set out in the evidence. ‘But in this case, the palpably false sections of evidence which I heard could not be the result of mistake, or faulty recollection. They originated, I am compelled to say, in a pre-determined plan of deception. They were clearly part of an attempt to conceal a series of disastrous administrative blunders and so, in regard to particular items of evidence to which I have referred, I am forced reluctantly to say that I have had to listen to an orchestrated litany of lies” (Mahon, 1981).

The above statement is unusual, but only because investigations or inquiries of the magnitude of the Royal Commission into the Erebus Disaster are few and far between. The new found understanding of organisational accidents afforded by the work of academics such as James Reason has shown that high level organisational failures of this nature are commonplace in high-technology industry accidents. This includes rail, maritime and space transportation (e.g. Clapham Junction, Herald of Free Enterprise and Challenger Disasters), chemical, nuclear power and oil production (Union Carbide at Bhopal, Three Mile Island and Piper Alpha in the North Sea).

The use of ‘good examples’ increases the willingness of expert witnesses to provide information and represents a more constructive approach than a critique of failures and errors. The benefits fall into two major categories - namely in terms of enhancing the safety of other operations through example and secondly in aiding in the preservation of the original safe operation. For example, results from this research have been made available to the wider aviation industry through conference papers and journal publications so that other operations
may be aware of 'best practice' to emulate. Results have also been made available to the
Australian industry to help prevent the onset of complacency or misinterpretation.

The use of case-study research as an academic methodology, particularly in the field of
aviation safety, has been rare to date. This is partly because, if done improperly, this type of
research can leave the reader with a very superficial 'big picture' or a variable picture which
reflects more about the ease of data collection or the researchers interests in particular areas.
This is not to suggest that the methodology used in this research is perfect and not prone to any
of the above problems. Indeed, as the methodology used is novel, and therefore untested, there
will be a lot of fine tuning that could and should be applied before it is used elsewhere. Some
of these points are highlighted in the main text, while others come out in the concluding
remarks and suggestions for future research.

A detailed account of how the methodology was developed and how its integrity was assured
is presented in the next section.
Chapter Three

Methodology

All academic research exercises achieve their integrity through the use of a structured methodology. The available options are considered here, along with the chosen approach and the questionnaire which was developed to collect primary data.
3.0 Research Methodology

Every research project has a set of aims and from these flow a set of hypotheses and a methodology to test them. The danger is for a researcher to become focussed on attempting to prove a hypothesis or forcing the research to fit preconceived ideas. In the pursuit of original research there are always times when the researcher may wish for easy answers and simple solutions. Whether these appear is a function of the work and not the worker and the key to survival is flexibility.

A sound research methodology is one which allows flexibility, but does not bow to the hidden agenda or bias of a researcher. However, a poor methodology may be one which either allows too much or even too little flexibility. A research project using a well established methodology, such as in the field of DNA Sequencing, allows very little flexibility from the rules if it is to maintain experimental integrity. The sort of research project which explores the interaction of many factors such as this one requires a flexible methodology by virtue of a lack of existing exploration in this area.

Research which covers broad areas of knowledge - such as the safety of the aviation system, requires a methodology as much as a highly focussed study would. However, as there are many different research methodologies in use, it is important to select one that gathers the most reliable and complete set of evidence to support or refute the main hypothesis.

This objectives of this research lend themselves primarily to a case-study design. “Case studies are the preferred strategy when ‘how’ or ‘why’ questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real life context. Such ‘explanatory’ case studies can be complemented by two other types - ‘exploratory’ and ‘descriptive’ case studies.” (Yin, 1989) The main objective of this research;

*To examine how Australia has managed to achieve an apparently good record for commercial airline safety.*

is very much a ‘how’ or ‘why’ question and is not one that can be answered using experimental methods. It attempts to tackle a broad subject which draws on the technical scientific aspects of subjects including engineering and meteorology to the less precise social sciences such as psychology and sociology. Nevertheless, it is impossible to simply focus on one aspect of the safety record if the full benefits of examining a system are to be exploited. This is not to say that there would not be merit in focussing on a particular aspect such as the use of GPWS or the effect of sea-air on corrosion. The objective of this work is not to cover every aspect of the Australian aviation system in extensive detail, rather to explore these aspects to a sensible depth so that their interactions can be explored at a systemic level.
In covering a relatively broad subject as a case study, there is always a danger of falling foul of one of the traditional criticisms of this type of research method; that is of either being too generalised or too specific, such that the results are difficult to use elsewhere. For this reason, it is important that the results are presented in such a way that they can be used in their constituent parts or collectively. In other words, it is important that other researchers using this work can examine individual factors, such as the effect of windshear / microbursts on operations, as well as the system-wide conclusions which can be utilised by other aviation (and non-aviation) systems outside Australia as well as within Australia. It is therefore apt that the methodology to be developed for this research task be correctly classified as ‘multimethod research’.

Brewer and Hunter (1989) argue that social science research tends to use one of four research methods which are often ‘...imperfect but useful’; namely,

- fieldwork
- survey research
- experimentation
- nonreactive research

Although each of these methods see widespread use, a level of uncertainty often remains when attempting to test a hypothesis using only one. The authors suggest that this is as a result of one of two reasons; ‘...either because the particular method employed fails to provide the data needed to test them or because they stem from possible biases inherent in the study’s single method.’ The development of a multimethod strategy is far from an admission that any one of the aforementioned methods are fallible. They each have applicability for particular research tasks, but cannot be used in isolation for a task as complex as a large case study. For example, survey research of the operators of a system is only of value if the questions are well constructed and do not lead the respondent. This can only be achieved through extensive previous knowledge (i.e. testing from the inside, which may bring its own bias) or nonreactive research of archives, statistics and so forth.

Brewer and Hunter go on to summarise the multimethod approach as follows; ‘Its fundamental strategy is to attack a research problem with an arsenal of methods that have nonoverlapping weaknesses in addition to their complementary strengths’. This dovetails with Yin’s (1981) definition of case study research;

A case study is an empirical inquiry that:

- investigates a contemporary phenomenon within its real-life context; when
- the boundaries between phenomenon and context are not clearly evident;
- and in which
- multiple sources of evidence are used
Multimethod case study research is a valid methodology for social science research providing it is able to withstand the following four tests of integrity:

<table>
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<tr>
<th>Four tests of Case Study Integrity</th>
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<tr>
<td>• Construct Validity</td>
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<td>• Internal Validity</td>
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<tr>
<td>• External Validity</td>
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<tr>
<td>• Reliability</td>
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\(\text{a) Construct Validity}\)

Yin (1981) suggests three tactics for ensuring construct validity:

- *Use of multiple sources of evidence*
- *Establish chain of evidence*
- *Have key informants review draft case study report*

All three have been utilised in the construction of this case study in the following way;

- *Use of multiple sources of evidence;*

Data have been collected from a variety of sources to maximise validity. This process commenced with extensive literature searches to survey what knowledge existed within each of the chosen areas of the case study (see later notes). This literature review was an iterative process which continued throughout the study. This is subtly different to many experimental studies which used literature reviews to prepare a base for the new study to start from. Although the research aims and methodology were developed in this way, the coverage of individual aspects of the case study required continued literature searching for secondary data. It is pointless collecting primary data for use in a large case study which has already been collated (and analysed) for a more micro-level project. Where secondary data did not exist, it was necessary to collect fresh data. Again, this data was purposely collected from a number of sources including letters from and interviews with expert witnesses, formal archives, observational exercises (participative and none participative) and through an attitude survey. These processes are discussed in greater detail in section 3.3. The number of different sources of evidence for each area depends on the availability of information and the strength of the available data. In some areas this meant that data collection was restricted by the available resources and this is noted in the text. However, the methodology can be used to greater effect elsewhere if more resources are made available.
Establish chain of evidence;

As this case study relates to an established operating system, it is logical that the chain of evidence is designed around that system. Although each area of focus is intended to make sense as stand alone concepts if a reader only wishes to access that information, the relationships and interactions between factors are highlighted in the text. A system of icons to aid this process has been established and is explained in detail in section 3.3.

Have key informants review draft case study report;

This process has been covered using the following techniques:

i) A number of conference papers have been presented during the course of this research to groups of learned professionals from aviation related disciplines. The full list of presentations is reproduced in the appendices of this thesis. These have allowed review of the basic concepts and selected findings by peer groups including academics and industry alike. Feedback from these papers have allowed the refining of ideas and revealed additional sources of evidence.

ii) The content of the thesis has been reviewed by the supervisors to assure its academic integrity. This is a standard procedure in the construction of Doctoral theses and not unique to case-study research. However, the supervisor’s position does not always exist in cases where a case-study is being constructed. It is recommended that if future uses of this research methodology do not have a research supervisor, an expert witness be established as mentor to retain construct validity.

iii) The rules for the submission of a PhD in the UK mandate an oral examination of the thesis by an expert external to and an expert internal to the candidate’s University. As these examiners are able to suggest significant changes to the content of the thesis, this acts as another validity test which would not be available to non-examined case-studies.

b) Internal Validity

Case studies which are causal or explanatory studies, such as this one, need to be wary of internal validity. This is to protect against the danger of suggesting a causal relationship that is not valid. This is especially important where perceptions and attitudes are collected alongside scientific measures and statistics when the former may seem to be in conflict. Aviation safety is a subject with many opinions and, as it relates to a complex system and time-series data simultaneously, is particularly prone to misconceptions. The solution to this problem is firstly for the researcher to be conscious of the problem and then to actively protect against it by only making inferences or conclusions on the basis of multiple sources of supporting evidence.
c) External Validity

External validity is concerned with establishing whether the results of the case study are useful outside of the immediate area of concern. In other words, would discovering the reasons behind Australia's good record for airline safety be useful for any other reason than describing how the record has established itself to date?

The results of this research are aimed at two distinct areas:

i) Aiding the preservation of Australia's good safety record by understanding which variables have been most important and which are undergoing a process of change. It is also designed to prevent the onset of complacency or at least clear up existing misconceptions.

ii) Aiding the wider aviation safety community in understanding the factors behind a 'safe system' so that they can be replicated and emulated elsewhere. Further, to enhance the understanding of systemic safety which may be of use not only to the aviation community, but other high technology sociotechnical systems such as the petrochemical industry.

As this work relates to a unique system - Australian aviation, it is impossible to test the entire investigation using "replication logic" (Yin, 1981) i.e. the application of the research methodology to other comparable systems. However, it is possible to apply the methodology to other aviation systems to test its integrity or apply a differently designed case-study methodology to the Australian system to compare results.

d) Reliability

Reliability is assured through the use of a case-study design structure which is documented both within the methodology section of this thesis and within the analysis section where specific technicalities are explained. Secondary data are only used where the original researcher has tested their reliability and primary data is subject to tests of integrity. A researcher will be able to utilise this thesis to repeat the exercise and reach similar conclusions.

As this case-study is presented as a thesis, it is a mandatory requirement for methodology, literature review and analysis to be presented as well as the conclusions. This is unlike many case-studies which are presented solely as results or findings. The structure of the process of doctoral thesis research helps to assure reliability.
The overwhelming strength of case-study multimethod research is its error tolerance capability. The supply of data from traditional investigative methods is susceptible to both the bias of the technique and those trained to use it. Conclusions drawn from multiple sources of evidence and collected using more than one technique are that much stronger than those using only one. Conversely, conclusions which may appear to be significant when reached using a single method such as survey research, may be disproved or have doubt cast upon them by a second methodology. An example may be the use of experimentation to overturn a widely held (mis-) perception which seemed significant in survey results.

The need for a new approach to examining airline safety has been borne out of the lack of a sound methodology for examining systemic safety. This is partly because the understanding of systems safety is still very much a new concept to aviation and also because of the resources required to complete such an exercise. Previous attempts in this area include the following:

3.1 Existing Methodologies

Existing studies of Australia's civil aviation safety record are few and far between. The only major work is the two-volume book 'Air Crash - The Story of How Australia's Airways Were Made Safe' (Job, 1991, 1992). Job was a Senior Inspector of Air Safety within the Australian Department of Civil Aviation, author of the Aviation Safety Digest and holder of a commercial pilot's licence. Such a background allowed the author to trace the development of Australian aviation following aircraft accidents and their investigations. The tone of the entire text is that of historical commentary regarding what went wrong and what compensatory steps were taken to prevent recurrence. It provides those working in modern commercial aviation with an insight into the historical processes that have come together to achieve the current state of play. However, it does not attempt to offer any academic analysis of the way the 'safe' system functions and therefore provides little in the way of a usable methodology for applying to other systems around the world.

Much of the information provided and areas studied are useful for exploring system health, but need highlighting through a structured methodology or model to be of use to a safety professional. Job provides a wealth of secondary data that will be used throughout this thesis, but does not provide a sound methodology by which to test the reasons behind systemic safety.

Analysis of aviation safety around the world can be broadly classified into three groups:

1. Official accident investigations (and associated reports)
2. Anecdotal-type books on air safety
3. Academic research exercises
The value of each in its original or adapted form for testing the hypothesis of this research is described below;

3.1.1 Official accident investigations

Accident investigation is a requirement under the 1944 ICAO Chicago Convention and broadly follows the guidelines of Annex 13 in structure. The principal objective is to establish 'what went wrong' with a view to prevention in the future. Led by an Inspector In Charge the investigation will be expected to examine all possible causal factors. However, in practice, certain avenues of inquiry can be discounted at a relatively early stage because of evidential finds. For example, when a flight crew reports an all-engine failure, investigators will pay less attention to causal areas such as controlled flight into terrain or improvised explosive devices (IEDs). Such investigations are designed to be reactive in their nature and to narrow areas of inquiry into a single, specific catalogue of events. As such, they are purely a method of examining a single event and not a fluid situation such as a safety record.

Accident investigation provides researchers with a database of causal factors which can be developed into a set of performance indicators of system health. It cannot provide a methodology for exploring the objective, 'what makes this system safe?'. It can only really answer 'what made this system unsafe on this particular day, at this particular place and involving this particular aircraft?'.

Faced with no existing methodology, the researcher's task was to build a skeleton of ideas on which to build one. During the course of research, that structure may be forced to change as a result of limitations or opportunities, albeit still within a structured framework. The result is two-fold: Firstly, a new methodology with guidance on its known advantages and disadvantages which may be applied to any aviation system or Australia at some point in the future. Secondly, the research is anticipated to produce a sound case study which examines why Australia has attained a good record for airline safety.

3.1.2 Anecdotal-type books on air safety

There are a number of air-safety texts which concentrate on reviewing accidents in varying levels of detail. The morbid fascination of the general public is usually enough to guarantee near best-seller status for such texts, especially when it is accompanied by a selection of photographs. Unfortunately, such publications tend to concentrate primarily on the danger of air travel; no doubt as a result of market demands. The content is a variety of information from official accident reports, eyewitnesses, anecdotes and even conjecture. A review of several different books will soon reveal disparities in the facts presented especially in complex accidents such as the 1977 Tenerife disaster and the shooting down of KAL 007.
The attention afforded to each accident is a function of how 'interesting' a story is to the reader and how many people were killed. Thus accidents such as Tenerife, Erebus and Lockerbie attract disproportionate attention and the reader is left with a distorted view of both the safety and hazards of aviation. Although some authors try to examine groups of factors (e.g. Barlay, 1990), most resort to a chronological review of accidents (e.g. Gero, 1993; Denham, 1996) or a compendium of selected accidents (Brookes, 1992; Stewart, 1986; Job, 1995 and 1996, Coote, 1993 etc.). While such text provide an interesting introduction to the subject of aviation safety, they do little to provide any sort of structured methodology for examining safety.

3.1.3 Academic research exercises

Few research projects have examined aviation safety at a system level. Barnett et al. (1979, 1989, 1992) at the Massachusetts Institute of Technology (MIT) examined safety records of world airlines (see earlier) and were forced to defend their findings against fierce criticism from, amongst others, a Transportation Research Board (TRB) panel. A more detailed breakdown of the work is presented in the statistical section of this thesis and will not be repeated here. In essence, the result was a method of comparing safety records of airlines and predicting the likelihood of a fatal accident involving that airline. Airlines were grouped by size (smaller airlines being shown to experience more accidents than their larger counterparts) and their apparent safety was calculated from their past performance.

The US National Transportation Safety Board (NTSB) criticised the methodology and conclusions warning that the infrequency of accidents meant extrapolating information from them was a dangerous undertaking and one at which MIT had not succeeded. There was also a strong reaction to the second paper, Airline Safety: The Last Decade (Barnett et al. 1989) for its attempt to examine the effects of the 1982 deregulation of the US domestic air market. All criticisms seemed to stem from the same concern; that the reliability of statistical investigations into such a complex subject as airline safety was open to question. Barnett et al. needed to assume a level of homogeneity in the airlines they considered.

For example, all airlines were deemed to have a choice regarding the airports they operated to and therefore considering airlines "...as hapless victims of airport conditions beyond their control" (1979) was dismissed by the authors. For future studies, comparison of airlines like KLM, operating from a country with flat approaches and a financially sound airport authority with an operation like Air Nuigini (Papua New Guinea) which operates in areas of high terrain and short landing strips in a poor country seems flawed. Different nationalities of airlines do not have full control over where they fly and therefore their operating environment cannot be assumed to be homogeneous.

Statistical analysis using the MIT methodology provides a valuable indication of safety trends over time, but needs to be developed further to be of use to those concerned with the details
of aviation safety. ICAO (1994) warn that, “statistics can be misleading in understanding the nature of accidents and devising prevention measures.” Statistics generally refer to causal factors experienced on a particular day to a particular aircraft and not deficient processes which may exist over a longer time period.

Oster, Strong and Zorn (1992 and 1992b) also examined the worldwide aviation safety record in response to what they describe as a perceived “...deterioration in the underlying safety of the aviation industry.” Again, the authors used accidents as the measures which is entirely justified on the grounds that they were examining safety records. Their conclusions relate to the comparative safety performance of different airlines around the world (see figure 2.2.10) with particular emphasis on the effect of deregulation on the US airline industry. While the methods utilised are statistically sound, they rely on accident statistics which are formed solely from the ‘primary cause’ of accidents. This means that they are susceptible to the historical bias of accident investigation towards ‘the last thing to go wrong’ as opposed to the multiple cause approach advocated in this thesis.

Unfortunately, the research does not focus on the reasons behind accident causal factors. This is understandable because of the magnitude of the task, but fails to take account of the fact that the quality and depth of accident investigation varies between countries and over time. The authors present an interesting analysis which enables them to make several conclusions about the performance of different levels of air carrier in the US, different regions of jet carriers around the world and the effect of public policies on the safety record. However, this work does not provide a methodology that is suitable for analysing a particular aviation system such as Australia.

In the absence of a detailed academic methodology which could be applied to the Australian aviation system, a new one was developed to test the hypothesis of this thesis. Its direction is drawn from a number of different sources which will be detailed below and, although the application is specifically Australian aviation, it may be used with any defined aviation system in the future.

### 3.2 Development

In aviation, studies of safety are traditionally reactive - the art of discovering what went wrong is well developed. (Arguably, such an approach is concerned more with the study of danger than safety.) At the same time, such a method has a number of disadvantages;

1. By definition, accident investigation requires something to have gone wrong. In aviation, this is usually at great expense and often with considerable loss of life - learning is from other people's mistakes. It is only possible to try and prevent the 'next time'. Therefore to establish safety, danger must be experienced.
2. Following accidents, there is often a lack of reliable witnesses. Flight crew have often been killed or highly traumatised and those involved at other levels in organisations such as the airline or regulator have much to lose. Even with the best resources, it is rarely possible for an accident investigator to go beyond the direct causal factors of a crash.

3. It is assumed that investigation will reveal what can prevent a recurrence of that accident in future. However, history shows that accident reports often tackle this question by focusing on the primary cause (which in the case of ‘pilot error’ is often deceased).

In 1993, Boeing took the bold step of suggesting a new focus for aviation safety studies. Commensurate with the growing tendency to consider accidents in terms of causal factors of an accident chain rather than the ‘last line of defence,’ primary cause, Boeing started to examine the multiple ways of preventing accident recurrence. Termed ‘accident prevention strategies’, Boeing examined a set of 232 commercial jet aircraft accidents (Boeing, 1993) for ‘...several possible avenues of intervention’ which could prevent such an event re-occurring. While some accidents (17.5%) could only have been prevented in one way (for example, aircraft lost to catastrophic structural failure), the rest have multiple prevention strategies (an average of 3.77 per accident) up to a maximum of twenty strategies per accident.

**An accident prevention strategy is required to meet these two criteria;**

a. A future accident might be reasonably avoided if this strategy were to be successfully employed.

b. At least one definitive action can be envisioned that will provide a substantial reduction in the frequency or probability that such an event will reoccur.

The advantage of such an approach is in terms of the multiple ways to prevent not just the same accidents happening again but also other variations on a theme. This allows cost effective safety measures to be selected on the grounds of maximum potential benefit. Such an approach also provides an indication of factors to examine in reviewing a safety system which is the context this thesis will utilise.

Ideally, the researcher would have data which identified prevention strategies, not just for accidents, but also incidents. This would provide a more stable sample of data and highlight factors that have been involved in serious incidents but not accidents. However, data from such incidents are either held in an uninterrogable form or cover only a few years. ICAO’s ADREP database could not be used for confidentiality reasons (Weber, 1994) and British Airways’ BASIS database covers only a few years of data for a single airline. (Although the BASIS system is available to outside users, each airline’s database operated independently.) Boeing’s analysis of accidents represents the best currently available analysis.
Boeing classified its prevention strategies into a total of thirty seven factors, reflecting the following categories of responsibility:

- Crew
- Airline Flight Operations
- Air Traffic Control
- Airport Management
- Weather Information
- Airplane Design / Performance
- Maintenance

The full set of categories is listed in appendix 3.2.1. The strategies were then applied to 287 commercial jet accidents which occurred between 1982 - 1991. For all accidents, this represented a total of 874 prevention strategies.

The Boeing approach does not represent a methodology for examining the safety of a system. It does however provide a set of areas to examine and it is in this area that it is of most use. Grose (1988) had previously suggested that in examining the safety of an airline, the notion of 'margins of safety' as a measurable and comparable set of indicators could be explored if "...a consensus within the airline industry endorsed the pursuit". Such an examination was subject to resolution of a true definition of the factors used to measure airline safety, a means of measuring them and a means of combining them into a final numeric value.

Grose offers a set of nine categories or 125 elements as "a baseline for such definition... ...of the factors deemed to be essential to measuring airline safety". The categories are defined as follows:

- Personnel (as transportation facilitators)
- Aircraft (as transportation vehicle)
- Airports (as access/egress points for transportation)
- Airspace (as medium through which passengers are transported)
- Airlines (as corporate entities that enable air commerce)
- Aviation (as technological community that supports transportation)
- Government (as public advocates for safe transportation)
- Public (as influence - via government - on all other elements)
- Passengers (as transportation system throughput)

The full list of 125 elements is presented in Appendix 3.2.2.

Grose’s factors represent a very detailed coverage of areas which could be studied. A quick scan of the list will convince the reader that some factors are significantly easier to quantify than others, both in terms of measurement and assessing their effect on other factors within
the system. For example, in the category ‘aircraft’, the ‘thrust-to-weight ratio’ is a piece of information that is easily located in the performance manual. The ‘collision avoidance capability’ is rather more difficult to estimate both in terms of the types of collision pairs which will be presented, the reactions of the crew, environmental conditions and so on. There are also hazards presented that are poorly understood by scientists such as the effects of ‘cosmic radiation’ or the effect of magnetic anomalies.

This methodology provides an extreme to Boeing’s prevention strategies that exceeds the resources of most researchers. It also requires access to data which is not easily accessible to one single agency; for example, behavioural factors within the airline, regulator and airports. Faced with the need for a practical way forward, it may seem that the most systematic way to proceed is to select a reasonable combination of Boeing and Grose’s factors to work through. However, even if this method is employed there has to be some way of reconciling the multiple factors to form an intelligible ‘big picture’. It is of no use to examine the safety of a system by stripping it down to its constituent parts if the interaction of these parts is not going to be explored. By definition, a complex system relies on multiple interactions between components and one of the greatest failings in understanding systems is failing to understand just how many interactions do occur.

The temptation is to review every factor in sequence, but the practicalities of research make this not only impossible but unwise anyway. Even when the evidence is collected, the idea of systematically reviewing every factor is impractical in an investigation of this depth. Although this was originally thought to be a sensible idea with a further chapter to link the factors together, the volume of such an exercise and the level of duplication required for each category to stand alone made this impractical. Such presentation would be incredibly hard going for the reader and would lose its full value.

The decision was therefore taken to present the multiple sources of evidence within the structure of the aviation system. That is to say that the results would be split into the following three components:

<table>
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<tr>
<th>Chapter Four</th>
<th>The Natural Environment</th>
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<tr>
<td>Chapter Five</td>
<td>The Human Environment</td>
</tr>
<tr>
<td>Chapter Six</td>
<td>The Operational Environment</td>
</tr>
</tbody>
</table>
3.3 Presentation of the Case Study

Within each of the three categories, the data analysis and discussion is split down into logical areas which encompassed all of the details of the original guidance document (see appendix 3.3.3) to ensure a clear flow of ideas and allow easy reference for readers who wished to target a specific area of concern. The detailed subheadings are documented below;

**Chapter Four - The Natural Environment**

4.1 Aviation Meteorology
- 4.1.2 Weather Types and their Occurrence in Australia
- 4.1.3 Microbursts and Windshear
- 4.1.4 Crew Fears Regarding Weather
- 4.1.5 Weather and Crew Perceptions

4.2 Physical Geography
- 4.2.1 Relief and the Environment
- 4.2.2 Effect of Relief on Collision Risk

4.3 Spatial Separation
- 4.3.1 The Effect on Historical Development
- 4.3.2 Trading Partners
- 4.3.3 Route Structure

**Chapter Five - The Human Environment**

5.1 Culture
- 5.1.1 Introducing the Concept of Culture
- 5.1.2 Culture and Aviation
- 5.1.3 National Cultural Traits of Australia
- 5.1.4 Organisational Culture
- 5.1.5 The Relative Safety of Aviation

5.2 Training
- 5.2.1 Recruitment
- 5.2.2 Evaluating Training Effectiveness
- 5.2.3 Level of Training
- 5.2.4 Experience and Currency
- 5.2.5 Joint Flight Crew Training
5.3 Communications
5.3.1 Crew Resource Management Training
5.3.2 Organisational / Industry Structure

5.4 Political Influence
5.4.1 Priorities for Aviation
5.4.2 Role of Regulator
5.4.3 Response to Occurrences
5.4.4 Economic Factors

5.5 Luck - What is it and does it exist?
5.5.1 The Origin of Perceived Luck

Chapter Six - The Operational Environment

6.1 Equipment
6.1.1 Aircraft Design and Selection
6.1.2 Aircraft Maintenance
6.1.3 Buyer Furnished Equipment
6.1.4 Regulatory Requirements

6.2 Airport Integrity
6.2.1 Size, Surface and Condition of Runway and Taxiway Surfaces
6.2.2 The Availability of Approach Aids
6.2.3 Obstacle Clearance
6.2.4 Prevailing Weather Conditions
6.2.5 Surrounding Terrain and Approach Procedures
6.2.6 Level of Traffic versus ATS Provision
6.2.7 Rescue and Fire Fighting Provision
6.2.8 Security and Terrorism
6.2.9 Aircraft Loading

6.3 Air Traffic Control
6.3.1 Level of Air Traffic Services
6.3.2 Collision Risk and Traffic Density
6.3.3 Concerns Regarding ATC Integrity
6.3.4 Communications and Language
3.3.1 Navigating around the Case Study

Case studies of this complexity are all but impossible to present sequentially in the detail required without the risk of the reader losing track of the many linkages. It is extremely difficult to try and cover every subject in its entirety at the point where one subject appears to lead straight into it. The order presented above is a logical way to present the case study, yet required a method of presenting the links before the concluding remarks of the thesis. The standard procedure of placing 'see also section x' or 'see also page x' is acceptable but does not do anything for the readability of the section and does not aid the selective reader to easily jump to the relevant sections.

A new system was therefore designed which used a series of three standard icons to denote the linked sections of the case study. The icons cover the three categories of analysis and are presented by the side of the text in the following way:

As the main body of text continues in a neat and uninterrupted flow any links, for example to a section within the human environment would be presented alongside. The icons mean the section is immediately recognisable and the exact section is printed beneath the text.

As the thesis continues, there may also be links to the natural environment section which would be shown with this simple and easily recognisable icon.

Finally, links to the third section, namely the operational environment, will be highlighted using this aircraft icon. The icons may appear in any section and are designed to be unobtrusive to the reader yet useful for fast review or searching.

Within the three environments of analysis, links back to the 'state of the art' section (chapter 2) are represented using the artists palette icon displayed here.

Far from being a gimmick, this feature is a simple tool for helping assure the construct validity of a case study. It helps present the chain of evidence when the subject is a complex system with numerous multi-level interactions. The opacity of such systems can make links difficult to see so this technique has been designed to help minimise this problem.
3.4 Research Tools

The integrity of a case study is secured through the use of multiple sources of data. This means that not only is secondary data collected from a number of independent sources, but it is also to be supported through the collection of primary data. In the case of this research, this has been achieved through three different methods:

1) Individual interviews with expert witnesses
2) Observational exercises
3) Questionnaire

3.4.1 Individual interviews with expert witnesses

There are a number of key positions within any industry where the employee will hold information which is not formally archived. Such information may be of great value to others but is not communicated either because its value is not recognised by the holder or for reasons of commercial confidence. In the case of this research, such expert witnesses may have held the key to areas of further research or the ability to put qualitative data into context. Interviews were therefore seen as the natural way of eliciting such information.

Such a method of data collection is subject to certain problems:

a) As the assistance of expert witnesses is entirely at their own discretion and for no form of reward, certain ideal witnesses were unable to be interviewed. For example, the Chief Executive of Qantas would be able to provide a corporate level overview of objectives. However, due to the pressures of Qantas being floated to the public during the duration of this research, the CEO was unavailable. Nevertheless, the overall level of support from industry was excellent and the assistance provided, invaluable.

b) There is a danger that the interviewer's technique may bias the direction of the interview. In general, each interview had a loose agenda and questioning was allowed to follow the witnesses responses. At all times, the interviewer was cautious not to lead the witness or simply ask the interviewer to agree or disagree. As witnesses were being asked specifically about areas in which they hold great expertise, the danger of them being led to answer in a certain way was minimised.

c) The benefits of an informally structured interview included the ability for the witness to develop "more as an 'informant' than a respondent" (Yin, 1984). Faced with a similar
agenda, some people were able to talk at much greater lengths than others and develop the discussion along more paths. For example, the interview with Ken Lewis, Director of Safety and Environment with Qantas and a former IATA SAFAC Chair lasted six hours without a break.

**d)** There is a risk that the witness will attempt to give false or selective information to achieve some hidden agenda. This is especially the case on matters which are safety critical. However, the proactive approach employed in this work was expected to minimise this threat. All expert witnesses were asked to comment on positive safety matters rather than the mistakes and errors which accident investigations traditionally focus upon. There should have been little or no commercial, political or financial gain for any of the expert witnesses to supply anything other than the truth. Nevertheless, the use of multiple sources of evidence is designed to offset such a phenomena if it occurred.

Expert witnesses used in this research included:

**Australia**

Capt. Fred Boomsma, Manager, Flight Operations, Ansett Australia
Capt. Neville Dickson, Manager, Flight Safety, Qantas Airways (Domestic)
Captain John Faulkner, ex-Manager, Flight Safety, Qantas Airways
John Fitzpatrick, Senior LAME, Qantas Human Factors Steering Group
John Guselli, Manager, Quality Assurance, Air Traffic Services, CAA Australia
Mike Innes, Manager, Engineering and Maintenance Safety, Qantas Airways
Captain Lionel Jenkins, ex-Manager, Airline Safety, Australian Airlines
Michael Kemmis, Manager, Corporate Safety and Fire Prevention, Qantas Airways
Ken Lewis, Director of Safety and Environment, Qantas Airways
Dr. Claire Marrison, Human Factors Manager, Bureau of Air Safety Investigation
Capt. Maxwell Loves, Projects and Development Manager, Melbourne Institute of Aviation
Bev Maunsell, Manager, Aircrew Safety, Qantas Airways
Capt. Max McGregor, Manager, Airline Safety, Ansett Australia
Group Captain Lindsay Naylor DFC, Director of Flying Safety, RAAF
Captain Gordon Phillips, Vice President, Australian International Pilots Association
Wing Commander Angela Rhodes, Commanding Officer, RAAF School of ATC
Geoff Smith, Regional Aviation and Defence Manager (NSW), Bureau of Meteorology
Captain Doug Spiers, Head of B737 Operations, Qantas Airways (Domestic)
Don Whitford, Regional Aviation and Defence Manager (Victoria), Bureau of Meteorology
Anthony Wilson, Manager, Flight Training Facility, Qantas Airways (Domestic)

**UK**

Robin Ablett, Research Project Manager, Safety Regulation Group, CAA
Capt. Stuart Grieve, VP - Operations, Britannia Airways
3.4.2 Observational Exercises

There is considerable value to be gained from observing the actions of individuals and groups in the workplace. Whereas interviews can lead to the 'proper answer' being offered, observing day to day operation can reveal areas where the theory is not matched in practice. Once again, however, there are certain negative aspects of such a research technique;

a) Individuals will invariably act differently once under observation (the so-called Hawthorne effect). From the researchers point of view this will lead to skewed data. From the subject's point of view this may lead to distraction from the task in hand which is especially critical when the activities being observed are of as critical a nature as flying an aircraft. It is important that subjects know why they are being studied and that there is no 'right or wrong way of behaving' and that the results will be deidentified so that they cannot be used against them at a later date by someone else. It is only once trust has been established that such exercises are worth undertaking.

b) Observational exercises may be conducted either in the real environment or in a test cell where conditions are strictly controlled. The latter method would require resources far in excess of those available to this research project and would require a high degree of cooperation from a considerable number of workers. The former method was therefore selected as the most suitable in this instance.

c) Real environment observational exercises require the co-operation of the subjects which in this case were airline crews. The high cost of air travel limited the number of observations which could be completed. In the ideal world, there would be more observations, but the generosity of the airlines involved (Qantas, Ansett and Excalibur) is gratefully acknowledged. The observations detailed in this thesis provide important information to support other sources of data and for the researcher wishing to carry out more detailed observations in the future.

d) Observations are prone to the subjective bias of the observer. All observations within this thesis were conducted by the same researcher to ensure consistency. The risk of 'confirmation bias' i.e. 'seeing what one wants to see' is a danger for anyone carrying out such work. A full understanding of the risks help guard against this. Ideally more than one
researcher observing the same activity would have been used, but the limited space of flight decks made this impossible.

The flights observed were as follows:

Qantas: London-Bangkok (All B747-400)
        Bangkok-Sydney
        Melbourne-Singapore
        Singapore-London

Ansett: Melbourne-Canberra (All B737-300)
        Canberra-Sydney
        Sydney-Adelaide
        Adelaide-Darwin
        Darwin-Alice Springs
        Alice Springs-Adelaide
        Adelaide-Melbourne

Excalibur: East Midlands-Palma (All A320)
          Palma-East Midlands

Two simulator (LOFT) sessions were observed:

Qantas: B737 at Melbourne
Ansett: BAe146 at Melbourne

An engineering incident investigation was also witnessed at Mascot Jetbase (QF) where a boroscope cover had been left off a 747 engine which then suffered a total failure on take-off and necessitated a turn-back to San Francisco.

3.4.2.1 Participant-Observation

On several occasions, the opportunity to become a participant in a training exercise was presented. As one of the 'learning group', it was easier for the other participants to accept the presence of an observer and there was also the opportunity to observe the group facilitator at work. This method "...has been most frequently used in anthropological studies of different cultural or subcultural groups" (Yin, 1984). In the course of this research, similar exercises were observed on four occasions - namely the emergency procedures / integrated Crew Resource Management (EP/CRM) recurrent training day. For all the operators concerned, this was an annual exercise where flight attendants and technical crew were brought together as two crews (approximately 22 people depending on aircraft types operated). In each case it was unlikely that all members of a 'crew' had worked together before.
QANTAS (Domestic): Recurrent EP/CRM training was held over two days at the Melbourne training centre with a mixture of operating crews from all over Australia. The first day was a mixture of classroom based discussion and cabin simulator sessions (using a full size 737 cabin simulator) with the second day being held at the city swimming pool as a classroom based morning and pool based raft exercise in the afternoon. Some crew stayed together overnight in a hotel although many returned home.

QANTAS (International): Training was also held over two days, but at the Mascot Jetbase in Sydney. Two crews were formed and the schedule was similar to that run by QF Domestic although a full size 747 section simulator was used as well as an in-house pool.

Ansett Australia: Training was held at the Melbourne training school using a classroom and full size moving 737 cabin simulator. No pool exercise was conducted. This training course has been revised since the observational exercise was completed.

Britannia Airways: Training was held at the East Midlands Training School over two days and comprised of a mixture of classroom teaching, role playing exercises and a practical fire fighting and rescue course in a smoke filled cabin simulator and fire wall. All crew members stayed together in the same hotel.

3.4.3 Questionnaire

Observational exercises and expert witness interviews allow the collection of high quality qualitative data from a small sample of people. To assure data integrity, it was necessary to supplement such data with primary qualitative and quantitative data from a larger sample, albeit at a less detailed level. This is where the use of a questionnaire became very useful. Not only does a well designed questionnaire provide a unique 'snapshot' of current issues within the aviation system, but it also provides the data to test sub-hypothesis derived elsewhere in the research process.

3.4.3.1 Design Process

The questionnaire was aimed to cover the technical crews of Ansett, Qantas and the RAAF as well as the air traffic controllers of the military and CAA (later AirServices Australia) and a small batch of the general public who were asked to complete an abbreviated version. Comparative data was originally to be supplied in the UK by Britannia Airways, Air UK, RAF and in Japan by All Nippon Airways (ANA) and Japan Airlines (JAL). Unfortunately, although full co-operation was eventually secured in Australia, the other parts of the world posed some problems.

The Japanese contribution, through the pilots of JAL and ANA, appeared to be progressing well and the questionnaires had been translated in anticipation of a positive outcome. It is
often said that decision in Japan is only ever reached by committee and after six months of consultation it was the last hurdle of the trade unions which became the surprise stumbling point. Both JAL and ANA had experienced severe organisational change up to 1995 and the unions felt that questionnaire responses would paint an unfair picture of the safety health of the airlines. Ironically, Qantas had merged with Australian Airlines and been floated to the public just prior to the questionnaire and no objections were ever raised. The notion that problems caused by such reorganisations 'do not count' or 'paint an unfair picture' is fundamentally flawed - accidents do not discriminate for such things. The use of Japan as a third group which was culturally different to both the UK and Australia was to have been a major strength of this methodology, but impossible due to these operational problems.

In the UK, Britannia completed its questionnaires with admirable efficiency and Air UK eventually seemed to be following suit. However, reorganisation within the airline, in particular the sell off of the Air UK Leisure sector, had led to a sudden about turn in policy. After several months of pondering (and a guarantee that they had been distributed), the airline decided it was 'safe' for them to go ahead and co-operate. Unfortunately this decision came too late for the research, being towards the end of the budgeted three years. This idea was therefore reluctantly shelved, although Air UK have given a guarantee to help with future research. Like Air UK, the RAF Inspectorate of Flight Safety had originally agreed to distribute the questionnaire to technical crew. However, a spate of nine hull losses in the opening four months of 1996 led to the focussing of resources on this problem with the unfortunate loss of assistance in administering a questionnaire. When research has not been commissioned by those who are required to fill in questionnaires, there is very little that can be done to pressure them to co-operate.

3.4.3.2 Questionnaire Objective

As a result of the prior collection of primary and secondary data, the questionnaire's purpose was to fill in the gaps and provide supporting or refuting data. The ideas for questions were therefore derived from the research plan and as a result of the expert witness discussions and observational exercises. The original draft of the questionnaire was then discussed with an expert panel from industry and academia to refine the questions and ensure they would be unambiguous to crews.

The expert panel consisted of:

Dr. Robert Caves  
Dr. David Gillingwater  
Mr. Ken Lewis  
Captain Max McGregor  
Ms. Diana Sanders  

Research Supervisor  
Research Director  
Director of Safety and Environment  
Manager, Airline Safety  
Behavioural Psychologist  

Loughborough University  
Loughborough University  
Qantas Airways  
Ansett Australia  
RMIT University
An expert panel of reviewers was deemed necessary due to the problems of securing a population suitable for answering a pilot survey. At each stage of design, the full panel was asked for their views on the structure and content of all questions. This was to ensure clarity and unambiguity and to avoid leading the respondents in their answering. A number of changes were made at this early stage including simple syntactical corrections (and translation to 'aviation-speak') and more major structural alterations. Fears were expressed regarding the structure of section four as to how many respondents would be able to answer the questions.

At this first stage of consultation, sample questionnaires were produced in the form of a finished questionnaire. Typesetting was accomplished using QuarkXPress, a Desktop Publishing package, and sample forms were printed in a number of formats. This allowed the panel to comment upon the readability of the forms in an attempt to help respondents fill in the form more easily and also to attract a higher response rate.

After simple corrections were made, a pilot version of the survey was issued with the original section four remaining, to three Rotary Clubs who had volunteered to assist. Members were allowed the full meeting (approximately two hours) to complete the forms at their own pace and were given little assistance other than the narrative printed with the introduction. (In the main survey, crews would be able to ask questions using a special support hotline although in the event, this number tended to only be used by individuals wishing to know more about the research.) Approximately 60 forms were returned accounting for a response rate of approximately 80%. The full questionnaire is reproduced in appendix 3.4.1

Special Note:

The reader should exercise caution in interpreting the term 'pilot survey'. While it is established practice to conduct a 'pilot survey' as a test before distribution of the main survey, a complication of this research was that, being issued to flying crew, it was often referred to simply as a 'pilot questionnaire' because it was being filled out by pilots!

The initial worries regarding section four were borne out in this pilot phase of sampling. The introduction had stressed that anyone experiencing difficulty in answering a particular question could choose to omit it. Without exception, the only question to amass a high drop-out rate was the problematic section four. Even the few that made an effort included a large number of respondents who answering in a way contrary to the question's explanation. Several attempts at percentages appeared alongside attempts to rank the factors. (The latter method was the one suggested to be the best alternative, but lacked the detail required by the researcher.)

A major reworking of section four was required if an adequate response rate was to be achieved. If the pilot survey was a fair indication, then even in a very large sample, the number who filled in the question would be inadequate to achieve statistical validity. The key to deciding upon a new format lay in the attempts to answer the original question and the success of answering other questions on the form using the lickert scale for ranking.
The objective of section four was to explore how individual’s acceptability of risk was affected by a number of factors including vocation, age and rank etc. The fundamental flaw in the original question lay in the fact that even perfect responses would tend to explore only one facet of risk acceptability, namely the way people estimate risk. If an individual attains safety by minimising risk so that risk countermeasures (safety measures) equate with risk exposure, then a person who overestimates risk may be expected to over-compensate. If a particular group appeared to severely over-estimate risk (or indeed, under-estimate) then would it be reasonable to suggest that they would err on the side of caution (or danger)?

An introductory passage was included which was later added to in some cases by a cover letter from the company endorsing the study. In all cases, the forms were to be returned to an internal address (at no expense to the respondent) from where the final batch was forwarded to the researcher. The format of the form was such that when completed it could be folded and stapled to form an envelope and posted. Total anonymity was preserved from the time a form was submitted onwards.

The rationale for each question of the survey is presented in the next section.

3.4.3.3 Problems

The consultation and approval stage took a long time in all organisations (with the exception of Britannia), not least because of the voluntary nature of participation. Even the contact representatives of each organisation were a little surprised at the number of different staff members who required consulting before questions were approved. Such a phase cannot be avoided and highlights the need for patience and allotting extra time in research. Although initial consultation with the Australian carriers began in November 1994, some forms did not reach crews until August 1995 and with the reorganisation of CAA / AirServices Australia, ATC replies did not appear until March 1996.

The production and distribution of the final questionnaire was an extensive task which was completed by the airlines involved at no cost. Their generosity is gratefully acknowledged and it is bearing this in mind that the problems of distribution are mentioned solely as a methodological issue. The shift patterns of flight crew (especially the international crews) meant that a large number of potential respondents did not receive questionnaires in time. As the airlines were offering their assistance gratis it was difficult to push for follow up letters and so on. The lower than originally desired sample rate is a function of this and must be accepted as a constraint of small-budget research.
3.5 Standard Questionnaire Format and Design Rationale

This section profiles the standard questions used in the final draft questionnaires along with the rationale behind the question design.

**Section One. (Test Sample)**

The first five questions represent the sampling frame data to establish who had answered the survey and to allow rank / seniority to be tested as a factor behind the attitudes which may be listed later in the survey. The wording of the questions varied between operations to account for military / civil and flying / ATC differences. All of the variations are documented in appendix 3.4.2

### 1.1 What is your current job title?

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1.</td>
<td>Captain</td>
</tr>
<tr>
<td>2.</td>
<td>First Officer</td>
</tr>
<tr>
<td>3.</td>
<td>Second Officer</td>
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<td>4.</td>
<td>Flight Engineer</td>
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### 1.2 Do you hold any one of the following positions?

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<tbody>
<tr>
<td>1.</td>
<td>Management pilot</td>
</tr>
<tr>
<td>2.</td>
<td>Check / training pilot</td>
</tr>
<tr>
<td>3.</td>
<td>Line pilot</td>
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</tbody>
</table>

### 1.3 What type of aircraft do you currently fly?

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<tr>
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<tbody>
<tr>
<td>1.</td>
<td>Airbus A300</td>
</tr>
<tr>
<td>2.</td>
<td>British Aerospace 146</td>
</tr>
<tr>
<td>3.</td>
<td>Boeing 737</td>
</tr>
<tr>
<td>4.</td>
<td>Boeing 747 Classic &amp; SP</td>
</tr>
<tr>
<td>5.</td>
<td>Boeing 747-400</td>
</tr>
<tr>
<td>6.</td>
<td>Boeing 767</td>
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</tbody>
</table>

### 1.4 How long have you held your current rank?

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<tbody>
<tr>
<td>1.</td>
<td>Up to two years.</td>
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<tr>
<td>2.</td>
<td>From two to five years.</td>
</tr>
<tr>
<td>3.</td>
<td>From five to ten years.</td>
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<tr>
<td>4.</td>
<td>Over ten years.</td>
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</tbody>
</table>

### 1.5 What is your age group?

<p>| | |</p>
<table>
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<th></th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>Under 30</td>
</tr>
<tr>
<td>2.</td>
<td>30-39</td>
</tr>
<tr>
<td>3.</td>
<td>40-49</td>
</tr>
<tr>
<td>4.</td>
<td>50+</td>
</tr>
</tbody>
</table>
Section One cont. - (Test Sample)

Question six represents an attempt to gain an insight into cultural background. University rules of etiquette make it difficult to ask information about nationality / background. This is further confused by the fact that airlines such as Qantas will only employ people with Australian citizenship. Therefore, although pilots may have arrived from the US, Canada and the UK etc, especially during the 1989 pilots dispute, they would be classified as ‘Australian’ if asked to write their nationality. As cultural influences tend to be deep rooted, even in ex-patriots, it was important to ask the question in such a way as to establish what nationality they represented culturally. It was felt that as many cultural traits are developed during an individual’s formative years, the chosen wording of this question was the cleverest way of eliciting this information.

1.6 In which country did you complete the majority of your education?

1. Australia. 1
2. United States Of America. 2
3. United Kingdom. 3
4. Canada. 4
5. Other (please state).

Question seven examines the training background of each pilot. The answers reflect all of the possible options available to Australian crews.

1.7 How did you learn to fly?

1. Private flying school (own expense) 1
2. Private flying school (scholarship) 2
3. Airline cadet programme (Australia) 3
4. Airline course (Overseas) 4
5. Military. 5
6. Other. 6

Section Two (Your occupation)

Questions 2.1 - 2.6 examine the perception of the ‘team’ and the attitude of the individual towards their colleagues. They cover issues related to crew resource management in the traditional (cockpit) and more advanced (aircraft) areas. Question 2.4 uses a new methodology to examine attitudes towards co-workers. A more detailed description is presented in section 3.5.2.

2.1 Which one of the following statements best matches your perception of the job of Captain?

1. The Captain is in charge and knows best in all situations 1
2. The Captain is the most experienced and skilled member of the flight crew. 2
3. The Captain is the manager of a team called "the flight crew". 3
4. The Captain is one component of a team called "the flight crew" 4
5. None of these statements is a fair assessment. 5
2.2 Which one of the following is the single most important thing about your job?

1. I get the remuneration that I deserve. 1
2. I am doing the job I really want to do. 2
3. I feel a sense of achievement at reaching the top of my profession 3
4. I am able to fly state of the art equipment. 4
5. Other (Please state: ) 5

2.3 Which one of the following statements best matches your perception of flight attendants?

1. They are an integral part of the crew at all times. 1
2. They are a useful support in emergency situations. 2
3. They can provide a support facility when asked to do so. 3
4. They are there to tend to the passengers' needs and requests. 4
5. They are waiters/waitresses in the sky. 5

2.4 Using THREE words of your own choice, please describe the majority of...

a) Superior Crew Members. 1.___________ 2.___________ 3.___________

b) Subordinate Crew Members. 1.___________ 2.___________ 3.___________

c) Managers. 1.___________ 2.___________ 3.___________

d) Yourself. 1.___________ 2.___________ 3.___________

2.5 Are there crew members you would prefer not to fly with? (Please circle one)

1. "Yes" 1
2. "No" 2
3. "Don't Know" 3

If your answer is "yes", approximately how many?

2.6 Are there crew members you consider it unsafe to fly with? (Please circle one)

1. "Yes" 1
2. "No" 2
3. "Don't Know" 3

If your answer is "yes":

a) approximately how many?

b) Have you done anything about it?

1. "Yes" 1
2. "No" 2
Questions 2.7/8 use a human factors performance issue to examine the relationship between commercial pressure and the ability to speak up and refuse to break rules. It also examines the relationship between the attitude towards fatigue and being medically unfit for the task. This is because levels of fatigue can be more degrading of performance than the more traditional 'medical' complaints. Fatigue is a condition which is quite separate to tiredness. Flying suffering from tiredness, especially at the end of a long trip, is acceptable, but fatigue represents a more serious physical condition which is a significant threat to safe operation. There are some who believe that flying whilst suffering from fatigue also counts as flying when medically unfit. There are also those who believe in flying whilst medically unfit to protect their earnings or not to let their crew down.

2.7 Have you ever flown for this airline suffering from fatigue?

1. Never 1
2. Very Occasionally 2
3. Sometimes 3
4. Fairly Often 4
5. Often 5

2.8 Have you ever flown for this airline when you were medically unfit?

1. Never 1
2. Very Occasionally 2
3. Sometimes 3
4. Fairly Often 4
5. Often 5

Questions 2.9/10 use a standard safety procedure (the go-around) to examine the attitude of individuals towards using such a procedure or being requested to use such a procedure. The latter question tests the ability of crew members to accept safety critical instructions from other members of the crew regardless of rank. There is more than one 'acceptable' answer as is the nature of the subject matter.

2.9 Which one of the following statements best describes your opinion of 'go-arounds'...?

1. I would consider I had made a serious error if I had to execute a go-around. 1
2. I would consider it to be an exceptional event if I had to execute a go-around. 2
3. I would consider making a go-around as an option in every landing. 3
4. I would have no problems with executing a go-around if I felt it necessary. 4
5. None of these statements is a fair assessment. 5

2.10 If you were the flying pilot and one of the flight crew called for a go-around during final approach, which of the following statements best describes your actions...?

1. I would ignore the call as I am flying pilot. 1
2. I would ignore the call unless it came from a senior officer. 2
3. I would inquire as to the reason for the call. 3
4. I would ask for confirmation and then execute a go-around. 4
5. I would execute an immediate go around. 5
Question 2.11 uses a situation which can be somewhat of a grey area to examine the reaction of crews to various commercial and peer group pressures.

2.11 You are ready for departure, but the weather is getting steadily worse. Which of the following statements best describes your thoughts...?

1. I would take off because my aircraft is equipped for all conditions.  
2. I would feel obliged to take-off for the sake of the passengers.  
3. I would feel obliged to take-off to keep on schedule.  
4. I would take-off if the rest of the crew were encouraging me to do so.  
5. I would take-off only if both my colleagues and I were completely confident.

Question 2.12 tests the attitude of individuals to authority on a safety critical issue. It examines how the individual would voice their fears relative to formal communication channels. It is purposefully worded to represent an issue of company policy rather than regulation (i.e. something that can be changed) and to represent a safety critical situation.

2.12 A senior manager introduces a new company rule you consider to be unsafe, which of the following statements best describes your actions?

1. I would simply ignore the new rule; its my life.  
2. I would complain about the rule to my colleagues.  
3. I would complain about the rule to my union representative.  
4. I would complain about the rule to my fleet manager.  
5. I would complain directly to the manager responsible for the rule.

Question 2.13/4 simply ask for the individual’s perception of communications channels within their airline. It was originally worded to cover the whole operation with a single question, but Qantas Flight Operations demanded that two questions were used. Unfortunately this decision came very late in proceedings and was therefore not applied to Ansett Australia which makes comparison difficult.

2.13 Do you consider internal communications in Flight Operations to be....?

1. Excellent.  
2. Quite good.  
3. Acceptable.  
4. Poor.  
5. Very poor.

2.14 Do you consider internal communications in the rest of Qantas to be....?

1. Excellent.  
2. Quite good.  
3. Acceptable.  
4. Poor.  
5. Very poor.
Section Three. (Safety).

Question 3.1 examines the individual's fears in regard to flight safety. It is worded in such a way that the respondent considers the importance of each threat to themselves rather than issues they consider may be important in aviation safety which may cover other pilots. The categories were developed from statistic breakdowns of accident causal factors and with the aid of the expert panel. The provision of an 'other' category covered any overflow.

3.1 Please rank the TOP THREE factors you consider pose the greatest threat to your flying safety? (With "1" representing the factor that concerns you most.)

(Write 1, 2 & 3)

a. Engine failure.
b. Snow / ice accumulation.
c. Windshear / microburst.
d. Weather (other than 'b' or 'c').
e. Judgment error (self).
f. Judgment error (others).
g. Mid-air collision.
h. Maintenance related failure (other than 'a').
i. Controlled Flight Into Terrain.
j. Security breach.
k. Runway incursion.
l. Management error.
m. Inappropriate regulations.
n. Other (Please specify) ____________

Confidence about safety matters is different to complacency and is therefore examined at different levels. Question 3.2 examines the 'won’t happen to me' side of confidence whereas question 3.3 examines the individual's confidence of his team (which should be assured through training including CRM). Question 3.4 examines the confidence in management which was expected to provide an indicator of organisational culture. It is expected that the result for 3.4 will be more pessimistic than that for 3.3 because of the natural relationship between subordinates and management and this will be accounted for.

3.2 How confident are you of not being involved in a flying accident? (Please circle one)

1. Very confident 1
2. Fairly confident 2
3. Mixed feelings 3
4. A little nervous 4
5. Very nervous 5

3.3 How confident are you that your crew will perform properly in the event of an abnormal situation?

1. Very confident 1
2. Fairly confident 2
3. Mixed feelings 3
4. A little nervous 4
5. Very nervous 5
3.4 How confident are you that management in general will reduce your possibility of having a flying accident to the absolute minimum?

1. Very confident
2. Fairly confident
3. Mixed feelings
4. A little nervous
5. Very nervous

Questions 3.5/6 inquire about the process of change and whether the individual believes that safety has been degraded within the last five years. This period of time represents a period of change within the Australian industry but avoids including the tempestuous pilots’ strike of 1989.

3.5 Over the last five years, do you think Australian civil aviation in general has become...?

1. More safe.
2. Remained about the same.
3. Less safe.
4. Don't know

3.6 Over the last five years, do you think your airline has become...?

1. More safe.
2. Remained about the same.
3. Less safe.
4. Don't know

Question 3.7 is purposely designed to be open ended as it represents an extremely important issue relative to this thesis and is designed to avoid leading. The coding was expected to be time consuming, but is an acceptable by-product of the process. The perceptions of the reasons behind Australia’s safety record are not expected to be the same as the reality and nor are they to be accepted as gospel. However, the importance of perception on risk taking (as discussed elsewhere) makes this line of questioning very useful.

3.7 In your own words, please tell us how you think Australia has managed to attain the record of zero hull losses for jet RPT operations;
Question 3.8 was printed to appear as respondents turned the page from 3.7 so as to avoid leading the way they answered the previous question. Although it is conceded that there is nothing to stop someone reading the form before filling in the answers, it was considered unlikely in this type of survey. The categories were formed on the basis of previous research and the opinion of expert witnesses and printed in no particular order. An ‘other’ was included to cover any additional categories.

3.8 Which of the following factors do you consider have been highly significant in Australia's safety record for commercial RPT jets?

1. Aircraft types flown.
2. Low incidence of snow / ice.
3. Low incidence of windshear / microburst.
4. Flight crew experience.
5. Flight crew training.
6. Ease of interaction between crews.
7. Maintenance integrity.
8. Relatively flat terrain.
9. Integrity of security.
10. Integrity of airport facilities.
11. Management commitment to safety.
12. Appropriate regulation by the CAA.
13. Availability of flying aids (e.g. GPWS, TCAS etc.)
14. Air traffic control.
15. Low traffic density.
16. Luck.
17. Other (Please Specify)

It is important to consider these factors in the context of safety and to provide a balance between operational efficiency and safety considerations.

Question 3.9 is another open ended question to examine the perceived threats for the future. This is an important question which will help with the determination of future requirements as well as highlighting the current issues relative to the degradation of safety margins.

3.9 In your own words, what do you consider will pose the greatest threat to the safety of RPT carriers in Australia in the future?

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
Section Four (Risk).

The objective of this section is to help us develop an understanding of differences in risk perceptions of air crew compared to the general public. It is designed to help us explore what is special about flight crews.

4.1 For the following activities, we would like you to mark how risky you consider each one would be to you personally if you participated.

*For each activity, please circle between 1 (Not at all Risky) and 5 (Highly Risky).*

<table>
<thead>
<tr>
<th>Activity</th>
<th>Not at all risky</th>
<th>Highly Risky</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Motorcycle riding</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>b. Car Travel (self driving)</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>c. Car Travel (other driving)</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>d. Flying as a passenger in a light aircraft</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>e. Flying as the solo pilot of a light aircraft</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>f. Flying as a passenger in a commercial airliner</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>g. Flying as the pilot of a commercial airliner</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>h. Cycling</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>i. Smoking 20 cigarettes a day</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>j. Drinking 20 pots of medium strength beer a week</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>k. Smoking 'soft drugs' e.g. cannabis</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>l. Australian rules football / rugby league</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>m. Snow skiing</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>n. Rock climbing</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>o. Freefall skydiving</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

4.2 To what degree do the following factors affect your willingness to accept particular risks?

*For each activity, please circle between 1 (No Effect) and 5 (Major Effect).*

<table>
<thead>
<tr>
<th>Factor</th>
<th>No Effect</th>
<th>Major Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. How much you are paid to accept that risk.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>b. Whether the risk could incur a financial penalty to you.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>c. Whether the risk could involve some injury to you.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>d. Whether the risk could result in your death.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>e. Who else is also accepting that risk.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>f. Whether your risk taking increases the risk to your family.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>g. Whether your risk taking increases the risk to other people.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>h. How much you understand about the risks of an activity</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>
3.6 Preserving the Edge - the Feedback Process

The principal aim of any thesis should be to further knowledge. The idea that academia thrives on discussing things that have already happened in industry or that are too theoretical to be of any practical benefit is one that is held by too many. It has always been the case that the true benefit of this research lies in its application and the benefits it can bring to the industry. While it may be unconventional for a thesis to contain details of feedback, there is both a significance to the way that the feedback was requested and issues of case-study reliability testing (see earlier comments).

Towards the end of the research period, during the Summer of 1996, a representative of Qantas Airways Safety Department approached the principal researcher to inquire as to whether the results of the work were ready for viewing. Qantas were keen to learn more of the research conclusions and were also keen to see that knowledge passed on to their competition, Ansett Australia. Neither airline had ever sponsored the research nor indeed asked for it to be done. As the research aims were to examine the reasons behind safety in Australia, there was no guarantee that the conclusions would be complimentary towards either carrier and may even contain comments to suggest that safety was in decline.

Qantas suggested that the principal researcher may wish to travel to Australia, as guest of the airline to present a series of seminars to a collection of their staff. Time would also be provided to visit Ansett, the RAAF and the Bureau of Air Safety Investigation. Ansett had previously asked for results to be presented in the form of a seminar, as had the RAAF and BASI. Flights were provided internationally by Qantas and domestically by Ansett.

The significance of this feedback process is twofold. Firstly, it provided the opportunity for a large collection of ‘expert witnesses’ to hear the conclusions of the research and make comments as to whether they considered them to be valid. Secondly, it demonstrated a very real willingness for the airlines to continue to learn about something they may be expected to hold significant expertise in.

Validation and Verification

Over the eight, two hour seminars, a collection of approximately 130 aviation professionals listened to the presentation of results. All were invited to comment and question at any point during the proceedings, and as cultural studies predict, this was exactly what took place. The range of delegates included such positions as:

RAAF:  Directorate of Flying Safety Staff  
Check and Training Staff  
Line Crew Members  
Acting Chief of Air Force Staff  
Six Air Commodores from various postings.

Ansett:  Safety Department Personnel  
Chief Pilot  
Quality Assurance Management

BASI:  Cross section of all safety and accident investigators

Britannia:  Director of Flight Safety  
Managing Director  
Board of Directors

All those attending were supplied with a 25-28 page feedback pack to take away and use. Qantas, the RAAF and Ansett also published an eight page summary of the research for all crews.

Most of the comments made by the expert witnesses are contained in the text elsewhere in this theory to support or refute earlier assertions. The general consensus, however, was entirely positive. All felt that the conclusions appeared entirely reasonable. Some of the perceived cultural differences between Ansett and Qantas, for example, appeared to be less significant than some of the experts had anticipated, but in the light of the supporting survey returns data, they felt their opinions may have been in need of some revision.

Open to suggestion

One of the greatest dangers for a safe operator is that of complacency. The feeling that they know all there is to know is one that some become guilty of, often to their ultimate disadvantage. Earlier discussion of the Australian aviation industry's willingness to listen and learn seems to have been borne out in the attitude to research feedback.

The principal researcher in this work was aged 22 during the first trip to Australia and only 24 at the feedback visit. Although academically qualified with a bachelors degree in Transport Management and Planning, the researcher lacked any sort of real experience in the aviation industry. Although this biographical information may initially seem to be of little significance, it is in fact highly important. At no point did any of those invited make comment about how young the researcher was and all were prepared to come along and listen before conclusions were drawn. This would not be the case in many other countries. The concept of allowing junior crewmembers to speak up seemed to be alive and well in an industry whose players are traditionally much older. This is discussed in greater detail within the Human Environment section of this thesis.
Chapter Four

The Natural Environment

All aircraft operate within the confines of the operational environment which includes physical geography, human geography and meteorology. All factors are considered here with respect to Australian operations within Australia and overseas.
4.0 The Natural Environment

Anecdotal evidence regarding the reasons behind Australia's apparently good safety record often targets three categories, namely those of weather, low traffic density and terrain. When flight crews of large-jet aircraft in Australia were asked 'How do you think Australia has managed to achieve the record of zero hull losses for jet RPT operations?', the top factor, mentioned by approximately 58% of respondents was the weather with low traffic density in 3rd place (33%) and terrain in 6th place (28%).

This section examines the influence of the natural environment upon Australian aviation safety. As such it is split into two main sections, aviation meteorology and physical geography. The latter category includes both the effect of terrain, in terms of its impact on meteorology and collision risk, and the contribution of spatial separation on the physical make up of the Australian aviation system.

Consideration is also given to the fact that Qantas and now Ansett International also operate outside of Australia. By definition half of all take-offs and landings experienced by international flights will occur outside of the country and this risk must be taken into account when examining the carriers' safety records.
4.1 Aviation Meteorology

The principles of flight are based on ‘good’ weather; clear air, light wind and no precipitation. As soon as weather phenomena are added to the equation, the ability to fly becomes a compromise. Basic diagrams to explain the principle of lift on an aerodynamic structure represent good weather conditions, yet it has been accepted within the aviation community (ever since Icarus died in the first fatal air accident) that numerous weather conditions have detrimental effects on an aircraft’s ability to fly.

Anecdotal evidence recurrently describes Australia as benefiting from ‘good aviation weather’ and it certainly seems to be the belief of flight crews that the weather has been an important factor in keeping operations safe. However, the challenge for the safety investigator is to discover whether this view is reality or just perception. To answer this, another question must be posed, and that is;

Does weather have a significant effect on the safe operation of commercial aircraft?

In terms of primary cause, the percentage of hull loss accidents due to weather phenomena are relatively low. According to Boeing figures (1993), the average percentage of total accidents with known primary cause due to weather was between 4.9% (1959-1992) and 3.3% (1983-1992). A further breakdown of primary causes for 393 accidents between 1982 and 1991 attributes nine accidents to ground de-icing / anti-icing and ten to windshear, with a total loss of 765 souls. Ashford’s (1994) analysis of 219 large aircraft accidents (see figure 2.6.2) reveal ‘atmospheric’ factors were causal factors 51 times;

<table>
<thead>
<tr>
<th>Factor</th>
<th>No. accidents where factor occurs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural overload</td>
<td>1</td>
</tr>
<tr>
<td>Wind shear / upset / turbulence</td>
<td>16</td>
</tr>
<tr>
<td>Poor visibility</td>
<td>22</td>
</tr>
<tr>
<td>Runway condition (ice, slippery, standing water etc.)</td>
<td>7</td>
</tr>
<tr>
<td>Icing</td>
<td>5</td>
</tr>
</tbody>
</table>

Poor visibility was a factor in 10% of accidents followed by windshear / upset / turbulence which featured in just over 7%. The disparity between atmospheric phenomena as causal factors and primary causes is attributable to the fact that aircraft and ground aids are designed, and crew trained to operate in adverse weather. Many accidents involving weather as a factor would not have occurred without a subsequent (or previous) equipment or human factor failure.
FAA Advisory Circular AC00-54, Pilot Windshear Guide (1988), records a total of 51 windshear related events between 1959-1983 which are broken down as follows:

<table>
<thead>
<tr>
<th>Weather System</th>
<th>Number of events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convective Storms</td>
<td>33</td>
</tr>
<tr>
<td>Front</td>
<td>7</td>
</tr>
<tr>
<td>Strong Surface Winds</td>
<td>2</td>
</tr>
<tr>
<td>Turbulent Air</td>
<td>2</td>
</tr>
<tr>
<td>Strong Winds on top of Temperature Inversion</td>
<td>1</td>
</tr>
<tr>
<td>Sea Breeze Front</td>
<td>0</td>
</tr>
<tr>
<td>Mountain Wave</td>
<td>0</td>
</tr>
<tr>
<td>Unknown</td>
<td>6</td>
</tr>
</tbody>
</table>

Figure 4.1.2 Windshear Related Events 1959-1983 FAA, 1988

The JAWS - Joint Airport Weather Studies Project (McCarthy and Serafin, 1984) adds that at least 27 civil airline windshear / microburst accidents and incidents had occurred between 1964 and 1984 resulting in 491 fatalities and 206 serious injuries. They also suggest that although the concept of microbursts dates back to the work of Fujita (1978) there were a number of accidents prior to that time that were probably the result of windshear (including the F27 at Bathurst, NSW in 1974).

Weather is a function of physical geography and is affected by climate, relief, latitude and season. It may be considered to be extraneous to the man-made aviation system and hence largely uncontrollable. However, there are very few weather phenomena that cannot be compensated for, and those that remain, such as low level windshear, are obviously the most hazardous. In addition, the geographic distribution of most weather phenomena are well known which means that equipment and crew training can accommodate expected hazards. The accident record demonstrates a small number of accidents where nature’s forces have been stronger than predicted and aircraft have just broken up in flight.

Example

In 1966, a Braniff BAC111 crashed near Falls City, Nebraska with the loss of 42 souls. While trying to fly through what appeared to be ‘a light spot in the cloud wall’ of a major storm front, the aircraft experienced a severe gust in excess of 155km/h which caused the tailplane to fail. A study following this crash, sponsored by the British Aircraft Corporation, revealed that the apparently clear area between two thunderstorm cells was in fact a highly turbulent roll zone and the old practice of flying below thunderstorm midway between its base and ground level was most dangerous.
4.1.2 Weather Types and their Occurrence in Australia

In Australia, the Bureau of Meteorology (a part of the Department of the Environment, Sport and Territories) issue warnings about the following weather phenomena;

- active thunderstorm area
- heavy hail
- severe turbulence
- severe line squall
- tropical cyclones/tornadoes
- severe icing
- marked mountain waves
- widespread sand/dust storm
- volcanic ash

and for aircraft operating below FL120, warnings of;

- hail
- moderate icing
- moderate (unexpected) turbulence
- the initial onset of phenomena producing extensive areas of visibility of < 8 km or cloud > 4 octas below 1500 feet altitude

An active thunderstorm area may contain hailstones, windgusts, heavy rainfall and even tornadoes. To consider each in turn:

Hailstones

Hailstones form when raindrops freeze at high levels. They grow as they are recycled through powerful up- and down-draughts. Hailstones the size of cricket balls have been recorded in Australia which can cause severe damage to aircraft. Hail can cause contamination of runway surfaces and can seriously obstruct visibility. In 1977, an American DC-9 crashed onto a State Highway after its windshield was cracked by giant hailstones and its two engines had flamed out, with the loss of 62 souls. It is the up- and down-draughts of wind (which enlarge hail) that are, perhaps, an even greater threat as they are not always associated with hail but are always dangerous to aircraft in the form of dry or wet windshear.

Windgusts

Falling rain and hail drag the surrounding air downwards, accelerated by evaporation of raindrops cooling adjacent air. Upon reaching the ground, the air spread as an outflow front which may even curl to form a horizontal vortex. Windgusts may cause aircraft to land offside the runway if approach encounters a crosswind. A sudden change in wind direction during the
critical phase of landing can seriously affect landing speed and even cause the aircraft to stall. If an aircraft flies through the centre of a storm cell, the wind direction may suddenly change from a strong headwind (good for landing) to a strong tailwind (poor for landing) which may force the aircraft into the ground. On 2nd August, 1985, a Delta L-1011 was on final approach to Dallas-Fort Worth Airport through the middle of a storm. As it passed through the core of the storm, the wind speed suddenly altered. The “machine’s speed in such conditions is meaningless; it is the speed of the air over the wings that is crucial. If this airspeed is below the aircraft’s stalling speed as the pressure of the windshear overcomes the prevailing wind and the air flow, then the aircraft will crash if there is insufficient height to recover from the resulting stall.”(Edwards, 1993) The L-1011 crashed on a highway, 1800m short of the runway, with a loss of 135 souls. Due to their significant threat, windshear and microbursts will be covered in greater detail elsewhere in the text.

Heavy rainfall

Heavy rainfall poses a two-fold threat to aircraft. The first is that in flight, rain can cause engines to flame out as the combustion chamber ingests too much water and too little oxygen. Less rare is the effect of rain at airport terminal level, where it can seriously affect visibility and can contaminate the runway. Standing water can dramatically reduce the coefficient of friction of runway pavements to zero, when aircraft begin to aquaplane. Aquaplaning is a particularly hazardous condition as the aircraft can neither make adhesion to brake, nor can it gain traction to execute a go-around. Aquaplaning is both a function of the intensity of rainfall, tyre pressure and the type and condition of the pavement.

The amount and intensity of rainfall in Australia is often underestimated because it tends to fall in short, heavy bursts and often occurs at night. Sydney actually boasts a higher annual rainfall than London. Rain falls at Sydney airport on an average of between 11 and 14 days per month with mean monthly rainfall of between 69 and 135mm. (BOM, 1989). The highest recorded rainfall for a month was 643mm in June 1950 and the highest amount on one day was recorded at 281mm in March 1942. At the other extreme, Darwin, in the tropical belt, experiences between zero and 21 days of rainfall on average, per month. Mean monthly rainfall ranges from 1 to 409mm with the highest recorded monthly rainfall occurring in March 1977 (1,104mm) and the highest daily rainfall in January 1897 (296mm).

Rainfall is generally not a serious problem to RPT level aviation by itself, but can often be compounded through a series of other factors. For example, when associated with strong downdraughts in the form of microbursts, or contributing to poor visibility on marginal approaches. As Ashford (1994) notes, the highest proportion of weather contributory factors relate to poor visibility which can lead to unstable approach, CFIT type accidents.
Tornadoes

These are a rare and very violent product of thunderstorms, and consist of a rapidly rotating column of air in a funnel shape. The vortex of a tornado can range in width from a few metres to several hundred metres and may contain winds that reach 450 km/h. They are infrequent, easily visible on radar and therefore avoidable. Whilst they pose an obvious threat to civil aircraft, they have not been responsible for any jet RPT aircraft losses.

Mountain Waves

Mountain waves occur when wind speed and pressure are affected by relief such as mountains or escarpments. In much the same way that lift is created by the shape of a wing, so clear air turbulence (CAT) can be created by sharp topographical features. Sometimes known as ‘Karman Vortices’, they are also known to occur around large structures such as power station cooling towers and skyscrapers.

In Australia, the Bureau of Meteorology highlight a number of areas where the topography lends itself to mountain waves and CAT. These include Perth, Adelaide, Richmond, Badgery’s Creek and to a lesser degree at island airports such as Lord Howe and Great Keppel. Mountain waves are difficult to see, especially if they occur in clear air, although the presence of lenticular (lens shaped) cloud in the lee of mountains are good indicators of waves or severe turbulence. As they form due to topographical features, they are more of a problem for general aviation aircraft and larger aircraft on climb and approach. Areas where such phenomena occur are generally predictable and therefore avoidable, although there is never room for complacency even for large aircraft. BOAC lost a B707 near Mount Fuji, Japan due to the effect of strong lee waves.

Sand / Dust Storms

Dust storms usually occur in late spring or summer but are relatively infrequent except in times of severe drought. They affect visibility over a wide area and can be potentially damaging to aircraft engines. They are associated with periods of intensive heating, fresh winds and down draughts from thunderstorms. There are have been no major accidents attributed to this type of weather phenomena (as primary cause), but it can be a contributory factor to other active failures such as loss of visibility on approach or dry windshear.

Icing

One of the most severe weather hazards to the safe operation of aircraft is that of icing. There are two separate types of icing hazards, namely airframe icing and engine icing:
a) Airframe Icing

This term is used where deposits of ice adhere to the structure of an aircraft where the outside air temperature (OAT) is at or less than 0°C. Airframe icing is not confined to aircraft in flight and may actually occur on the ground, especially on the cold metal of an aircraft's structure. Icing is also not confined to visual precipitation conditions and can thus be associated with clear air.

There are three types of ice that may occur on an aircraft, namely hoar frost, rime ice and clear ice. Hoar frost is a crystalline deposit formed in clear air where temperature is less than 0°C and relative humidity is high. It can occur to aircraft on the ground as frost which is not particularly hazardous, provided it is removed before take-off. Hoar frost can affect the aerodynamic efficiency of an aircraft's lift surfaces and reduce vision.

Rime is a white, lumpy deposit formed by the rapid freezing of supercooled water droplets which contact the airframe. The supercooling traps air between the ice crystals which creates an opacity that makes rime ice easily visible. It is most common on leading edges and intakes, and can form between 0°C and -40°C, but is usually encountered between -10°C and -20°C. It is most common in stratiform cloud but may also be encountered in cumuliform. As well as disrupting the airflow over an airframe, rime ice can also block air intakes and pitot tubes.

Clear or glaze ice is a transparent sheet of ice that can be smooth or rippled in its form. It is usually formed by the slow freezing of supercooled water droplets, especially on the ground and in temperatures between 0°C and -15°C. Glaze ice adheres very strongly to the airframe and is therefore the most dangerous type of airframe icing. In 1990 an SAS MD-80 crashed soon after take-off as clear ice was ingested into the fuselage mounted engines. The flight decks of modern passenger jets do not afford a view of wing surfaces, especially on aircraft like the stretched DC-9 family which has the wings positioned a long way aft of the nose. The aircraft had been incorrectly ground de-iced, partly because of the almost invisible nature of clear ice. In flight, the most hazardous forms of ice develop when the aircraft flies through supercooled rain or drizzle as the aircraft may suddenly become covered in a layer of clear ice.

The formation of airframe icing is affected by a number of factors such as air temperature and moisture. At altitudes where the temperature is less than -41°C, water clouds are rare and therefore the risk of icing is minimal. Heavy icing is also uncommon below -25°C but above this, the risk increases as the temperature raises to 0°C, especially for clear ice. Clouds with a high water content or large water droplets (such as cumuliform) tend to produce clear ice although aircraft do not tend to fly through long periods of such cloud unless flying along a front.

The relief of overflown terrain can increase the depth of cloud and the size of water droplets so icing can be expected to be more severe in elevated areas.
Ground icing within Australia is not a major problem because of the climate and location of major airports. Only a very small part of the landmass experiences average daily minimum temperatures below 0°C as shown in Figure 4.1.2.1. However, this is not to say that ground temperatures do not drop below freezing. Figure 4.1.2.2 plots contours of frost days (where temperature is less than or equal to 2°C) for Australia and initially seems to show a fairly high occurrence of frost. However, close examination reveals that high volume traffic airports such as Sydney, Brisbane, Perth, Darwin and Cairns lie close to or on the zero contour. Melbourne however, does lie on the 50 day contour and Canberra, Launceston and Hobart all lie on the 200 contour. De-icing facilities are available at all of the frost-prone major ports although jet traffic from airports such as Canberra is relatively light.

![Figure 4.1.2.1 Areas Where Average Daily Minimum Temperature <0°C BOM, 1989](image-url)

**b) Engine Icing**

Engine icing can affect different types of engines in different ways. Carburettor engines suffer icing from the air intake, but as these types of engine are not used for Commercial RPT operations, they will not be considered within this text. For gas turbine (turbofan) engines, icing can affect the fuel systems and air inlets which can in extreme conditions cause a flame out or compressor blade damage.
An in-flight emergency involving power loss on all four engines of a BAe146 occurred in 1992 when the aircraft entered unusually warm air at high altitude (31,000 ft) over Western Australia. "The investigation determined that during high altitude cruise, the aircraft entered an area of moist air significantly warmer than the surrounding air. This resulted in a need to select engine and airframe anti-ice which in turn placed high bleed air demand on the engines. Under these conditions the fuel control units were unable to schedule sufficient fuel to the engines, thereby causing them to lose power, a phenomenon known as 'roll-back'." (BASI, 1994c) This incident highlighted an operational limitation of the BAe146 series and has been compensated for by restricting the operating ceiling of the aircraft in Australia.

The loss of the Seaview Commander 690B en route to Lord Howe Island was not a commercial jet RPT operation and therefore does not technically fall within the remit of this thesis. However, the BASI findings (BASI, 1996) indicate that there were both icing conditions at the time of the aircraft’s disappearance and modifications for flying in icing that had not been done which were contributory factors to the accident. Australia is not immune to in-flight icing conditions and hence there is no room for complacency.
**Volcanic Ash**

Volcanic ash can reach high altitudes and can be extremely hot and large in particle size. Simkin (1994) explains that although volcano belts cover less than 0.6% of the earth's surface, at least 1300 have erupted in the last 10,000 years. Also, as volcanoes tend to have long active lives, it is very likely they will erupt again in the future although typically only at a rate of 60 per annum. During the years 1975-85, Simkin notes that more than 63 eruption penetrated aircraft cruising altitudes. Of the 16 largest eruptions over the last two centuries, all but four have been the first known from that volcano which emphasises the need for up to date information to keep aircraft separated from eruptions. In 1982, a British Airways B747 overflew Mount Galunggung, Java and suffered multiple engine failures. It had unwittingly flown through the centre of a volcanic ash cloud. Although the aircraft eventually managed to recover altitude, the ash had fused itself to most of the airframe and scoured all of the windows. Although the eruption had been photographed by a weather satellite, the information had not been passed on to the airlines. On board weather radar is incapable of detecting such conditions as "...an airliner’s weather radar is tuned to reflect off water droplets, not dry particles such ash" (Edwards, 1993).

There are no active volcanoes in Australia although volcanic dust clouds do drift into Australian airspace from the north. However, there is a major string of active volcanoes to the north of Australia which sit below major air routes. The main hazard to intercontinental flights is at night, especially from Plinian eruptions that eject large amounts of fine ash and gas to high altitudes. Figure 4.1.2.3 demonstrates the distribution of active volcanoes to the north of Australia relative to Qantas International routes. (From CSIRO, 1990). Note that these routes are also flown by Ansett and other international carriers.

SIGMET (Significant Meteorological Advisory) notices are issued by the meteorological authority responsible for the flight information region (FIR) in question. They will be the result of an eruption notification and confirmation from the Japanese geostationary meteorological satellite (GMS) which is updated hourly. The system relies upon notification of any initial or subsequent eruptions from the national responsible body of the volcano’s origin. The GMS can track the progress of an ash cloud although water/ice clouds can make ash cloud difficult to distinguish. According to Whitby and Potts (1994), during 1985-90, a total of 81 volcanic ash SIGMETs (or VOLMETs) were issued and in 80% of these it was not possible to identify and track ash clouds because of the presence of water/ice clouds. Further to this there is little knowledge of how long an ash cloud remains a hazard to aviation.
Figure 4.1.2.3 Qantas International Routes North and Volcanoes CSIRO, 1990
Australia experiences a variety of extreme weather conditions, not least because of its magnitude and the fact that it covers several climatic zones. However, the general perception remains that the country is blessed with '...good aviation weather'. "...Weather tends to be stable for most of the year" and, according to Smith (1995), "...ice and fog are virtually unheard of". This means that not only are aircraft less exposed to variable weather conditions, but they are forced to fly in marginal conditions for less time. However, this may also mean that aircrews have little experience of flying in poor weather and consequently may be more likely to make significant errors in such conditions and does not provide an explanation for the fact that Qantas have never had a weather related accident at an overseas port.

It is fair to say that, on average, Australian airports do not suffer from the worst types of marginal conditions i.e. standing water, slush, snow or ice, especially when compared to European or North American locations. Indeed, an initial survey of main Australian airports seemed to support this concept: Jack Caine, Duty Manager (FAC) for Perth Airport reports that, "Very few hours have been lost in Perth due to bad weather; there wouldn't be more than five hours closure in the last ten years." (Caine, 1994). This is a similar story to Brisbane where Hall (1994) states that, "Hours closed to bad weather in last ten years would be approximately 4-6 hours per annum. Frequency of fog cover approximately 2-3 hours (early morning) 4-6 times per year."

However, this is a potentially incomplete picture which needs some balance to account for 'a lack of incidence verses a lack of incidents' and to highlight the potential problems of 'occasionally bad' weather.

A lack of accidents due to a particular cause is not necessarily indicative of an absence of the hazard. In fact, the relationship may be exactly the opposite; an acute awareness of a particular hazard, such as high terrain, may be the reason that a lack of accidents has occurred. Hence, although a high number of weather related accidents in a certain area may be a function of geography, a low number of weather related incidents in a particular area may actually say nothing about the level of incidence of that particular phenomena. In other words, just because there have been few major accidents or incidents in Australia where weather has been a major contributory factor, does not mean that the weather is good. As the Boeing's (1996) statistical breakdown of accident statistics, 'weather accidents' account for a low proportion of accidents and as such, the population of large-jet RPT accidents is, statistically, quite small.

A lack of incidents can be quite misleading, either by inducing complacency or at least creating false perceptions about hazards. The truth might be as simple as a lack of traffic or even a lack of reporting. For example, windshear accidents involving GA aircraft may go undetermined if the pilots is killed on account of a lack of CVR / DFDR equipment and the short lived nature of shears. Another example comes from the database of runway accidents attributed to weather factors;
Case Study - Weather and Runway Accidents

Boeing (1993) explains that approximately 60% of hull loss accidents occur in the close vicinity of the airport (taxi, takeoff, final approach and landing phases) and evidence from Hewes (Ashford, 1993) supports this, estimating 80% of all accidents occur within 3000 feet of the runway centre line. It may therefore be expected that a high proportion of weather accident occur on or near to the runway. A study by Rhodes (1994) examined runway deviations in the context of assessing the risk of collision between two large aircraft on close parallel runways. In all, 286 incidents involving US Part 121 aircraft were examined covering the period from 1960 to early 1994.

The USA clearly have had the most runway excursions but similarly, it also had the greatest traffic density. Operations within the USA account for approximately half of the world’s aviation. A higher proportion of runway excursions have occurred in good weather which may be indicative of the proportion of time operations take place in each type of condition. Alternatively, this may be related to the type of accidents which occur e.g. unstabilised approaches which may be less prevalent in poor weather approaches when risk perceptions is heightened. This is an area for further research and beyond the remit of this thesis.

However, it is worth noting that the number of accidents in Australia is so small as to statistically insignificant. That is to say that, even if the number of incidents were factored to account for the traffic difference between Australia and USA, this would not give a useful comparative figure. The above graph suggests that there have been zero runway excursions in poor weather in Australia, but as the sample size is only two this is probably not an accurate proportion, if operations were increased. This serves as a useful example of where the small size of Australian operations can lead to misinterpretation of the lack of incidents. It is a warning which is reinforced through the closer examination of the subject of windshear / microbursts.
Windshear related accidents and incidents pose a significant threat to the safe operation of all sizes of aircraft. A US National Academy of Sciences report (1983) documents 27 windshear events involving aircraft over 12,500lbs in the 18 year period between 1964 and 1982 with a total loss of 491 souls. The FAA’s Advisory Circular 00-54 (FAA, 1988) also documents a total of 51 windshear related events between 1959 and 1983 although unfortunately there are no details regarding location, aircraft size or survivability. Windshear is a phenomena which regularly effects flying operations. However, severe windshear is recognised as “...a serious hazard to airplanes during takeoff and approach” (FAA, 1988). Melvin (1994) adds that “Too many windshear accidents have been analysed with an emphasis on pilot error... In most cases the analyses were flawed... and this has caused considerable misunderstanding of various aspects of windshear hazards.” Terrell (1988) adds the warning that “...the detection of severe windshear in the terminal area (particularly microburst activity within thunderstorms) is presently unsatisfactory.”

The effect of severe windshear, especially at low levels, appears initially to be most prolific in the USA. This is not to suggest a direct causal effect of the geography of North America (see figure 4.1.3.1). As Potts (1991) notes; “Few aircraft encounters attributable to downburst encounters have occurred outside the continental USA, largely because of the lower traffic densities in those areas of the globe conducive to their development”.

“Due to a lower density of aviation traffic and more conservative air traffic control and pilot practices, the threat posed by microbursts in Australia is less severe than in the USA. This is reflected in the very low number of accidents in Australia attributed to downburst or microburst encounters. Notwithstanding this, it is evident that microburst pose a threat over...
tropical Australia which has previously been unrecognised and previous studies suggest there is also a significant hazard in southern Australia. As traffic density increases at airports around Australia the likelihood of a microburst encounter will also increase.” (Potts, 1991).

“When one considers that ‘moderate’ rain echoes would not require the Australian Terminal Area Severe Turbulence (TAST) system to be activated, together with the observation that annual thunderstorm occurrence at Sydney (~28) and Brisbane (~35) are comparable to Chicago (~34), a significant hazard to safe operation is considered to presently exist and such hazard will increase with traffic density.” (Spillane and Lourensz, 1986)

The research question was therefore; how can it be determined whether continental USA has a greater incidence of microburst than mainland Australia? David Hinton of the NASA Langley Research Centre is acknowledged to be one of the world’s leading experts in the occurrence of hazardous windshears and their effect on aircraft. (Bracalente, 1995) Hinton suggests that the only certain method of answering this question is not practical. In the absence of any previous national study in Australia, this would mean “field studies requiring installation of large doppler radars... over a period of years to determine the frequency near major airports.” Middleton (1996) adds that although there is a doppler radar at Sydney Kingsford Smith Airport it is placed in a position that is sheltered from this type of occurrence and no useful data is currently collected because of a bureaucratic dispute between the Bureau of Meteorology and Federal Airports Corporation. The only other method suggested involves estimating from the number of days per year of weather producing high microburst potential. Although the FAA’s Advisory Circular AC00-54 (FAA, 1988) has attempted to do this to produce the following map (see figure 4.1.3.2), there is some question as to its universal validity. Whilst the map gives guidance as to which areas of the world suffer the highest proportion of thunderstorms, this does not always equate to windshear / microburst prevalence. Nevertheless, as a guide for international comparison, it provides a useful starting point.

![Figure 4.1.3.2 Worldwide Contours of Microburst Potential FAA, 1988](image-url)
The apparent low level of thunderstorm days over Australia, for example, is in marked contrast to the findings of the two studies that have been conducted there. Melvin (1994) observes that "...no evidence exists that any of the known microburst encounters have occurred in supercell storm cells" even though "...many pilots have been trained to avoid these in the belief that this will prevent any encounters." Fujita and Caracena, recognised authorities in this field, have repeatedly emphasised that "...microbursts are frequently generated from benign-appearing cells." As the FAA diagram does not differentiate between severity of storms it is difficult to accept the contours as reliable indicators of the risk of severe microburst encounters.

The Australian Bureau of Meteorology has not attempted to map the frequency of microburst / windshear encounters as such, but were able to produce a graph which helps to predict where these events are most likely. Produced from the Bureau's records of severe thunderstorm activity, they were able to plot the following contours;

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**Figure 4.1.3.3** Annual Thunderstorm Frequency Bureau of Meteorology, 1996

The Bureau of Meteorology add that "The geographical spread of severe thunderstorms in Australia is difficult to determine because of our low population density and lack of observations over most of the continent. While records of storm impacts show that the most damaging storms have occurred in the populous south east quarter of the continent, analysis of
wind, hail and tornado data suggests that severe thunderstorms are a significant threat throughout the Country.” (BOM, 1996)

Of note is that once the levels of aviation activity are added to the above map, it becomes especially pertinent that Sydney, Perth and the Gold Coast are all contained within the high storm zone. Darwin on the other hand, where anecdotally, the most severe storms are, is only rated as moderate. In 1991, Sydney airport saw 235,400 aircraft movements, nearly double that of its nearest competitor in Australia, Melbourne (134,900 movements). The position of Kingsford Smith Airport next to the coast means that when storms occur, they are usually severe in nature. In many cases they will hit aircraft that are either taking off heavily laden for, or arriving from long sector international flights. Add to this the fact that overseas pilots may rarely make landings at Sydney, will be subject to traffic restrictions and changing arrival procedures and the latent defects that need to exist prior to a crash appear to be in place.

4.1.4 Crew fears regarding weather

Although one of the most frequently quoted anecdotal reasons behind Australia’s apparently good aviation safety record is the ‘blue sky’ or ‘benign weather’ theory, the question of windshear / microburst encounters are very much the concern of Australian flight crews. Civil and Military pilots were all asked the following question:

<table>
<thead>
<tr>
<th>3.1 Please rank the TOP THREE factors you consider pose the greatest threat to your flying safety? (With &quot;1&quot; representing the factor that concerns you most.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Engine failure.</td>
</tr>
<tr>
<td>b. Snow / ice accumulation.</td>
</tr>
<tr>
<td>c. Windshear / microburst.</td>
</tr>
<tr>
<td>d. Weather (other than 'b' or 'c').</td>
</tr>
<tr>
<td>e. Judgment error (self).</td>
</tr>
<tr>
<td>f. Judgment error (others).</td>
</tr>
<tr>
<td>g. Mid-air collision.</td>
</tr>
<tr>
<td>h. Maintenance related failure (other than 'a')</td>
</tr>
<tr>
<td>i. Controlled Flight Into Terrain.</td>
</tr>
<tr>
<td>j. Security breach.</td>
</tr>
<tr>
<td>k. Runway incursion.</td>
</tr>
<tr>
<td>l. Management error.</td>
</tr>
<tr>
<td>m. Inappropriate regulations.</td>
</tr>
<tr>
<td>n. Other (Please specify)</td>
</tr>
</tbody>
</table>

The result was a little unexpected, particularly in respect to the answers given as to why Australia had managed to stay safe.
What are the top three greatest threats to your flying safety?

The Qantas crews, which were a mixture of domestic and international, rated the threat of mid-air collision to be their greatest fear. However, a very close second, chosen by nearly 17% as one of their top three fears, was that of windshear / microburst encounters. In both cases, the type of incident is one where the flight crew will have little control over the outcome if the event occurred. Mid-air collision involving a large jet aircraft and any other type of aircraft are generally fatal because of the kinetic energy of impact generated by the inertia produced at flying speeds. Microburst / Windshear encounters which occur at low level on take off or landing tend to leave the pilots of modern jets with a technological impossibility. If the pilot has reduced thrust to avoid overspeed when the aircraft first hits a microburst and then attempts to re-apply thrust he must wait for the engines to spool up which usually takes more time than is afforded by the altitude involved and the strength of the down-draught (see results for RAAF transport crews).

The results were then split to represent Domestic and International crews to examine whether the windshear / microburst threat was perceived to be greater for those flights which operated out of Australia. The Domestic classification used the B737 and A300 fleets and the International flights used B747 fleets. The B767 was excluded at this stage as the aircraft is operated on both domestic and international sectors. The two graphs are presented below:
What are the top three greatest threats to your flying safety?

**International**

- Engine Failure
- Snow / Ice Accumulation
- Windshear / Microburst
- Weather
- Judgment Error (Self)
- Judge Error (Others)
- Mid-air collision
- Maintenance Failure
- CFTI
- Security Breach
- Runway Incursion
- Management Error
- Inappropriate Regulations
- Acts of Aggression

**Domestic**

- Engine Failure
- Snow / Ice Accumulation
- Windshear / Microburst
- Weather
- Judgment Error (Self)
- Judge Error (Others)
- Mid-air collision
- Maintenance Failure
- CFTI
- Security Breach
- Runway Incursion
- Management Error
- Inappropriate Regulations
- Acts of Aggression

Figure 4.1.4.2 Answers from Qantas Crews (International - B747)

Figure 4.1.4.3 Answers from Qantas Crews (Domestic - B737 & A300)
The difference between Domestic and International crew results is negligible for the category 'microburst / windshear' which suggests that they do not consider the problem to be a function of geography. The international crews do rate that factor over and above anything else, unlike the domestic sector which rates mid-air collision to be slightly more of a problem (this may be a function of TCAS fitment which is covered later).

**Answers for Ansett Australia**

![Bar Chart]

The results from Ansett Australia (which were from the domestic sector only) show a significant difference between their opinions and that of Qantas crews, particularly in the area of mid-air collision risk (which will be covered later under air traffic control) and the split of judgment error between themselves and others. The importance of microburst / windshear encounters is only heightened by this response in that it is very much the prime concern of crew members. This diminishes the possibility that the Qantas result has been skewed by the experience of those pilots flying international sectors. The risk in Australia is not reasonably proven to be any less than anywhere else in the world and even if the prevalence of this weather phenomena could be shown to be significantly less, this opens up the new possibility that infrequent exposure can mean low experience and an diminished ability to cope should it ever be encountered.
Predictive windshear detecting radar was approved by the FAA in 1995 but has only been ordered by one airline which is based in the US. Neither Ansett Australia nor Qantas have announced any intention of purchasing such a system at the present time.

Answers for RAAF Transport Crews

![Bar chart showing top three greatest threats to flying safety](image)

The RAAF transport crews represented the B707, Dassault 900, HS 748, DH Caribou and C130 Hercules fleets. Apart from the B707 and Dassault 900 aircraft crews, the majority of answers were from the prop fleet which is less susceptible to the effects of low level windshear / microburst encounters. The amount of 'hand-flying' is much greater and the engine reaction times are much faster than for modern jet aircraft. This is reflected in the results where windshear / microburst ranks only the 9th most important factor and behind the weather (other) category. Current fleet replacement plans do not call for an increase in the jet transport fleet with the only large aircraft currently on order being the C130J new generation Hercules and a tender request for a Caribou replacement (which is evaluating CASA / IPTN 235 sized 'Baby Hercules' equivalents). The future problem may arrive when retired military transport crews convert to flying airline jets although this would only be a small number of crew members.
Military and civil air traffic controllers were asked a similar question to examine their perception of the threats and to see whether this was significantly different to the views of the pilots. The results are printed below;

**Answers for Civil Air Traffic Controllers**

![Bar graph showing the top three greatest threats to flying safety](image)

In the eyes of the civil air traffic controllers, the importance of windshear / microburst has slipped to fifth place. It is overshadowed by the perceived importance of judgment error (by others), maintenance / engine failures and weather (other). This raises an interesting question about the perceived importance of this hazard. Although the decision to land or take-off rests entirely with the aircraft Captain, there are a number of factors which are known to heavily influence that decision making process. This includes commercial pressure, slot allocation and weather reports from previous aircraft. While an air traffic controller has no authority to make an aircraft land or take-off, they do have the responsibility of reallocating slots should an aircraft decide to go-around or delay take-off. In the event of an aircraft electing to go-around or delaying its approach to allow a storm cell to pass and other aircraft being prepared to continue (perhaps because of more experience or a higher performance aircraft), it is up to the controller to insert the aircraft into the arrivals order. This may cause considerable delay to the
aircraft which may be particularly significant for aircraft with short turnaround times or involved in hubbing operations.

If the air traffic controllers' perception of the threat of windshear / microburst is significantly less than the perception held by the flying community, then there is the possibility that the reaction to precautionary go-arounds or approach / take-off delays is going to be less favourable. The message to pilots then becoming more aligned to 'have a go' than 'be sure'.

Answers for Military Air Traffic Controllers

The military controllers rate windshear / microburst low (9th) down the list of perceived threats which is consistent both with the perceptions of the civil controllers and the military flight crews. There is no jet passenger traffic at airports where approach is solely provided by military air traffic control. Military traffic will constitute the jet transport fleet as discussed above, which is a predominately propeller driven fleet, and the fighter (Aeromacchi, F-18 and F-111) aircraft which are capable of fast approaches and are therefore less susceptible to windshear. Civil traffic using en route military ATC is at no risk from this type of weather phenomena.
4.1.5 Weather and Crew Perceptions

Whilst weather conditions may be shown to be relatively less extreme than elsewhere in the world, the fact only counts for something if operations reflect that additional margin of safety. Risk homeostasis might suggest that faced with severe weather conditions, pilots will modify their performance to a ‘safe’ level and therefore in good weather conditions, a similar modification of behaviour occurs. The argument to be answered is whether pilots who have little experience of flying in poor weather conditions compensate for this through added caution. Conversely, do pilots who are used to flying in poor weather conditions fly better because they have a lot of experience or is this cancelled out by behaviour modification?

Analysis of weather related accidents re-iterates the importance of the human component as the single greatest factor in aviation safety. Although there are still some areas open to debate, aviation meteorology is a relatively well developed science and many ‘weather’ accidents occur because of fallible decision making on the part of the crew or other humans in the system. Such decisions can range from the ‘press on’ attitude, where not all factors are considered in making a risk-taking decision, to high level policy decisions regarding, for example, the fitment of weather or predictive windshear radar.

Attitude towards weather conditions can be just as critical as the actual weather conditions themselves. This is particularly true for high-capacity RPT aircraft which are more able to cope with extreme weather conditions than GA aircraft. The decision to go or not go can be influenced by many considerations, some of which are non-operational. Subtle commercial or organisational pressures can sully the judgment of even the most competent crews as the accident rate shows.

On 10th March 1989, an Air Ontario Fokker F-28 failed to climb on take-off from Dryden, crashing approximately 1km beyond the end of the runway. The aircraft’s wings were contaminated with snow and ice following ‘hot refuelling’ and a delay after ground de-icing. The investigation into the accident was far reaching (See Moshansky, 1992) and examined a whole range of systemic errors in what must be the most thorough investigation of its kind ever. Pressures on the crew to fly included an unserviceable APU (Auxiliary Power Unit) and lack of ground start facilities at Dryden which meant that the aircraft had to be ‘hot refuelled’ (one engine kept running). The weather was deteriorating (snow and sleet) and both passengers and crew were eager to get home in time for Thanksgiving. Compounding factors included insufficient information to the crew regarding cold-soaking of the wings, poor communication between cabin and technical crew, a lack of ground support and a declared emergency landing by a Cessna 152 which delayed the F-28’s take-off. Finally, well before the accident, a decision had been made to use an inferior de-icing fluid in Canada, on the grounds of cost, which had a much shorter holdover time than the fluid used by the Europeans. (Reason, 1992)

Whilst the accident provides an excellent case study, thanks to the thoroughness of Moshansky’s investigation, it is not unique. The apparently vast number of error was not indicative of a particularly bad accident, rather, a thorough investigation. Very simply, the crew
assessed all of the risks that they perceived and decided to take off; they did not expect to crash. It is easy to suggest with hindsight that warnings were there, but difficult to criticise individual active failures in isolation. Although two passengers expressed their concern about snow on the wings to the Flight Attendant, she did not have sufficient training to recognise this as a problem or feel that she should communicate it to the Flight Deck.

Australian crews were asked how they felt they would react to a similar situation using the following question:

<table>
<thead>
<tr>
<th>2.11 You are ready for departure, but the weather is getting steadily worse. Which of the following statements best describes your thoughts...?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I would take off because my aircraft is equipped for all conditions</td>
</tr>
<tr>
<td>2. I would feel obliged to take-off for the sake of the passengers</td>
</tr>
<tr>
<td>3. I would feel obliged to take-off to keep on schedule</td>
</tr>
<tr>
<td>4. I would take-off if the rest of the crew were encouraging me to do so</td>
</tr>
<tr>
<td>5. I would take-off only if both my colleagues and I were completely confident</td>
</tr>
</tbody>
</table>

However, the results were very flat and might suggest that the question was poorly constructed. All of the major carriers returned huge majorities in favour of answer five. The proportions were Qantas, 98.7%; Ansett, 97.3%; RAAF, 96.8% and Britannia 95%, none of which were significantly different from each other. This may indicate a wholesale acceptance of CRM principles (as all of these operators have CRM courses) or alternatively, that the respondents felt that they should answer in a particular way. It is the aircraft crew’s prerogative not to take-off in poor weather and therefore although they may feel organisational pressures, they are not obvious and so the above answer reflects an affirmation of their own prerogative.
4.2 Physical Geography

The physical geography of a particular area affects aviation in three distinct ways;

a) The effect of relief on environmental conditions

b) The effect of relief on collision risk

c) The effect of spatial separation on routes and aircraft range

Every airport has a unique set of challenges for a pilot on both take-off and landing. This is in terms of surrounding high terrain, buildings and local weather phenomena such as low level shear or rotary turbulence. En route, the physical environment also affects meteorological conditions and in certain circumstances, the risk of collision. Finally, the geography of the area in which operations occur will influence facets of the aviation system such as aircraft type selection, sector length and demand. To consider these externalities in turn;

4.2.1 Relief and the Environment

Physical geography has a direct effect upon weather conditions and although any area is prone to extremes, there are several traits of climatic zones which, by definition, are prevalent. This may be expressed in the annual rainfall figures, number of fog hours / days or average temperatures. It may also be a way of predicting extreme phenomena such as tornadoes, cyclones, duststorms or jetstreams. The presence or otherwise of relief induced weather or climatic phenomena within Australia may be a significant component of the natural environment in which aviation operates.

Crowder (1995) observes that “Australia is an old continent. Much of its area is relatively flat and its mountains are small by comparison with those of all the other continents.” The effect is the exceptionally arid central region. Global rainfall averages at approximately 1000mm, but 50% of Australia receives less than 300mm per annum and 90% less than 800mm (Crowder, 1995). (See figure 4.2.1.1). Skies remain almost annually blue, except for the more inhabited coastal strips. This helps to propagate the myth that Australia is typified by blues skies and ‘good aviation weather. However, as discussed in the previous section, weather conditions within Australia do include a number of extremes which are potentially hazardous to aviation.
The higher level of rainfall around the coastal regions, particularly the eastern seaboard and northern coast is not just a function of its close proximity to the sea. If the relationship were that simple, then the coast along the Great Australian Bight and North West of Australia would not be so dry. (Annual median rainfall of 200mm). The tropical climatic zone and high coastal terrain are largely responsible for the high level of rainfall in the far northern latitudes and the Great Dividing Range for the average to high levels of rainfall along the eastern seaboard. Strong winds such as the Southeast Trade Winds and Westerlies gather moisture as they sweep across the Pacific, which is then released as precipitation as they reach high ground.

Even areas of only moderately high terrain are enough to dictate zone of high precipitation. Around Sydney, the Blue Mountains are the main reason for higher average rainfall whereas in Melbourne it is the Dandenongs. Similar effects are also visible near the Darling Range, Perth, the Mount Lofty Ranges, Adelaide and Mount Wellington, Hobart (See figure 4.2.1.2)

These areas account for the overwhelming majority of RPT movements and as meteorological conditions are most significant at take-off and landing, there are considerable safety implications. For example, extreme phenomena such as windshear / microburst are more prevalent in areas of storm activity.
Heavy rainfall may be associated with a degradation of visibility, contamination of runway pavements and the formation of in-flight icing. However, the effect of terrain is not just on the frequency or severity of precipitation. Windshear associated with rotary shear or mountain lee waves can have a significant effect on flight operations through turbulence. Whilst this is primarily a problem for GA aircraft because of their size, it can also be extreme enough to effect RPT jet aircraft. In 1966, a BOAC B707 was destroyed close to Mount Fuji, Japan in clear conditions by lee turbulence. Whilst aviation learned a great lesson from that incident, it is unlikely that such forces exist within Australia; Mount Fuji is some 12,400 feet high and Mount Kosciusko (Australia's tallest) is only 7,300 feet. Less extreme examples of rotary shear and lee waves are to be found in Australia, but as RPT crews operate to a limited range of destinations where hazards are well known, the overall risk to RPT safety is quite minimal.

Another meteorological phenomenon associated with relief is the formation of temperature inversions and associated degradation of visibility. Sydney is a prime example where easterly winds meet the physical barrier of the Blue Mountains and Great Dividing range. As such smog is a common occurrence in the Sydney basin which can significantly affect visibility.
4.2.2 The effect of relief on collision risk

For many years, the greatest source of fatalities in civil aviation have been as a result of controlled flight into terrain (CFIT). A controlled flight into terrain accident occurs when a serviceable aircraft collides with terrain (or water) when still under the apparent control of the flight crew. A survey by Boeing of worldwide airline fatalities between 1988 - 1993 (aircraft over 60,000 lbs take-off weight) revealed 1,883 deaths due to CFIT from a total of 3,513 for all causes (just over 53%) even though such accidents only accounted for 28 of the 76 accidents which were studied (Hughes, 1994).

![Worldwide Airline Fatalities Classified by Type of Accident - 1988-1993](image)

Reiner observes that; “Most CFIT accidents occur in terminal areas, more so on arrival than departures, and often very close to the top - within 100 to 200 feet - of terrain features” (Reiner, 1992). He also goes on to suggest that; “In every jet transport CFIT accident to date (1990), impact occurred with enough excess energy to have cleared the obstruction if the warning and pull-up had been sufficiently timely.”

The ultimate question for this thesis is to answer whether the risk of CFIT is any different for the Australian carriers or within Australia. Is the height or profile of terrain in Australia a factor in the lack of CFIT accidents or are there other, more pertinent factors?

Hughes (1994) suggest that; “Factors which increase the risk of having a CFIT accident include flying into airports located in mountainous terrain that have only non-precision
approaches and no radar coverage.” He adds that in the US and Europe, these destinations tend to be served by secondary level, regional carriers, and as a consequence, the accident rate for this type of operation is two or three times that of large jet operations. The level of terrain, however, is only one factor in the prevention of Controlled Flight Into Terrain (CFIT) accidents. Around 46% of CFIT accidents have occurred where terrain is relatively flat (less than 1000 ft. higher than airport elevation)(Boeing, 1994) and the most significant factor, according to Boeing is a lack of Minimum Safe Altitude Warning (MSAW) equipment.

Figure 4.2.2.2 Terrain Above 1000m ASL

There are few parts of Australia that may be considered to be mountainous. Indeed, it is the flattest continent on earth and figure 4.2.2.2 demonstrates what high terrain there is. Approximately 2% of terrain in Australia is above 1000m in height (ASL). (Shown in pink on the above map.) This is predominantly in the Snowy Mountains area of South West New South Wales, Australian Capital Territory and North East Victoria with an additional mountainous area in Tasmania. The only major RPT airports that are situated close to high terrain are Canberra, ACT which is surrounded by mountains and Cairns, QLD which has a large Escarpment to the West.

The reporting of nuisance GPWS (Ground Proximity Warning System) alerts on approach to Canberra is very high. (A nuisance warning is where the GPWS is ‘fooled’ into making an alert by rising terrain, especially on approach where the terrain about to drop away before the
Jet Aircraft on approach to Canberra, especially arriving from the North with gear up and flying at approximately 290 knots were routinely getting GPWS warnings. Qantas responded to this by restricting speed to 200 knots and requiring gear to be lowered earlier. (Quinn, 1997) The latter measure will prevent any GPWS warnings and the former will reduce the number of warnings caused by excessive approach speed. Whilst this may reduce the ‘boy who cried wolf’ effect of recurrent nuisance warnings, it also disables a safety system which is in fact working correctly. This does not imply that the revised operating system is unsafe in normal operations, but it increases the risk of an uncorrected unstabilised approach. A similar situation occurs at Cairns where aircraft approaching from the West overfly a long escarpment which rises to a slope of approximately 30°. Recurrent warnings have been reduced by employing a similar strategy of slower approach speeds and early gear deployment.

Whilst the issue of high terrain is obviously relevant to collision risk at airports such as Cairns and Canberra, that risk is also influenced by other factors. These include the prevailing meteorological conditions - Canberra is prone to low level cloud and fog, and Cairns is prone to tropical storms; reaction to GPWS warnings, especially in areas which experience a high volume of nuisance warnings and cancellation of GPWS functions e.g. by early gear deployment. Slower approach speeds may mean that there is more time to recognise and respond to an unstabilised approach, but also mean that there is less kinetic energy available to clear an obstacle.

‘Flat terrain CFIT accidents’, such as the loss of an Eastern L1011 on approach to Miami in 1972 when the flightcrew were distracted by a failed warning bulb and did not realise that the
autopilot had been disengaged, illustrate that CFIT accidents are not just a function of terrain. In other words, the aircraft was on such a trajectory that it was going to hit the ground regardless of the height of the terrain. The crucial factor in these accidents is crew performance, both in terms of vigilance and situational awareness.

In aircraft where GPWS is fitted and working, crew members must take a decision to ignore warnings if an accident is to occur, except in instances of particularly steeply rising terrain. In a multi-crew environment such a decision has to be endorsed by several crew members and as such, effective crew resource management (CRM) aims to improve the quality of communications and decision making. “Provided that all the relevant information was available to them, it is difficult to see what could be done to resolve this particular problem other than emphasise the potential consequences during training and whenever else an opportune moment presents itself.” (CAA, 1982) The goal of effective CRM is to ensure that the right information is communicated to the right person at the right time and in the right way. CRM was not introduced as a CFIT evasion strategy, yet, when used properly, it can have the effect of reducing the number of such occurrences.

In November, 1983 an Avianca B747 collided with terrain during an ILS approach to Madrid Airport in spite of a serviceable GPWS. The Spanish Accident Investigation Board found that; “The pilot in command did not take the required corrective action when the GPWS alarm signals were activated.” (Doss, 1990) and cited as contributory factor the “...failure of the crew to take corrective action in accordance with the operating instructions of the ground proximity warning system.” In other words, the accident could have been avoided through at least two key prevention strategies; namely better GPWS training and better CRM training. Additionally, assuming that Avianca used reasonably standard operational procedures a stabilised approach would not have brought them into contact with terrain.

The fact that CFIT type accidents have continued in spite of GPWS warnings serves to highlight the fact that a safety countermeasure can be undermined if behaviours are adapted to compensate for it. If the fitment of GPWS means that less attention is paid to stabilising approaches, then the safety strategy has not worked. Similarly, if GPWS warnings are ignored or avoided through procedures such as dropping landing gear early, then the usefulness of the system is degraded.

Collision risk is obviously linked to terrain, but is not necessarily a function of high terrain. Exceptionally flat approaches are able to create an ocular illusion which can lead to undershoot collisions with terrain. This phenomena can also occur at airfields with exceptionally long runways.

Australia may have relatively low terrain and operations do not experience the same level of complex terrain as in, for example, Papua New Guinea or South America, but this does not mean that operators are not prone to collision with terrain.
4.3 The Effect of Spatial Separation

"Australia is a long way from anywhere and sometimes even from herself"
(plaque outside the Sydney Opera House)

Australia is a country of sparse population. Roughly the same size as the United States at 2,966,368 square miles, it averages only five people per square mile. Eighty percent of the population live in the cities. The main six centres of population being Sydney, Melbourne, Brisbane, Perth, Adelaide and Canberra which account for about 10 million of the country’s 16 million inhabitants. (National Geographic, 1988)

Figure 4.3.1 Australia Compared to USA to Show Size Similarity  
Source: postcard

In comparison, the population of the USA in 1997 was estimated to be 260 million.

The effect of this physical set up is apparent at several different levels:

1) The effect on historic development.
2) The nature of travel patterns.
3) Route structure.
4.3.1 The Effect on Historical Development

Modern day Australia was discovered by Captain James Cook's *Endeavour* in 1770 and colonised as "...part of Europe - New South Wales, as Cook called it - not of Asia" (Terrill, 1988). It was used as a British penal colony between 1788 and 1868 which saw 162,000 convicts transported from the mother country.

Blainey (1977) tackles the importance of distance to the development of Australia in his book 'The Tyranny of Distance'. He prefaces the text with a valuable warning:

"Distance - or its enemy, efficient transport - is not simply an explanation for much that happened in Australia's history. Once the problem of distance is understood it becomes difficult to accept many of the prevailing interpretations of other events in Australia's history. Distance itself may not explain why they happened, but it forces a search for new explanations...

...It illuminates the reasons why Australia was for long such a masculine society, why it became a more equalitarian society than North America and why it was a relatively peaceful society."

Although the focus of the text is ostensibly aimed at the transportation challenges of the eighteenth century, it provides an interesting historical insight that provides some clues as to why the aviation industry developed in the way it did.

Australia's English roots proved to be incredibly important in the way it developed over the 200 or so years after colonisation. (Although the country had an indigenous aboriginal population, their development as a race was still in the stone age by western civilisation standards. The Aborigines lived in nomadic tribal groups that subsistence farmed the land and suffered greatly at the hands of the invading populous.) By 1859, six colonies had developed; New South Wales and Tasmania which were the main convict destinations, Victoria and South Australia which were convict free and Queensland and Western Australia which started off convict free but eventually used them as labourers. Although convicts who had served their time were often given land to start a new life on, there were also a great number of true pioneers who set themselves up as farmers and later as gold prospectors.

One of the crucial points from this early history is in crafting the Australian culture. Although many traits represent an imported Anglo culture, there were certain new traits that represented, not just the type of people that were transported or chose to travel there, but also the challenges that were presented to them. For example, that of distance, not just on a world scale but within the country. Blainey (1977) illustrates that whilst Australia was 12,000 miles away from Europe, her coastline also represented a similar distance. As the State capitals were a significant distance apart (see table below) long distance travel was an inescapable barrier to trade, especially when compared to domestic travel in the United Kingdom.
The first voyage of convicts in 1788 took six months of sailing time to reach Botany Bay (Sydney). Between the early 1850's and 1870's, the average passage between London and Australia shrunk from 90 to 45 days. This was largely the result of fast steamships, trans-European trains and the opening of the Suez Canal.

### 4.3.1.1 The coming of the railways

Within Australia, internal transportation developed slowly. Navigable inland waterways were few and far between and prone to significant variation in their usefulness due to periods of prolonged drought. Inshore coastal shipping benefited from the development of the steam ship but this remained a slow method of intra-state travel because of the great distances involved. The arrival of the railways in the mid 19th Century brought a new optimism for fast transport, but its true potential was never realised because of the high cost of permanent way. The small population (by 1860, the population was only 1,097,305 (Dyster and Meredith, 1990).) and great intra-state distances meant profitability was poor and development was slow. Even though by 1881, Australia had nearly 4000 miles of railway, it was not a linked network. The fourteen different railways companies were all physically separated and operated on a variety of different gauges. Even the important route between Melbourne and Sydney stopped at the New South Wales - Victoria border and passengers and freight had to be transhipped. Nevertheless, the 600 mile journey by train reduced the trip to 18 hours which was less than half of the time of a coastal steamer. (Blainey, 1977) By 1921, the length of railways in Australia was 26,000 miles - in proportion to its population, Australia had more railway than any country in the world. However, it was not until 1962 that trains operated all the way between Sydney and Melbourne on a single track gauge and 1995 before the trunk rail route from Brisbane to Perth via Sydney, Melbourne and Adelaide was totally converted to the same standard gauge.

![Figure 4.3.2 Point to Point Distances Between Capital Cities (kms)](image)

Vast distances prevented the railways from attaining the dominance that they achieved in Europe. Even now there are only two passenger trains a day between Melbourne and Sydney and three between Sydney and Canberra.
4.3.1.2 The Road Transport Revolution

The first Model T Fords arrived in 1909 and Australia boasted just 5000 motor cars by 1910. By 1930, there were nearly 600,000 cars and trucks. Roads ranged in standard from tarmacadam urban and suburban routes to dirt roads which covered most of the longer distances. Even today, large sections of the route between Perth and Adelaide is dirt road. New transport opportunities, low ground rents and an abundance of land led to a suburban sprawl of many cities and towns which is reflected in the number of single storey residential properties compared to the mother country.

Car ownership within Australia developed to become an absolute essential especially in the sparsely populated outback areas. However, the distances involved still placed restrictions on the development of road transport as a long distance transportation mode. Accident statistics demonstrate a relatively high number of fatalities which is partly due to a significant proportion of fatigue related accidents. Although fuel remained relatively cheap within urban areas, the logistics of distribution meant that operating costs in country areas remained high.

Even in the 1990s, a car journey between Melbourne and Sydney would typically take in excess of 13 hours and a journey between Melbourne and Adelaide at least 12 hours. To cross the Nullarbor Plain between Adelaide and Perth is recommended to take a minimum of three days.

4.3.1.3 The New Opportunities of Aviation

Aviation arrived in Australia in 1910 in the form of an amazing stunt by the American escapologist, Harry Houdini. Although initially a source of entertainment, the potential of aviation for conquering Australia's great distance handicap was undeniably great. Within Australia, the road, waterway and railway networks remained sparsely developed for the size of the continent and her trading partners remained in the Northern Hemisphere where the only method of transport remained the ship. A second demonstration in 1914 by the Frenchman Maurice Guillaux involved flying a single bag of 2,000 postcards between Sydney and Melbourne in three days. Although a success, the true birth of civil aviation in Australia was not to occur until five years later following the First World War. (Job, 1991)

Wartime had brought considerable technological advances in aircraft and, after hostilities had ceased, converted military aircraft began operations carrying passengers and mail. In 1919, the Australian Government offered £10,000 to the first crew to fly from England to Australia in less than a month. This challenge was met in December that year by Sir Ross and Sir Keith Smith in a Vickers Vimy and raised the profile of civil aviation in Australia. A number of airlines grew up following the armistice but it soon became obvious that without some form of subsidy, no-one was prepared to invest heavily in such a new and unproven technology.
On 24th November 1920, the Air Navigation Act was passed in Federal Parliament and created the Civil Aviation Branch within the established Department of Defence. Lieutenant-Colonel H. H. Brinsmead was appointed Controller of Civil Aviation with his duties being described as; "The inspection, registration and certification of airmen, aircraft and aerodromes and to advise on matters affecting the organisation of airlines and schemes for the encouragement of civil aviation." (Job, 1991) The Commonwealth Government considered several routes for subsidy to operate mail services before announcing in 1921 that the route from Geraldton to Derby (later Perth to Wyndham) would be operated, with their backing, by Major Norman Brearley's Western Australian Airways. The airline, better known as 'Airways' tendered to operate a fleet of six Bristol Tourer aircraft which could each carry two passengers and less than 200 lb of mail. (Edmonds, 1994)

The first airline service commenced on Sunday 4th December 1921 with three aircraft. The first accident occurred the following day when one aircraft made a forced landing in rough country, followed immediately after by the second accident (and first fatal Australian airline accident) as one of the other aircraft attempted to establish the ground position of the first aircraft. (Buddee, 1978) Brearley immediately suspended services and informed the Controller of Civil Aviation by telegraph that;

"Inform you fatal accident. Aviators Fawcett and Broad killed through machine crashing 100 miles north of Geraldton due to Commonwealth not having landing and emergency landing grounds prepared as agreed. Other planes returned. Brearley has decided not to proceed until suitable landing grounds ready. Geraldton ground dangerous and condemned by Public Works Department."(Job, 1991)

Although the cause of the accident was not the integrity of the airfield (the Civil Aviation Branch's finding was 'Error of judgment; pilot banked too steeply in landing in rough country'), it was felt that if the first aircraft had been able to make a safe landing, the second would not have executed its fatal manoeuvre in attempting to follow it. Subsequent surveys by Brinsmead's team allowed Brearley to recommence operations in May 1922 which was followed by an accident free year, almost complete adherence to timetables and a small profit. For many this is seen as the true birth of civil aviation in Australia.

Meanwhile another small aviation company was founded in Queensland in 1920 with the intention of competing in the 'Great Australian Air Race'. However, when their backer died, the two pilots, Wilmot Hudson Fysh and Paul McGinnes were unable to take part. Instead they were commission by the race organisers to survey the route across Australia covering 2,166 km in about 50 days. (Buddee, 1978) It was this experience which gave Fysh and McGinnes a realisation of the communication problems and potential for aviation in the outback. This was also the point that they met up with Fergus McMasters who was destined to become their business partner in their airline. Originally formed on 19th August 1920 as the 'Western Queensland Auto Aerial Service Limited' and then changed shortly after to the 'Australian Trans-Continental Aerial Services Company Limited' before being amended again in
November to become the ‘Queensland and Northern Territory Aerial Services Ltd. or QANTAS as it is better known. Now over 77 years old, Qantas is one of the oldest established airlines in the world.

It is not the objective of this thesis to present a detailed history of how the Australian aviation industry developed. However, there are a number of events which have occurred up to the ‘jet-age’ which have a major significance in terms of safety. They are documented below;

4.3.1.3a The Southern Cloud Mystery

On Saturday, 21st March 1931, Australian National Airways Avro Ten VH-UMF Southern Cloud was lost in poor weather en route between Sydney and Melbourne. The aircraft did not have an form of radio and no-one witnessed it crash. Although there was no official search and rescue (SAR) organisation in Australia at that time, the Deputy Controller of Civil Aviation organised a search which involved 30 civil and military aircraft over 18 days. However, in spite of these efforts, the wreckage could not be found and it was concluded that no occupants could have survived.

The remains of the aircraft were finally discovered in October 1958 by a construction worker in the Snowy Mountains area of New South Wales. Although an official investigation was not conducted at this late stage (it was deemed that there would be little in the way of technological advance that could be learned from this 27 year old accident), it was obvious to the Investigator in Charge that the aircraft had collided with terrain at high speed. The significance of this accident is two-fold; Firstly, that although the accident occurred in the more populous South Eastern area of Australia, the wreckage was not discovered for 27 years. At this stage in Australian aviation’s history, the possibility of survivors being found and rescued was remote. Secondly, the Air Accidents Investigation Committee’s Inquiry held in 1931 in the absence of the wreckage made a series of recommendations which were to influence the development of civil aviation in Australia. The most significant recommendations being as follows;

- That ... the carrying of two-way wireless ... be made compulsory in aircraft engaged in regular scheduled passenger services. Action should be taken to give immediate effect to this on the Sydney / Melbourne / Launceston service.

- That the Departmental scheme for a ground wireless direction finding organisation be proceeded with and expedited as an urgent measure.

- That endeavours be made to have an additional synoptic chart drawn by the Weather Bureau ... that arrangements be made for observations of current weather at selected points along air routes at 7am daily, and ... the corrected aviation forecast, together with a statement of actual conditions over the routes, be issued for rapid distribution to all civil aviation terminal aerodromes and RAAF Stations.

Figure 4.3.3 Significant Recommendations of the Southern Cloud Investigation Job, 1991
4.3.1.3b Stinson A Trimotor VH-UHH 'Brisbane'

Another significant accident occurred on 19th February 1937 in the MacPherson Range of Mountains in Southern Queensland. A Stinson A Trimotor operated by Airlines of Australia was en route from Archerfield to Sydney via Lismore with two crew and five passengers when it collided with terrain. Although searches were commenced by air, water and land, they were called off five days later with 'no hope of finding the aircraft'. However, Bernard O'Reilly, a bushman from within the MacPherson Ranges believed that he knew where the aircraft had crashed, based on the last sightings of the aircraft by his neighbours. A week after the accident, he set off alone into the bush to search for the aircraft. Two days later he discovered the wreckage of the aircraft and two survivors.

The story has passed into Australian folklore as a story of courage and determination in the tradition of the Australian bush and yet its significance as a cultural indicator is not to be underestimated. The secondary implication of the accident was the reaction of the Australian public to what was almost another 'Southern Cloud'. Although, recommended after the loss of the Southern Cloud, civil aviation requirements still did not require the fitment of radios on airliners. Only three days after the Brisbane disappeared, the Minister of Defence announced that radio beacons would shortly be installed at the principal airports of Australia.

4.3.1.3c Douglas DC-2 VH-UYC 'Kyeema'

In 1937, Australian National Airways (ANA) acquired controlling interests of Airlines of Australia. Operating under the latter company badge, DC-2 VH-UYC Kyeema was scheduled to operate with an ANA crew between Melbourne, Adelaide, Sydney and Brisbane on 25th October 1938. On approach to Essendon airport from Adelaide, the aircraft collided with the slope of Mount Dandenong with the loss of 18 souls. Although the aircraft was fitted with a primitive radio, it was not yet able to use the Lourenz radio range finding system which was still being tested nearly two years after the Brisbane accident. The accident investigation focussed on the role of the radio contact between aircraft and the ground and suggested that the reporting system did not adequately prevent accidents;

"At an early stage in this inquiry, it appears to us that a serious element of risk existed whenever miscalculations or errors of observation on the part of the pilot occurred during a flight, and it was suggested that it would be a simple matter to introduce a system whereby the movements of aircraft could be checked by a competent person on the ground." (Official Accident Inquiry cited in Charlwood, 1981)

It was following this accident that the Air Traffic Control system was created in Australia. Radio ranges, aeradio stations and direction-finding units were introduced and supplemented by a uniquely Australian feature, the Flight Checking Officer.
4.3.1.3d Douglas DC-3 VH-ANK ‘Lutana’

By 1948, civil aviation had undergone significant technological advancement as a result of the Second World War and the Australian ATC system had benefited from an ICAO conference held in Melbourne in 1947. However on 2nd September 1948, ANA DC-3 Lutana struck a mountain near Nundle in New South Wales en route from Brisbane to Sydney with the loss of 13 souls. The aircraft was under the control of radio ranges at Brisbane, Kempsey and Sydney and flying at night. After overflying the town of Kyogle, the aircraft drifted west of its track, but this fact was not detected either by the crew or the ATC. When the aircraft was given permission to descend to 4000 feet on its way into Sydney it was in fact 100 miles off track in an area of mountainous terrain.

The subsequent inquiry criticised the ATC system for paying too much attention to aircraft separation rather than keeping the aircraft clear of terrain. Charlwood (1981) cites the following remarks from the official inquiry chairman; “It appears to me that a criticism that can justly be levelled against the Department is that it is not using modern scientific aids which were discovered and used during the war, that they are requiring information from the pilot which should be known to them or which could be obtained by them accurately and instantaneously from the ground without choking the communication channels. I have in mind such scientific aids as radar, and automatic position finding by cathode ray direction finders.”

4.3.1.3e Fokker F27 VH-TFB ‘Abel Tasman’

Although a number of accidents occurred following the loss of the Lutana, the next highly significant accident involved a TAA Fokker F27 Friendship on 10th June 1960. The aircraft was scheduled to fly from Brisbane to Mackay with stops at Maryborough and Rockhampton and departed the latter with four crew and twenty-five passengers, which included nine schoolboys on their way home for the Queen’s Birthday long weekend. Upon approach to Mackay, weather conditions deteriorated and the aircraft held for forty minutes at 5,000 feet awaiting an improvement in conditions. (Job, 1992) When eventually cleared to land with fog lifting and ground visibility up to three miles, the aircraft struck the sea with the loss of all on board. Although no definite cause for the accident was ever reached, the significance of the accident is that it remains the worst accident involving an Australian aircraft in terms of lives lost. Further, the tragic loss of nine schoolmates shocked the nation and has never been forgotten.
4.3.2 Trading Partners

Australia's links with the mother country, England, were incredibly strong during the late eighteen and nineteenth centuries. This was not just in terms of the incumbent population and culture but also in terms of the import and export of products. Trade figures for 1887-91 show just how much Australia was forced to rely on the UK. Even more significant is how large the proportion of very far distance trading partners is. In terms of imports, 76% of trade was with European countries and only seven percent were specified as Asia or New Zealand, although some of the 11% of 'other countries' may be reasonably expected to be from Asia e.g. trade precious metal trade with Ceylon. Nevertheless 82 of the 89% that are labelled specifically on the Dyster & Meredith figures are northern hemisphere, 'western' trading partners that are positioned at the other side of the world.

By the early twentieth century, although the UK's dominant position as the premier trading partner had slipped somewhat, the majority of trade remained with the North Atlantic countries. When Qantas Airways was founded in 1920, approximately three quarters of the international trade remained with the USA, Canada and the states which formed the EC.

"Australia, with a small population spread over a very large island and geographically isolated from most of the rest of the world, has always relied heavily on aviation both domestically and internationally" (Felton, 1988)

![Australia's Main Trading Partners 1887-91](image1)

![Australia's Main Trading Partners 1887-91](image2)

The trade potential for aviation was great and was recognised almost immediately in the form of Air Mail services which started with a flight between Melbourne and Sydney in 1914. It was funding for the delivery of mail that allowed the first operators (including Qantas) to develop, not least because early aircraft had a very low capacity. For example, the Armstrong Whitworth FK-8 used by Qantas from 1922 carried just three passengers.

The international route between London and Australia opened in 1934, operated by Qantas and Imperial Airways. "From such an endeavour was borne something of enormous importance to
this remote isolated continent.” (Buddee, 1978) Freight was primarily mail, but the vastly reduced travel time between Australia and England meant that trade visits could be reasonably made. Within Australia, the Air Mail and passenger business grew and was supplemented by some unusual uses of aircraft. For example, an operation called ‘Air Beef’ was set up in 1949 to transport meat from an inland slaughterhouse to the coast at Derby for shipment. This service was developed because local roads were so bad and lasted until 1961.

However, major threats to the success of these early services were reliability and economics. Yields were very low and operations generally required Government subsidy (through Air Mail) to survive. The loss of aircraft represented a significant cost, not least because replacement airframes were imported from the US and UK by ship. For these reasons, the need for reliability was high and then compounded by the spatial separation of Australia.

If an aircraft became lost on a flight, the chances of rescue were limited. If the aircraft was flying close to telegraph wires, the pilot carried a primitive transmitter which could be connected to the wires to call for help. If the aircraft landed away from telegraph wires then the sparseness of the Australian population often meant they could not be located. Poor engine reliability, weather conditions and navigation often dictated that early aircraft would make landings away from airfields. This was less of a problem in Europe and North America where the population density was higher and there was a greater chance of help being close by. Australia was in the unenviable position of being a vast country with meagre population density and surrounded by an even bigger ocean.

This meant that an above average level of reliability was needed for Australian operations to maintain the efficiency and safety of its operators compared with those in Europe and North America. Demands for high reliability were particularly loud from those within the industry and led to the development of an industry culture which still exists in one form or another today. The potential for trade was great and the potential for catastrophic failure also high. Whilst this may have been expected to lead to a culture of corner cutting in order to deliver results, the role of key individuals in the development of airlines such as Qantas and Ansett assured that the opposite was true. The strong influence of dedicated aviators and mechanics with a desire to do things ‘right or not at all’ set a standard which has become an expectation.

In recent years, aviation has become almost the sole form of international travel to and from Australia and therefore has reached a political and social position that is still even more critical than many developed countries around the world. Fast high speed train and ferry links have maintained a competitive edge with aviation in many countries by virtue of airport location, congestion and the cost of air travel. This is not the case for Australia which sustains an expectation of efficient and safe air operations. In turn this must translate into a deliverable on the part of the airline if they are to avoid a significant political backlash.
4.3.3 Route Structure

Two of the potential problems in comparing safety records which were highlighted by Barnett, Abraham and Schimmel (1979) were:

a) Different airlines fly routes of different lengths.

b) Different airlines fly into different airports through different airspace.

The authors believe that there is no reason to give special consideration to flights of different length relative to the risk of an accident. Their conclusion was in response to a statistical exercise to look at 46 accidents involving US Domestic airlines between 1957-76.

Boeing’s accident summary (1996) plots a profile of hull loss accidents against stage of flight they occurred as follows;

<table>
<thead>
<tr>
<th>Load, taxi, unload</th>
<th>Takeoff</th>
<th>Initial climb</th>
<th>Climb</th>
<th>Cruise</th>
<th>Descent</th>
<th>Init. appr.</th>
<th>Finals</th>
<th>Landing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.8%</td>
<td>14.2%</td>
<td>9.5%</td>
<td>6.8%</td>
<td>4.3%</td>
<td>6.7%</td>
<td>11.7%</td>
<td>23.6%</td>
</tr>
</tbody>
</table>

Hull Loss Accidents - Worldwide Commercial Jet Fleet 1959-95

<table>
<thead>
<tr>
<th>Percentage of accidents</th>
<th>56.6%</th>
</tr>
</thead>
<tbody>
<tr>
<td>flaps retracted</td>
<td></td>
</tr>
<tr>
<td>Nav Fix</td>
<td></td>
</tr>
<tr>
<td>Outer Marker</td>
<td></td>
</tr>
<tr>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>57%</td>
<td></td>
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<tr>
<td>11%</td>
<td></td>
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<td>12%</td>
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<tr>
<td>3%</td>
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<td>1%</td>
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</tr>
</tbody>
</table>

Exposure, percentage of flight time (based on average flight duration of 1.5 hours).

Figure 4.3.3.1 Redrawn from Boeing, 1996

Even at first glance, it becomes obvious that although the cruise phase is by far the longest component of any flight, the majority of accidents occur within the shortest phases. In the average 6% of a flight that is takeoff, initial climb, final approach and landing, a staggering 68.6% of accidents are recorded. By this token, aircraft types that are used for short haul may appear to have significantly worse accident rates than their widebody counterparts. This is especially so if accident rates are compared in terms of flying hours or simply annual accident rates. Caeser (1994) observes that the risk exposure for a short-haul B737 flying 10-15 sectors a day is approximately four times higher than that of a long-haul B747 flying 3-4 sectors.
This is a function of several factors including:

- Airframe stress of recurrent pressure cycles.
- Proximity of hazards on takeoff, climb, approach and landing.
- Aircraft operating at extremes of performance envelope on takeoff and landing.
- Greater percentage of time spent on high workload tasks.

Short sectors work the aircraft harder. The effects of pressure change as aircraft ascend and descend place stresses on the integrity of the airframe. Operating at lower altitudes also exposes aircraft to greater corrosion, especially in the saline air associated with 'island hopping' flights.

In April 1988 an Aloha Airlines B737 lost a large section of its roof on a flight over Hawaii. The airframe had completed 90,000 cycles (the second highest by any 737) and had been used exclusively for Hawaiian island hopping throughout its life where flights were, on average, 20 minutes long. The repeated pressurisation, depressurisation and exposure to corrosive sea water had led the aircraft to disintegrate in flight. The aircraft survived to land despite exceeding all of its fail-safe design features.

Crews are also exposed to a far greater risk of performance overload in the critical takeoff and landing phases. "Crew workload is one of the most important human factors issues in aviation. Sustained high workload levels will overtax the crew, thus decreasing the margin of safety and increasing the probability of an accident." (Blomberg, Schwartz, Speyer and Fouillot, 1988, Speyer and Blomberg, 1989) This does not necessarily suggest that short-haul crews make more errors than long haul but does raise a number of interesting questions.

In its integrated crew training course manual, Britannia (1995) illustrate the profile of workload using the following diagram:
However, it cannot be inferred that mistakes are made proportionally to workload as this is not the case. "...It is errors that cause aviation accidents, not workload" (Blomberg et al., 1988) Errors can be made at both extremes of workload - underload and overload and anywhere in between. "The optimization rather than the reduction of flight crew workload is recognised as a major goal of human factors engineering." (Braby, Muir and Harris, 1991) Short sector length will expose air crews to more of the high workload phases of a flight than long haul which may reduce the danger of task overload, but conversely, prolonged periods of relative inactivity (i.e. cruise) followed by a period of high workload such as during approach and landing may also cause alertness problems. Does this benefit crews in providing experience of these important areas of flying or will crews become blazed to the hazards through complacency?

Captain Heino Caesar of ASCO (1994) suggests it to be the former;

"... (short haul) crews have a better arousal level, there is less chance for boredom, they are continually engaged in meaningful work. Their aircraft are more compact, less critical to handle with two engines overpowered by definition. The crews stay constantly highly experienced in the manual handling as well as the automatic flight guidance system programming due to more frequent take offs and landings."

Barnett, Abraham and Schimmel's (1979) examination of 46 US domestic airline accidents questioned whether flight-length was a significant factor in the accident record. For each accident the length of sector was recorded to provide a flight-length distribution which could then be compared with the 'actual' distribution from the 1975 Official Airline Guide. In testing their hypothesis that flight risk is related to flight length, the authors concluded that"...collectively, the US domestic airlines perform their longer flights at about the same level of safety as their shorter ones." This, they felt, provided no basis for special consideration to airlines with unusually long routes. Unfortunately, the conclusions of the MIT group are not as useful as they may initially seem.

The data used (1957-76) cover a period of rapid change within the industry. During this time, the accident rate varied considerably (see graph below) as airlines introduced jet aircraft. This change included the early Comet metal fatigue disasters and a number of transition accidents where crews did not successfully make the change in style from flying propeller driven aircraft to jets. The industry was also still playing host to a number of ex-WWII pilots and the 'gung-ho or wrong stuff' habits that they often brought with them. More importantly, the period coincided with the introduction of new aircraft to different lengths of route and the cascade effect this had on operations. For example, the B707 which was introduced in the late 1950's as a front line, long haul jet, was being replaced by early widebody types such as the B747 Classic, DC-10 and L-1011 by the early 1970's. The B707's would be cascaded down to shorter haul flights that may have been operated by older aircraft. By this time, the aircraft were known technology and not prone to some of the mishaps or failures that were experienced during the earlier, longer haul, years.
The sample of accidents used also fails to explore the rather wider issue of international operations. The USA is a closed system in terms of a unitary regulator (the FAA) and single language. This would mean that variations in routes, ATC quality and aerodrome facilities are all within the minima set by the FAA, or in the former case, by geography. Admittedly, the quality of facilities is not a function of the length of a route, but longer routes do tend to include the crossing of state boundaries and the differences in regulation that this inevitably means. It is difficult to represent the relationship between distance and risk exposure for this reason - a journey of 1000 miles may be very safe or very dangerous depending on where the aircraft has to fly over or to.

The extremes of short-haul and long-haul are not fully represented by the American domestic market. The longest coast to coast flights do not push aircraft to the same performance limitations that, for example, a 13hr 40min Singapore-London sector does. On such flights, the danger comes not just from the performance of the crew or the extended reliability required from the aircraft, but also from the fact that the aircraft will be taking off with a full fuel load and on many routes, a full complement of passengers and freight. Elements of the flight that cross large expanses of water or over ‘third world airspace’ also increase the level of hazard on long haul flights in a way that is not experienced by the US domestic market.

Time zone differences are also important. The difference between Pacific Time (GMT-8) and Eastern Time (GMT-5) is only three hours and has a limited effect on circadian rhythms. However, a longer sector such as London to Singapore (+8 hours) or a transmeridian flight such as Auckland - Los Angeles will have a profound affect on sleep patterns and performance levels. Graeber, Dement, Nicholson, Sasaki and Wegmann (1986) and Nicholson, Pascoe, Spencer, Stone and Green (1986) noted the effects of jetlag on performance and physiological state, which included disruption to the sleep-wake cycle, insomnia, tiredness, gastric problems and longer term sleep deprivation. (Cabon, Mollard, Coblentz, Fouillot and Speyer, 1991). Stone’s (1991) examination of London - Tokyo flights suggests that on return from such long haul trips, crews can take anything up to six days to resynchronise their body clocks and get back to normal performance.

‘Heavy crewing’ is one strategy which is employed to offset the effects of tiredness and fatigue on long-haul flights. This is a procedure whereby an extra First or Second Officer is carried to act as a ‘Cruise Pilot’ and allow the other pilots to take a rest break. Flight and Duty time limitations imposed by the regulator make such a procedure necessary although it should be noted that Qantas exceed this requirement by 80% (Qantas, 1997). Custom built rest areas on long-haul aircraft such as the B747-400 allow crewmembers to sleep and freshen-up in flight to maintain vigilance and performance. Graeber, Rosekind, Connell and Dinges (1990) conducted a study of controlled napping which “…clearly demonstrated that a pre-planned cockpit nap was associated with significantly better behavioural performance and higher levels of alertness.” In recent timea, Qantas has adopted an official policy of controlled napping and as Graeber et al. (1990) note, “there may be considerable safety benefits from such a sanctioned policy.”
Caesar's work, (1995) mainly with Lufthansa, where he was their first safety pilot, goes further to state that "Since the risk is not the time in the air but the frequency of take-offs and landings, the Australian airlines including Qantas run a lower risk." However, this seems contrary to Caesar's view that long haul flights have an 'unfavourable record' because of the extreme arousal-alertness concept where prolonged periods of boredom are followed by burst of intense activity. To this end, he notes the way that airlines such as Qantas train to account for a lack of experience at "...less routine handling" of large aircraft.

Qantas pilots operating the B747-400 on routes such as Sydney-Los Angeles, Frankfurt or London may only make one or two physical landings in a month due to the number of crew operating the aircraft and the large number of flying hours accumulated in single sectors. The lack of hands-on experience is supposed to be mitigated through experience in the flight simulator. CASA requirements for simulator training equate to one check per year (in addition to one route check) whereas Qantas policy is for flight crew to complete three simulator checks per annum. This exceedance costs the airline approximately $12 million per year. (Qantas, 1997)

International crews are therefore forced to fly in conditions that are hugely variant and with minimal hands-on experience in that type of aircraft. For a given pilot, this may mean that of the two landings he makes in a month, one may be in a hot, tropical storm in Singapore or Hong Kong and the other may be in foggy and icy conditions at Heathrow or Frankfurt. The suggestion is that the long-haul nature of the flying only heightens the criticality of take-offs and landings which negates the 'positive averaging' effect of flying long cruise sectors.

In summary, Australian carriers fly a wide variety of routes using jet aircraft which cover both short sectors (30-40 minutes) and ultra long sectors (13-14 hours). It is all but impossible to equate sector length to risk as some of the risk of short sectors (e.g. excessive workload) are balanced out on long sectors (e.g. circadian disrythmia). However, various risks associated with e.g ultra-long distance flight have been ameliorated through safety strategies such as extra training and heavy crewing. Therefore, although active failures caused by deficient vigilance or excessive workload may not be easily proven to be minimised in the Australian system, higher level safety strategies may reduce latent 'decision-making' failures. For example, policy decisions regarding the exceedance of regulations point to an aspect of high level safety culture over and above commerciality.

A second point considered by Barnett, Abraham and Schimmel's study (1979) was in regard to the 'fixed infrastructure' of the aviation system; namely airports and air traffic control areas;

b) Different airlines fly into different airports through different airspace.

Every airport and piece of airspace brings with it a unique set of problems for any aircraft. In the former case, this may be in terms of approach aids, runway length, local weather conditions
or approach path and in the latter this may be in terms of traffic density, control procedures, uncontrolled traffic and quality of air traffic control.

Although there are minimum requirements set by international agreement to be met before aircraft can be operated into particular areas, there is usually a 'margin of safety' between requirement and provision. For example, in terms of runway length, an aircraft would not generally be operated into an airfield where the declared distances were exactly the same as its required minima. It is more likely that there will be some extra margin which provides a safety net above that required by law.

Airlines have a choice of the routes they fly and airports they use. If an airport is deemed unsafe then it is the airline's prerogative not to fly there. Barnett et al. (1979) consider it "...unreasonable to treat airlines as the hapless victims of airport conditions beyond their control" and count accidents at 'hazardous areas' in their analysis of airline safety records.

The International Federation of Airline Pilot Associations (IFALPA) has an ‘Annex 19’ of airports awarded ‘black stars’ for dangerous deficiencies. (Barclay, 1991) The list covers airports all around the world but is strictly confidential due to its politically sensitive nature. An approach to IFALPA for access to this list was turned down for this reason, although it is known that neither Qantas nor Ansett fly to any of the airports mentioned on the list (Lewis, 1995).

The important question to answer is whether airlines make decisions about whether it is safe to fly into a particular airport or whether airport selection is solely the domain of the commercial department. The Vice President (Operations) of Britannia Airways (Grieve, 1994) explained that in their case, the decision about where to fly was made mainly by market forces. Once a destination had been selected, the operations department would be able to make comments about certain operational matters although the litmus test was always "If airline X can fly into that airport with the same type of aircraft then why can’t we?" The message within Britannia and within Lufthansa (Caesar, 1995) was that if they did not operate to a particular destination, then another airline would. An example of an airport where crews would prefer not to fly in Europe is the “stone aircraft carrier” (Grieve, 1994) at Funchal, Madeira in the Canary Islands. The runway starts and ends with a sheer cliff which allows little room for error. From a purely operational point of view, the airlines would probably choose not to operate large jet transports to this destination, but from a commercial point of view, this is a key location for the European holiday market and airlines such as Britannia (100% owned by the tour operator, Thomsons) have little choice but to operate there.

Qantas’ international routes represent premier destinations which are often the country’s capital cities. As such, the level of service is usually already high and there has been little need to exercise any sort of safety-led right not to fly there. In an incident where a strike at Singapore Changi airport meant that the RFFS cover was below ICAO minima, Qantas did suspend operations when other airlines did not, but this was a relatively isolated incident. It
may, however give an important indication of the difference in safety attitude between Qantas and other international carriers at the time.

Within Australia, changes to the level of RFFS cover at small regional airports has led to a situation where B737, F28 and BAe146 sized aircraft are operating into aerodromes with below ICAO equivalent minima. This is discussed in greater detail within the operational section of this thesis.

Differences in Airspace; The effects of flying in different airspace are numerous. Firstly, the effect may be in terms of the quality and effect of air traffic control and the type of control that is being used. This is discussed in greater detail in the Air Traffic Control section of this thesis.

Secondly, the effect may be in the form of the prevalent weather patterns, which in turn may be a function of the level and profile of terrain. This is discussed further in the Natural Environment chapter of this thesis.

### 4.3.3a Case Study - Sydney Airport

Sydney Kingsford-Smith Airport is the largest airport in Australia, serving the Premier City and acting as an International Gateway for Domestic Services and the Administrative Capital, Canberra. Positioned on the North Shore of Botany Bay, 11km South of the Central Business District, the airport is surrounded on three sides by industrial and housing developments. There are three runways - two oriented North-South and one East-West.

As the airport is based towards the centre of the city, there is a considerable problem with aircraft noise. As such, it is one of the few airports in Australia which observes a night curfew and is the centre of much political argument. Attempts to manage the problem have been controversial. When the third Sydney runway was opened to traffic in November 1994, protesters blocked access to the terminal buildings and then formed political parties to bring the issue to prominence.

Attempts by the CAA and later by Airservices Australia to adequately share noise amongst the suburbs led to confusing approach and departure procedures and allegations that operational issues (such as crosswinds) were being ignored for political gain. A Bureau of Air Safety Investigation study (BASI, 1997) highlighted the magnitude of the 'Failure to Comply' problem at Sydney Airport;

<table>
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<td>Brisbane</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Other</td>
<td>11</td>
<td>16</td>
</tr>
</tbody>
</table>

Figure 4.3.3.3 Failure to Comply Incidents BASI, 1997
Failure to Comply incidents recorded at Sydney represented a greater proportion of the total than could be accounted for simply by the greater number of movements. A series of events contributed to this unusually high number of incidents. These are represented on the following chart;

The introduction of STARs (Standard Arrival Routes) which were in accordance with ICAO obstacle clearance standards and designed by CASA in conjunction with Airservices Australia (BASI, 1997) brought a sudden and dramatic peak in failure to comply incidents which was repeated in February 1995 with the introductions of new SIDs (Standard Instrument Departures). These procedures were designed to increase efficiency at Sydney and Melbourne, especially at peak movement times. However, confusion surrounded the introduction of these procedures, not least because some of the ATC procedures used in conjunction with them did not follow accepted worldwide practice. For example, it became common practice for STARs to be cancelled part way through and even to be resumed later. This was contrary to the spirit of the "standard" procedure and was especially a problem for fast-jet RPT and foreign operations.

The opening of the third (parallel) runway in November 1994 was expected to increase airport capacity considerably. However, political intervention led to the closure of the East-West cross-runway in an attempt to assuage the concerns of consumer groups who were becoming politically powerful on the issue of noise. As a result, a sizable proportion of pilots which responded to the survey element of this research expressed concerns about landing in strong crosswinds. Some months later, the crosswind runway was reopened and soon after the Liberal Party rose to power in the 1996 General Election, approach procedures were changed again. Some argue that this was to redistribute noise away from Liberal constituencies and over Labour ones, but such suggestions begin to exceed the remit of this thesis. However, it is fair to say that political interventions on the subject of Sydney airport were frequent and will
continue to be so, especially with the issue of a second airport site remaining unresolved. Although efforts have been made to address some of the systemic issues behind ‘Failure to Comply’ incidents, the political interference continues. The policy of ‘noise-sharing’ has demanded a series of quite complex and unusual operating practices. These include experimental systems such as SODPROPS (Simultaneous Opposite Direction Parallel Runway Operations) which involves aircraft departing over Botany Bay Southward as arriving aircraft fly Northwards to the parallel runway. This phase of operation only occurs early in the morning and at weekends when traffic is relatively light, although it should be noted that this is when many international flights arrive with crews who may have less experience of operating in the airport.

Sydney airport represents an extreme in Australian operations, not least because of its high volume of traffic. However, the operating environment, which is partly set up by the physical geography of the surrounding urban development is also affected by the other part of the natural environment, namely the weather. As mentioned elsewhere, Sydney is subject to some extreme meteorological conditions which may combine with operational complications to set up a breakdown of safety. This point is crucial - that although operational problems per se may not be sufficient to cause an accident, they do form latent defects within the safety system which reduce the available margin of safety.
The human environment represents the key component of the aviation system, providing the interface between the operational and natural environments. The hitherto underestimated prevalence of human error is considered in the context of the Australian aviation system and therefore constitutes the most significant part of the analysis.
5.1.1 Introducing the Concept of Culture

Hofstede (1980) defines culture as "the collective programming of the mind which distinguishes the members of one state from another" and then proceeds to say that "culture is to a human collectivity what personality is to an individual." Using a simple triangular diagram (figure 5.1.1), he demonstrates the level at which culture influences the way individuals act;

![Three Levels of Uniqueness in Human Mental Programming](image)

Hofstede (1980) defines culture as "the collective programming of the mind which distinguishes the members of one state from another" and then proceeds to say that "culture is to a human collectivity what personality is to an individual." Using a simple triangular diagram (figure 5.1.1), he demonstrates the level at which culture influences the way individuals act;

Human nature, the broadest of the behaviour controlling characteristics is beyond the remit of this research project. However, the effects of culture are very relevant and will be covered in much greater detail. Being placed as it is between the extremes of individuals and the human species and collectively described as "groups" or 'categories", it is clear that there are multiple layers of culture to be examined.

Trompenaars (1993) refers to several different levels of culture, the highest being that of a national or regional society. Within particular organisations, attitudes may be described as a corporate or organisational culture and within specific functions, Trompenaars suggests that people will share "...certain professional and ethical orientations. Although the focus of his work is primarily oriented towards national culture, this research will attempt to cover areas of national and organisational culture. It will also explore the areas of professional cultures specific to aviation. This is subtly different to Trompenaars' brief definition of 'professional orientation' which gives the impression of being a subset of an organisational culture. It is the contention of this thesis that there are facets of the aviation industry culture that span and influence a number of apparently different corporate cultures. The expectation is that not only
will there be certain cultural traits specific to the aviation industry at world and national levels but also to specific roles within that profession such as pilots, air traffic controllers etc.

As the schematic below demonstrates, although a national culture can influence an entire industry culture and in turn the industry culture may influence both organisational and professional cultures, there are multiple cultures that can exist within any one group.

![The multiple layers of culture (schematic).](image)

That is to say that there will be several organisational cultures within any industry culture and there may also be several professional cultures.

As an example, the above diagram may be applied to the Australian aviation system. The organisational cultures may represent those of Ansett Australia and Qantas Airways and the professional cultures may represent flight crew and maintenance crews. Just as both maintenance and flight crew of, say, Ansett Australia will share certain organisational culture traits, so too maintenance crew of Ansett and Qantas will share other professional traits.

Merritt (1993) simply defines culture as “...the values and practices we share with others that help us define us as a group, especially in relation to other groups.” Patience (1991) quotes Geertz’s description of man as “an animal suspended in webs of significance he himself has spun” and develops it further to explain that “...these webs of significance inspire and constrain human consciousness and action within relatively ordered arrangements of social
structure. These arrangements include moral, aesthetic, linguistic and other signifying elements which we employ to symbolise our understandings of the world around us.” Tylor (1924) suggests that culture may be defined as “that complex whole which includes knowledge, belief, art, morals, law, custom and any other capabilities and habits acquired by man as a member of society”. Essentially, culture is a form of subtle mental programming that may only be apparent when compared to other, different, cultures.

Likened to a fish in water - culture is all around us but it cannot easily be seen.

For many however, culture seems very visual and easily defined characteristic that is represented through the artistic disciplines of music, visual arts and literature. This perhaps develops a misconception that certain groups can have ‘more culture’ or even ‘no culture’, whereas the reality is that all groups have a distinct and unique culture that may be represented in different ways. These areas of ‘popular culture’ do not tell the full story of the multiple elements that make up any one cultural group.

Culture is a much deeper subject than just ‘popular culture’
Culture becomes part of a child’s education from as soon as they are capable of learning and is highly influential in the way it develops and becomes educated. It helps define both their attitudes to and expectations of other people and interacts with their personality to develop links with other groups (and therefore compatible cultures).

The importance of culture and communication as influencing factors is highlighted by Gudykunst and Ting-Toomey (1988) who write; “Communication and culture reciprocally influence each other. The culture from which individuals come affects the way they communicate, and the way individuals communicate can change the culture they share."

5.1.1.1 The need for a softly, softly approach?

One of the hazards of considering culture, especially in the context of safety issues, is that certain countries may be offended by attempts to link poor safety records with national culture. Further, activists may also interpret such studies to be racist and therefore unacceptable. It is with this in mind that the following statement should be noted:

Improved safety is a universal goal and the complex nature of many procedures and pieces of equipment which were often designed without awareness of different cultures and so lend themselves more to the designing culture. It is therefore logical that as cultures differ, so their compatibility with different procedures or equipment will also differ. It does not elevate some cultures to be greater than others, but as this research will show, there is a direct link between certain cultural traits and the safe operation of civil aircraft that should not be ignored in the name of politics.

There are numerous accidents from the accident record that illustrate how culture may have been a significant factor. Phelan (1994) explains how in 1980 a Korean B747 undershot whilst making a final approach in fog and hit a gun emplacement before crashing onto the runway. The aircraft burned but most of the passengers and crew were able to evacuate. However the cockpit voice recorder (CVR) testifies that both (Korean) pilots survived the impact and, despite lengthy pleas by the (Canadian) flight engineer, they chose to remain and die in the flames as they had ‘disgraced themselves and their families’. A different accident is recalled by a senior Australian aviation figure where a Japanese DC-8 Captain attempted suicide by flying his aircraft into the sea. The co-pilot is heard on the CVR tape ‘politely asking the pilot not to land in the sea as it may endanger the passengers’. “If that were an Australian flight deck, the co-pilot would have punched the pilot and taken over the controls rather than let him crash the aircraft!” explained the official.

Of course, there will always be anomalies within cultural groups but it is still possible to group behaviour patterns usefully. Before the variation of culture is related specifically to aviation, it is important to look at the wider picture of cultural study and the pioneering work done in this area by the likes of Geert Hofstede (1980, 1991) and Fons Trompenaars (1993).
5.1.2 Hofstede and Trompenaars' Indices of Culture

Trompenaars (1993) suggests that the exploration of culture should distinguish differences on three levels: our relationships with other people; the passage of time and the influence of the environment. Using a series of questionnaires, the author surveyed 30 companies in 50 countries to compile a database of 15,000 participants answers. The sample represented 75% from management positions and 25% from general administrative tasks.

Although Trompenaars had spent some time working with Hofstede, he clearly admits that they do not always agree on the nature of culture. What is clear however, is that there is more agreement than disagreement in their coverage of the subject and it is of great value to the reader to explore their work further before concentrating specifically on aviation.

In his work, Hofstede conducted probably the most widely quoted study of cross-cultural psychology studying 117,000 computing industry employees in 66 countries through the HERMES programme. Hofstede suggested four areas of cultural difference that can categorise national cultures. For each of these areas, he developed a scale by which to rate each country on a scale between 1 and 100. The indices are described as follows:

5.1.2.1 Individualism

This is the "relationship between the individual and the collectivity that prevails in a given society". While different species are seen to be gregarious (e.g. wolves) and others solitary (e.g. tigers), Hofstede suggests that even within a species, there are variations. Although humans may be classified as 'gregarious' there are differences in, for example, the complexity of family units. This extends into human society through societal norms in the form of value systems of major groups of the population. These institutions may be educational, religious, political and utilitarian, for example.

Within the context of a particular organisation, the individualism norm will be revealed through the relationship between a person and that organisation. For example, a more collective culture would call for a "greater emotional dependence of members on their organisations". Johnston (1993b) simplifies the dimension by describing strongly individualistic cultures such as the USA as giving primacy to "...personal initiative and individual achievement" and strongly collectivist cultures as displaying "...much tighter and social obligations to clan, class or group."

The results index to describe the level of individual within each country is based on work goals survey data and is represented as a simple mathematical transformation of the results onto a scale between zero and 100. The highest individualism values are found in U.S.A., Australia and Great Britain; the lowest (and therefore most collectivist) are found in Panama, Ecuador and Guatemala.
### Individualism Index

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<td>14</td>
<td>47/48</td>
</tr>
<tr>
<td>Argentina</td>
<td>46</td>
<td>22/23</td>
<td>Colombia</td>
<td>13</td>
<td>49</td>
</tr>
<tr>
<td>Iran</td>
<td>41</td>
<td>24</td>
<td>Venezuela</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td>Jamaica</td>
<td>39</td>
<td>25</td>
<td>Panama</td>
<td>11</td>
<td>51</td>
</tr>
<tr>
<td>Brazil</td>
<td>38</td>
<td>26/27</td>
<td>Ecuador</td>
<td>8</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Guatemala</td>
<td>6</td>
<td>53</td>
</tr>
</tbody>
</table>

Mean of 39 countries: 51

Figure 5.1.5: Individualism Index  Adapted from Hofstede, 1991
5.1.2.2 Power - Distance

This index basically concerns itself with human inequality. In society this can occur in a number of different ways from social status to wealth and from power to laws and rights. The index used by Hofstede to illustrate this inequality is called power-distance and is “a measure of the interpersonal power or influence between boss (B) and subordinate (S) as perceived by the least powerful of the two, S.” Hofstede’s work in this area is in fact derived from that of Mulder (1980) who defines power-distance as “the degree of inequality in power between a less powerful individual (I) and a more powerful other (O), in which I and O belong to the same (loosely or tightly knit) social system.” The suggestion is that power distance within an organisation is, to a considerable extent, determined by national culture.

<table>
<thead>
<tr>
<th>Country</th>
<th>Actual</th>
<th>Rank</th>
<th>Country</th>
<th>Actual</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysia</td>
<td>104</td>
<td>1</td>
<td>South Korea</td>
<td>60</td>
<td>27/28</td>
</tr>
<tr>
<td>Guatemala</td>
<td>95</td>
<td>2/3</td>
<td>Iran</td>
<td>58</td>
<td>29/30</td>
</tr>
<tr>
<td>Panama</td>
<td>95</td>
<td>2/3</td>
<td>Taiwan</td>
<td>58</td>
<td>29/30</td>
</tr>
<tr>
<td>Philippines</td>
<td>94</td>
<td>4</td>
<td>Spain</td>
<td>57</td>
<td>31</td>
</tr>
<tr>
<td>Mexico</td>
<td>81</td>
<td>5/6</td>
<td>Pakistan</td>
<td>55</td>
<td>32</td>
</tr>
<tr>
<td>Venezuela</td>
<td>81</td>
<td>5/6</td>
<td>Japan</td>
<td>54</td>
<td>33</td>
</tr>
<tr>
<td>Arab countries</td>
<td>80</td>
<td>7</td>
<td>Italy</td>
<td>50</td>
<td>34</td>
</tr>
<tr>
<td>Ecuador</td>
<td>78</td>
<td>8/9</td>
<td>Argentina</td>
<td>49</td>
<td>35/36</td>
</tr>
<tr>
<td>Indonesia</td>
<td>78</td>
<td>8/9</td>
<td>South Africa</td>
<td>49</td>
<td>35/36</td>
</tr>
<tr>
<td>India</td>
<td>77</td>
<td>10/11</td>
<td>Jamaica</td>
<td>45</td>
<td>37</td>
</tr>
<tr>
<td>West Africa</td>
<td>77</td>
<td>10/11</td>
<td>U.S.A</td>
<td>40</td>
<td>38</td>
</tr>
<tr>
<td>Yugoslavia</td>
<td>76</td>
<td>12</td>
<td>Canada</td>
<td>39</td>
<td>39</td>
</tr>
<tr>
<td>Singapore</td>
<td>74</td>
<td>13</td>
<td>Netherlands</td>
<td>38</td>
<td>40</td>
</tr>
<tr>
<td>Brazil</td>
<td>69</td>
<td>14</td>
<td>Australia</td>
<td>36</td>
<td>41</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>68</td>
<td>15/16</td>
<td>Costa Rica</td>
<td>35</td>
<td>42/44</td>
</tr>
<tr>
<td>France</td>
<td>68</td>
<td>15/16</td>
<td>Germany (F.R.)</td>
<td>35</td>
<td>42/44</td>
</tr>
<tr>
<td>Colombia</td>
<td>67</td>
<td>17</td>
<td>Great Britain</td>
<td>35</td>
<td>42/44</td>
</tr>
<tr>
<td>Salvador</td>
<td>66</td>
<td>18/19</td>
<td>Switzerland</td>
<td>34</td>
<td>45</td>
</tr>
<tr>
<td>Turkey</td>
<td>66</td>
<td>18/19</td>
<td>Finland</td>
<td>33</td>
<td>46</td>
</tr>
<tr>
<td>Belgium</td>
<td>65</td>
<td>20</td>
<td>Norway</td>
<td>31</td>
<td>47/48</td>
</tr>
<tr>
<td>East Africa</td>
<td>64</td>
<td>21/23</td>
<td>Sweden</td>
<td>31</td>
<td>47/48</td>
</tr>
<tr>
<td>Peru</td>
<td>64</td>
<td>21/23</td>
<td>Ireland</td>
<td>28</td>
<td>37</td>
</tr>
<tr>
<td>Thailand</td>
<td>64</td>
<td>21/23</td>
<td>New Zealand</td>
<td>22</td>
<td>35</td>
</tr>
<tr>
<td>Chile</td>
<td>63</td>
<td>24/25</td>
<td>Denmark</td>
<td>18</td>
<td>28</td>
</tr>
<tr>
<td>Portugal</td>
<td>63</td>
<td>24/25</td>
<td>Israel</td>
<td>13</td>
<td>44</td>
</tr>
<tr>
<td>Uruguay</td>
<td>61</td>
<td>26</td>
<td>Austria</td>
<td>11</td>
<td>40</td>
</tr>
<tr>
<td>Greece</td>
<td>60</td>
<td>27/28</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5.1.6 Power-Distance Index Adapted from Hofstede, 1991

Johnston (1993b) adds that in countries with a high power-distance “…social inequality is readily accepted” - leaders are expected to be decisive and subordinates are expected to know their place.
Hofstede summarises the results of other research into the connotations of power-distance differences in a table. A selection of results that are relevant to this research project are highlighted below.

<table>
<thead>
<tr>
<th>Low PDI Countries</th>
<th>High PDI Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students put high value on independence.</td>
<td>Students put high value on conformity.</td>
</tr>
<tr>
<td>Managers are seen as making decisions after consulting with subordinates.</td>
<td>Managers are seen as making decisions autocratically and paternalistically.</td>
</tr>
<tr>
<td>Close supervision negatively evaluated by subordinates.</td>
<td>Close supervision positively evaluated by subordinates.</td>
</tr>
<tr>
<td>Stronger perceived work ethic; strong disbelief that people dislike work.</td>
<td>Weaker perceived work ethic; more frequent belief that people dislike work.</td>
</tr>
<tr>
<td>Managers more satisfied with participative superior.</td>
<td>Managers more satisfied with directive or persuasive superior.</td>
</tr>
<tr>
<td>Subordinates’ preference for manager’s decision-making style clearly centred on consultative give-and-take style.</td>
<td>Subordinates’ preference for manager’s decision-making style polarised between autocratic-paternalistic and majority rule.</td>
</tr>
<tr>
<td>Managers like seeing themselves as practical and systematic; they admit a need for support.</td>
<td>Managers like seeing themselves as benevolent decision makers.</td>
</tr>
<tr>
<td>Employees less afraid of disagreeing with their boss.</td>
<td>Employees fear to disagree with their boss.</td>
</tr>
<tr>
<td>Employees show more cooperativeness.</td>
<td>Employees reluctant to trust each other.</td>
</tr>
<tr>
<td>Managers seems as showing more consideration.</td>
<td>Managers seems as showing less consideration.</td>
</tr>
<tr>
<td>Informal employee consultation possible without formal participation.</td>
<td>Formal employee participation possible without informal consultation.</td>
</tr>
<tr>
<td>Higher - educated employees hold much less authoritarian values than lower - educated ones.</td>
<td>Higher - and lower - educated employees show similar values about authority.</td>
</tr>
</tbody>
</table>

Figure 5.1.7 Effects of Extreme Power-Distance  Adapted from Hofstede, 1991
5.1.2.3 Uncertainty Avoidance

Uncertainty avoidance is another trait of national culture, that describes the variability of tolerance for uncertainty within a nation, based on three indicators; rule orientation, employment stability and stress. All individuals and organisations face levels of uncertainty which are a function of the environment they live and work within. Different cultures have different values of the importance of avoiding uncertainty and different ways of accomplishing this avoidance. Hofstede’s index for 39 HERMES countries are as follows:

<table>
<thead>
<tr>
<th>Country</th>
<th>UAI</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greece</td>
<td>112</td>
<td>1</td>
</tr>
<tr>
<td>Portugal</td>
<td>104</td>
<td>2</td>
</tr>
<tr>
<td>Belgium</td>
<td>94</td>
<td>3</td>
</tr>
<tr>
<td>Japan</td>
<td>92</td>
<td>4</td>
</tr>
<tr>
<td>Peru</td>
<td>87</td>
<td>5</td>
</tr>
<tr>
<td>France</td>
<td>86</td>
<td>6/9</td>
</tr>
<tr>
<td>Chile</td>
<td>86</td>
<td>6/9</td>
</tr>
<tr>
<td>Spain</td>
<td>86</td>
<td>6/9</td>
</tr>
<tr>
<td>Argentina</td>
<td>86</td>
<td>6/9</td>
</tr>
<tr>
<td>Turkey</td>
<td>85</td>
<td>10</td>
</tr>
<tr>
<td>Mexico</td>
<td>82</td>
<td>11</td>
</tr>
<tr>
<td>Israel</td>
<td>81</td>
<td>12</td>
</tr>
<tr>
<td>Colombia</td>
<td>80</td>
<td>13</td>
</tr>
<tr>
<td>Venezuela</td>
<td>76</td>
<td>14/15</td>
</tr>
<tr>
<td>Brazil</td>
<td>76</td>
<td>14/15</td>
</tr>
<tr>
<td>Italy</td>
<td>75</td>
<td>16</td>
</tr>
<tr>
<td>Pakistan</td>
<td>70</td>
<td>17/18</td>
</tr>
<tr>
<td>Austria</td>
<td>70</td>
<td>17/18</td>
</tr>
<tr>
<td>Taiwan</td>
<td>69</td>
<td>19</td>
</tr>
<tr>
<td>Germany (F.R.)</td>
<td>65</td>
<td>20</td>
</tr>
<tr>
<td>Thailand</td>
<td>64</td>
<td>21</td>
</tr>
<tr>
<td>Iran</td>
<td>59</td>
<td>22/23</td>
</tr>
<tr>
<td>Finland</td>
<td>59</td>
<td>22/23</td>
</tr>
<tr>
<td>Switzerland</td>
<td>58</td>
<td>24</td>
</tr>
<tr>
<td>Netherlands</td>
<td>53</td>
<td>25</td>
</tr>
<tr>
<td>Australia</td>
<td>51</td>
<td>26</td>
</tr>
<tr>
<td>Norway</td>
<td>50</td>
<td>27</td>
</tr>
<tr>
<td>South Africa</td>
<td>49</td>
<td>28/29</td>
</tr>
<tr>
<td>New Zealand</td>
<td>49</td>
<td>28/29</td>
</tr>
<tr>
<td>Canada</td>
<td>48</td>
<td>30</td>
</tr>
<tr>
<td>U.S.A</td>
<td>46</td>
<td>31</td>
</tr>
<tr>
<td>Philippines</td>
<td>44</td>
<td>32</td>
</tr>
<tr>
<td>India</td>
<td>40</td>
<td>33</td>
</tr>
<tr>
<td>Great Britain</td>
<td>35</td>
<td>34/35</td>
</tr>
<tr>
<td>Ireland</td>
<td>35</td>
<td>34/35</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>29</td>
<td>36/37</td>
</tr>
<tr>
<td>Sweden</td>
<td>29</td>
<td>36/37</td>
</tr>
<tr>
<td>Denmark</td>
<td>23</td>
<td>38</td>
</tr>
<tr>
<td>Singapore</td>
<td>8</td>
<td>39</td>
</tr>
</tbody>
</table>

Figure 5.1.8 Uncertainty-Avoidance Index  Adapted from Hofstede, 1991

Australia is ranked within the third quartile range and away from USA, Canada and Great Britain which are all countries it has been close to in the individualism and power-distance.

Countries with a high uncertainty-avoidance score tend to seek clarity and order in society to a level where it becomes intolerant or inflexible. On the other hand, countries with a low UAI score tend to be more adaptable and tolerant by accepting uncertainty as a fact of life. Hofstede suggested a high correlation between PDI and individualism and Smith, Dugan and Trompenaars (1994) speculate that “...empirically speaking, they may be manifestations of the same underlying dimension.”
5.1.2.4 Masculinity

Fundamentally, the cultural issue here is “whether the biological differences between sexes should or should not have implications for their roles in social activities” (Hofstede, 1991). The pattern is based on a ‘masculine’ tendency to be assertive and a “feminine” one to be nurturing. It is not a statement on sexual politics as it is concerned with the “personality” of a culture defined within those two polar descriptions of masculinity and femininity.

![Masculinity Index (MAS)]

<table>
<thead>
<tr>
<th>Country</th>
<th>MAS Rank</th>
<th>Country</th>
<th>MAS Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>95</td>
<td>Canada</td>
<td>52</td>
</tr>
<tr>
<td>Austria</td>
<td>79</td>
<td>Pakistan</td>
<td>50</td>
</tr>
<tr>
<td>Venezuela</td>
<td>73</td>
<td>Brazil</td>
<td>49</td>
</tr>
<tr>
<td>Italy</td>
<td>70</td>
<td>Singapore</td>
<td>48</td>
</tr>
<tr>
<td>Switzerland</td>
<td>70</td>
<td>Israel</td>
<td>47</td>
</tr>
<tr>
<td>Mexico</td>
<td>69</td>
<td>Turkey</td>
<td>45</td>
</tr>
<tr>
<td>Ireland</td>
<td>68</td>
<td>Taiwan</td>
<td>45</td>
</tr>
<tr>
<td>Great Britain</td>
<td>66</td>
<td>Iran</td>
<td>43</td>
</tr>
<tr>
<td>Germany (F.R.)</td>
<td>66</td>
<td>France</td>
<td>43</td>
</tr>
<tr>
<td>Philippines</td>
<td>64</td>
<td>Spain</td>
<td>42</td>
</tr>
<tr>
<td>Colombia</td>
<td>64</td>
<td>Peru</td>
<td>42</td>
</tr>
<tr>
<td>South Africa</td>
<td>63</td>
<td>Thailand</td>
<td>34</td>
</tr>
<tr>
<td>U.S.A</td>
<td>62</td>
<td>Portugal</td>
<td>31</td>
</tr>
<tr>
<td><strong>Australia</strong></td>
<td><strong>61</strong></td>
<td>Chile</td>
<td>28</td>
</tr>
<tr>
<td>New Zealand</td>
<td>58</td>
<td>Finland</td>
<td>26</td>
</tr>
<tr>
<td>Greece</td>
<td>57</td>
<td>Denmark</td>
<td>16</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>57</td>
<td>Netherlands</td>
<td>14</td>
</tr>
<tr>
<td>Argentina</td>
<td>56</td>
<td>Norway</td>
<td>8</td>
</tr>
<tr>
<td>India</td>
<td>56</td>
<td>Sweden</td>
<td>5</td>
</tr>
<tr>
<td>Belgium</td>
<td>54</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Mean of 39 countries** 51

Figure 5.1.9 Masculinity Index Adapted from Hofstede, 1991

Johnston (1993b) writes that “in masculine cultures (e.g. Italy, Australia) ambition and performance are highly valued, and are measured by material success. Forceful behaviour and drive are readily accepted.” This is in contrast to more feminist cultures where there is a stronger emphasis on “...values such as warm social relationships, quality of life and care of the weak” (Smith, Dugan and Trompenaars, 1994).

Hofstede observes a number of societal norms that are associated with low and high masculinity index scores:
Australian Aviation Safety: A Systemic Investigation and Case Study Approach

Low Masculinity Score

People Orientation
Work to Live
Service Ideal
Interdependence Ideal
Intuition
Levelling: don’t try to be better than others
Unisex and androgyny ideal
Stronger position of mother in the family

High Masculinity Score

Money and Things Orientation
Live To Work
Achievement Ideal
Independence Ideal
Decisiveness
Excelling: trying to be the best
Machismo (ostentative manliness) ideal
Weaker position of mother in the family

Figure 5.1.10 Effects of Extreme Masculinity Scores Adapted from Hofstede, 1991

The consequences of the extremes of the masculinity index are as follows:

Low MAS Countries. High MAS Countries.

Consequences for Society at Large;

Trying to be better than others is neither socially nor materially rewarded.
There are rewards in the form of wealth or status for the successful achiever.

Social adaptation-oriented school system. Performance-oriented school system.

Less occupational segregation: e.g. male nurses.
Some occupations are considered typically male, other female.

Slower car driving, fewer accidents.
Faster car driving, more accidents.

Consequences for Organisations;

Some young men and women want careers, others do not.
Young men expect to make a career; those who don’t see themselves as failures.

More women in more qualified and better-paid jobs.
Fewer women in more qualified and better-paid jobs.

Lower job stress.
Higher job stress.

Less industrial conflict.
More industrial conflict.

Figure 5.1.11 Consequences for Society of Masculinity Scores Adapted from Hofstede, 1991
The next stage of Hofstede’s work was to attempt to integrate the four dimensions. To do this, he carried out a “hierarchical cluster analysis” which classified the countries into clusters of similar levels of variables. The result is eight groups formed of 12 clusters. Australia falls within the category described as ‘Anglo’ which is described as follows:

**Cluster 9 - Anglo**
- low to medium PDI
- low to medium UAI
- high IDV
- high MAS

Australia
Canada
Great Britain
Ireland
New Zealand
USA

This group is probably quite unsurprising and contrasts with extremes of culture which include two of the Asian groups highlighted below:

**Less Developed Asian**
- high PDI
- low to medium UAI
- low IDV
- medium MAS

Pakistan
Taiwan
Thailand
Hong Kong
India
Phillipines
Singapore

**More Developed Asian**
- medium PDI
- high UAI
- medium IDV
- high MAS

Japan
Hofstede's work, along with the subsequent investigations by Trompenaars have received much critical acclaim in what is a relatively new area of social science. However, the former's work has also been criticised for his sampling frame which although it covered 53 countries, was concentrated on a single multinational firm, namely IBM. As Smith et al. (1994) point out "Hofstede regarded his matching strategy as a strength, though doubts can be raised as to whether those employed in servicing and marketing in an industrialised nation are necessarily equivalent to those in similar roles in a third world nation". This is a valid point for discussion which would also translate to the aviation industry: the socioeconomic profile of pilots between pilots can be very different. The level of skill and training required to successfully operate say a Boeing airliner may be the same whether the pilot is from a third or first world nation, yet the average earning or GDP per capita may be vastly different.

However, this argument may not be so significant in terms of examining differences between similar occupations in different countries. Hofstede's sample of IBM employees may indeed represent a particular section of society which may not give a completely accurate picture of the full socio-economic range, but at least the data are stabilised by a common profession. The University of Texas Aerospace Crew Research Project's (Merritt, 1993, 1997; Helmreich and Wilhelm, 1997) attempts to replicate Hofstede's work in the aviation field support the validity of his study and to examine it application to the aviation industry "...It was to test this assumption of universal versus culture-specific pilot behaviour that I undertook the replication study" (Merrit, 1997). The Individualism and Power-Distance indices were selected as being the most relevant to aviation. The conclusion was that "...pilots had higher yet more convergent scores on Individualism than observed in Hofstede's data, a result attributed to modernisation, economic independence, and self-selection into an individualistic profession. The utility of the Masculinity index for the pilot profession was called into doubt (which is not to question Hofstede's results, but to affirm the unique attributes of the pilot profession)."

The University of Texas study provides a unique opportunity to look at cultural indicators in the aviation context. Notwithstanding this, using Hofstede as a basis lends credence to the initial work as a guide to cultural difference. Work by others in aviation such as Johnston (1992, 1993, 1993b), Redding and Ogilvie (1994) and Ooi (Flight International, 1994) has all used Hofstede as a base and hence its inclusion here as a vital starting point for understanding differences. Whilst an entire thesis could be devoted to the subject of cultural difference and still only barely scratch the surface, the basic introduction of the subject is included here sets the scene for the specific examination of the Australian aviation system.
5.1.2 Culture and Aviation

Aviation is a truly international business. It is difficult to imagine any air operation that does not involve some form of multinational collaboration, whether it be in the design, construction or maintenance of aircraft or the supply of flight planning information, air traffic services or operational crew. As such, the industry is exposed to the full range of cultures (from national down to work-group) on a daily basis which ultimately affects the way it functions.

Culture is a subject on which many people are self-appointed experts. Experience of other cultures, particularly national cultures, contributes to a level of understanding that is all too often incomplete and laced with misinterpretation. The stereotype is one such unfortunate outcome of cultural exposure, but one that everyone is guilty of using and believing. The mental image of Australians as Crocodile Dundee figures is as real in the minds of Englishmen as the image of pin-striped suits, umbrella and bowler hat in the minds of their antipodean counterparts.

The realms of stereotyping and self-styled experts are no more apparent than in the aviation industry where exposure to other nationalities is perhaps more common than most professions. It is not fair to say that all stereotypes are wrong or that expertise based on experience is deficient for the very reason that exposure to other cultures is so high. The aviation industry boasts some great experience in the areas of culture although sheer logistics prevents real multicultural expertise. There is enough anecdotal evidence around the world to tie up a researcher for the rest of their working life if it were to be collected. Even if such a task were to be attempted, the danger will always be that the stories would be collated from a particular cultural viewpoint i.e. that of the researcher.

In April 1996, the IATA Director-General, Pierre Jeanniot addressed the Asia / Pacific Economic Co-operation Working Group aviation seminar in Vancouver, Canada. (Flight International, 1996) Acknowledging the "...cultural characteristics involved in human factors", Jeanniot suggest that, "...it is important that this area be explored professionally in an atmosphere devoid of any emotive cultural sensitivities so that compensating measures can be developed." It is these "emotive cultural sensitivities" that provide the greatest challenge for researchers both from the point of view of the researcher as well as the researched. The editorial by Flight International (1996) notes that a study of culture will not be easy. "It must be international in content, outlook and subject, and it must not be a study by Westerners of the anecdotal cultural differences between themselves and others".

Early attempts to examine cultural differences, particularly in accident records have suffered somewhat from a lack of data. (Boeing's attempted is mentioned elsewhere in the text.) The fear of offending member states appears to be one of the reasons that international umbrella organisations such as ICAO and IATA have been reluctant to publish any safety figures that separate member states. As was mentioned earlier in the review of safety statistics, the use of geographic regions is as specific as either seem to go. When a search of the ICAO ADREP
database was requested to split accidents / incidents by state of occurrence, the Australian Representative to the Council (Weber, 1994) explained that although the Secretariat would provide what assistance they could, the information contained on ADREP “...is provided by States on the understanding that it is used for accident prevention purposes rather than for comparing safety records of the airlines of those states.” Changing thinking such that an understanding of the influence of national culture (or even national economic factors) is recognised as being a worthy safety pursuit will not be an easy task for any researcher.

The area of aviation culture which seems to have advanced the most is related to the development of crew resource management (CRM) within the flight deck. A great deal of the early developments in CRM occurred in the US with an apparently positive effect on flying safety. With this initial success as encouragement, certain airlines attempted to sell CRM courses to overseas airlines. One anecdotal source of evidence tells of a group of Korean air crew who were told that CRM required an openness of communication on the flight deck such that even the most junior crew member could speak up if they considered there to be a problem. All of the participants strongly agreed with the sentiments of the course facilitator and then went back to line flying and continued with the belief that the Captain is always right and junior crew members do not question his judgment. In the context of the classroom, the American facilitator held the key position of power and was therefore ‘always right’. Whatever he said about the way the students should behave was agreed with. As soon as the crews were back flying, the Captain held the key power position and went back to being always right and therefore not open to question.

The major players in examining the effects of CRM and in particular how it relates to culture have included the joint NASA / University of Texas / Federal Aviation Administration (NASA/UT/FAA) Aerospace Crew Research Project run under the direction of Robert L. Helmreich. Their work in the area of aviation human factors has covered nearly 20 years and started with expertise in CRM concepts and training that were specific to the USA (see Merritt, 1993, 1993b, 1997, Helmreich and Wilhelm, 1997). As the profile of the CRM concept has continued to be raised around the world, the NASA team have been able to examine cross-cultural difference in the way people train and react to training. The addition of a cultural dimension to the teams work is a relatively recent phenomena, but one they see as being ever more important. Merritt comments that “…as CRM extends beyond the cockpit and across national boundaries, we are now recognising that the CRM practices which we held to be universally applicable are indeed culturally influenced.”

Johnston (1992) recognises the contribution of culture by stating that; “The social processes which contribute to crew functioning vary within each separate culture and, indeed from organisation to organisation across that culture.” He further suggests that even apparently cultureless phenomena such as the use of ‘standard operational procedures (SOPs)’ are effected by cultural variations in application by crewmembers. Directing his investigations specifically towards CRM training, Johnston argues that such training “…may be ineffective or rejected in the absence of cultural compatibility”.

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Previous to the work of Merritt and Johnston, however, was that of Redding and Ogilvie (1994) at the University of Hong Kong, into the cultural effects on communication in the cockpits of commercial aircraft. The authors suggest that although flying crew carry “...feelings, attitudes, beliefs and values..” which are derived from their individual personalities, it is possible to aggregate these features into larger groups such as national cultures. “This cultural level of difference, although it is assumed not to operate in affecting professional behaviour of flying crew, may in fact, be operating unconsciously and in ways which are difficult to perceive.”

Much of the focus of Redding and Ogilvie’s work is aimed at the impact of hierarchy on the openness of communication, a concept which is now embraced more formally under crew resource management. Breakdowns in crew performance being distinctly different to individual failings and indeed much more prevalent. Ashford’s study of 219 large aircraft (over 5700kg MTOW) (see earlier) found that ‘failure to cross-check / co-ordinate’ was an accident causal factor in 118 accidents or 54% of the total. (Ashford, 1994).

It was the expert opinion of several aviation safety professionals around the world (Lewis, 1993; Learmount, 1993; Green, 1993) that one of the fundamental strengths of the Australian aviation system is an openness in communication, particularly on the flight deck. Lewis, Head of Safety and Environment for Qantas Airways suggests that, “Perhaps the element that exists in Australia that is more prevalent than in other cultures, is that Australians respect authority but do not defer to it. In other words, if the First Officer is not happy with what the Captain is doing, he will tell him so.” The late British aviation psychologist, Roger Green enlarged on this point by stating that “...the nature of crew interactions on the flight deck in Qantas is different from most airlines for two possible reasons.” (The first reason relates to heavy crewing, which is mentioned elsewhere in this thesis.) The second reason is ”...that Aussies are naturally both socially relaxed and disrespectful of authority. The suggested impact of this is that status differences do not count for a lot on the flight deck and captains thus find it easy to make the best use of the other crew members’ ideas and FOs have no inhibitions about letting the captain have the benefit of their own thoughts”. Nevertheless, a note of caution is warranted at this point. The substitution of organisational culture for national culture is a great temptation, especially when considering flag-carriers. In other words, some cultural traits observed at national level in aviation may in fact be organisational cultural traits and therefore deeper investigation by the researcher is required.

5.1.2.1 The State of the Art

Redding and Ogilvie’s (1984) early study of culture and communication examined 151 flight crew from eight different carriers in an attempt to establish whether;

- the attitudes of flight crew reflect their cultures
- the atmosphere on a flight deck reflects a specific culture
- attitudes or flight deck atmosphere effects communications
Their model of the factors which contribute to the quality and frequency of communications is shown below and provides an interesting way of illustrating what factors may be relevant in a safety investigation such as this thesis. The authors do not attempt to measure organisational culture, but accept that each airline will inevitably have a different culture.

Redding and Ogilvie convey some frustration in the value of their results which seems to stem from the small samples available to them. Apart from limitations in the number of flight crew who were prepared to file questionnaire returns, finding enough airlines that fit within certain cultural groupings (such as Hofstede’s Power-Distance and Individualism extremes) also seemed to prove difficult.

Nevertheless, the authors conclude that there is some evidence that:

- societal values about the distribution of power are brought into the cockpit
- that they influence the climate in which communications take place
- that the more open flow of communications is conducive to better performance

In summary, they also warn that these conclusions remain tentative and further research is needed in the area before steadfast conclusions can be drawn.

Johnston (1992) presents the work of Ooi (1991; 1992) in terms of his attempts to simplify some of the classical work done by Hofstede into broad differences between Eastern and Western Cultures. At its simplest level, Ooi summarises the differences as follows;
One of the many cultural ‘concerns’ that these differences present is in what is termed the cockpit power gradient. Similar in nature to Hofstede’s concept of power distance, the cockpit power gradient essential concerns itself with the ability of a crew to work as a cohesive crew as oppose to a hierarchy.

As flight decks become more multicultural the power gradients may be expected to become more unpredictable. Already Malaysian Airlines fly with 35% expatriate crew members which represent 16 different countries (Flight International, 1994) and Singapore Airlines fly with 48 different nationalities of crew members. Ooi presents a summary of the differences in the following table.

<table>
<thead>
<tr>
<th>Possible Combinations</th>
<th>Power Gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western captain / Eastern first officer</td>
<td>Flat / steep</td>
</tr>
<tr>
<td>Western captain / Western first officer</td>
<td>Flat / flat</td>
</tr>
<tr>
<td>Eastern captain / Western first officer</td>
<td>Steep / steep</td>
</tr>
<tr>
<td>Eastern captain / Eastern first officer</td>
<td>Steep / flat</td>
</tr>
</tbody>
</table>

At such a high level, significant cultural differences are to be expected. The fact that it is possible to use the terms ‘Eastern and Western cultures’ without needing to define them too closely is one indicator of how well recognised the differences are. However, the use of such findings at the micro level of training and operations is somewhat limited. There are so many other variables to add to the above equation before it presents any useable conclusions about the problems of multicultural crewing. For example, in terms of large aircraft manufacturers, there are only a small number of players around the world. Boeing, Lockheed and McDonnell
Douglas build with western (American) cultural backgrounds, Airbus with western (European) philosophies and the likes of Ilyushin, Tupolev and Yakovlev with eastern (Russian) principles. These aircraft types are then flown by a mix of cultures around the world. Therefore although every B747, for example, is essentially built as the same aircraft regardless of whether it is to be flown by a Chinese or American crew or, indeed, a mix of the two it is difficult to tell how much effect a cockpit gradient is having on different ‘cultural designs’ of aircraft.

Johnston (1992) dares to discuss the effect of regional variations on accident causation, but notes how rarely the subject is broached partly because of “...the absence of research and partly the potential sensitivity of the subject”. He also notes that what little evidence there is in the field is largely unstructured and anecdotal and therefore of little scientific validity. Kenton-Page (1995) of Hughes Flight Training is a Captain with a long history of training UK and foreign nationals. He documents that in training various nationalities, particularly in the area of crew resource management, there are major differences in attitudes. He states that “...some nationalities consider the ‘Anglo’ culture inferior to theirs which makes it very difficult to put across any new concept and especially one that may be in conflict with their culture.” CRM is very much a concept that has developed from Anglo cultures, particularly in the USA, UK and Australia. The concepts of junior crew members being able to speak up and question the actions of their superiors is difficult enough for some ‘Anglo’ pilots to accept, but in countries with higher power-distance ratios, it is often near to impossible. Kenton-Page describes the ‘Father/Son’ relationship which varies from being a real father and son flying together with the understandable difficulties that such personal relationships can bring, to a cultural, functional ‘Father/Son’ hierarchy on the flight deck which is evident in, say, the Japanese. He adds that Hughes “...also come across difficulties because of a tribal or caste system. This is so ingrained that I feel it may be an intractable problem.” (Kenton-Page, 1995)

Perhaps unwittingly, Kenton-Page seems to hit the nail on the head with his statement regarding ingrained tribal or caste (cultural) traits. To describe them as an intractable problem could well be symptomatic of the ‘Anglo’ attitude towards the results of decades of anecdotal cultural studies. As mentioned earlier, the differences in culture only become apparent when we look at how different other cultures are in comparison. The temptation is to look at the subject from the point of view that, ‘our own culture is the base line, so what is strange about everyone else?’ The use of accidents where collectivist Eastern nationals have flown to their deaths as examples of bad CRM for use in American and British training courses has helped propagate the myth that the West is getting things right and the Eastern nationals will have to undergo a massive change to get to our level.

This assumes one thing - that the Western way of flying aircraft (if it were ever possible to define that) is the only safe way to operate an aircraft. Although the Japanese seem to be recurrently singled out for displaying behavioural traits that seem hazardous to successful CRM, their strict attitude to flight deck operations may actually be something very safe. The sight of Japanese flight crew wearing pure white gloves whilst they fly may give the
impression of a highly regimented atmosphere, not conducive to junior crew members questioning their superior’s actions. However, the strict adherence to Standard (or Basic) Operating Procedures (SOP’s) that such discipline requires is also one of the reasons that Qantas’ Head of Safety and Environment (Lewis, 1995) believes has kept Qantas safe.

A quick review of Boeing’s Sears (1986) table of accident causal factors reveals that deviation from basic (standard) operational procedures was the number one cause. Provided that the operational procedures are well thought out and sensible, the culture which engenders strict compliance may be a very good thing. It is when problems start to arise that the decision making skills and ingenuity of the whole flight crew becomes of prime importance. It is possible that some ‘poor CRM’ accidents in non-Anglo cultures are balanced out through a lower ‘deviations from SOP’s’ accident rate.

<table>
<thead>
<tr>
<th>Top Ten Significant Accident Causes and their Percentage of Presence</th>
</tr>
</thead>
<tbody>
<tr>
<td>33% Pilot deviated from basic (standard) operational procedure</td>
</tr>
<tr>
<td>26% Inadequate crosscheck by second crew member</td>
</tr>
<tr>
<td>13% Design faults</td>
</tr>
<tr>
<td>12% Maintenance and inspection deficiencies</td>
</tr>
<tr>
<td>10% Complete absence of approach guidance</td>
</tr>
<tr>
<td>10% Captain did not respond to crew input</td>
</tr>
<tr>
<td>9% ATC failures or errors</td>
</tr>
<tr>
<td>9% Crews not conditioned for proper response to abnormal conditions</td>
</tr>
<tr>
<td>9% Other</td>
</tr>
<tr>
<td>8% Weather information insufficient or in error</td>
</tr>
</tbody>
</table>

Figure 5.1.2.4 Redrawn from Sears, 1986

While this example remains largely theoretical, it does highlight the multiple effects of culture upon aircraft operations. The effect of various cultural dimensions should not be considered in a vacuum as the effects are rarely mutually exclusive. This challenges some of the more simplistic approaches to aviation safety and culture which have risked trivialising what is still a new and potentially very rich vein of knowledge.
In 1994, Phelan (Flight International, 1994) presented graphs from Boeing which illustrated an apparent correlation between accident rate per million departures and Hofstede’s Power-distance and Individualism indices. Although no correlation co-efficient or basic statistics are supplied, a trend line is plotted for each graph indicating relatively strong correlation.

The relationship between power-distance and accident rate suggests that as the relationship between manager and subordinate becomes a more steep gradient, so too the accident rate would increase. This would seem to support the general arguments behind crew resource management training.

The second graph suggest that as individualism increases, so the accident rate diminishes. This may be because of the perceived ability to speak up when things seems wrong rather than following the collective view. Australia, USA and UK are all countries with a high individualism and low power-distance score.

The risk of this important, yet relatively simplistic article, was of suggesting that the cultural dimension in itself was the reason behind the variety in safety records. Although Phelan did not set out to make such a statement, the limitation of publishing space made it difficult to launch such a fundamental concept to the aviation community at large. A number of letters of complaint ensued including the following;

"Sir - Your article ‘Cultivating Safety’ (Flight International, 24-30 August, p22) advises caution when reflecting on the relationship between culture and aviation safety. This requires not only an appreciation of national sensitivities, but an awareness of how cultural identity can lead to unwarranted moral evaluation. Unlike the issue of race, differences founded upon culture might appear to be innocuous. To suggest however that Iran is ‘collectivist’ implies that it is too collectivist, otherwise this would hardly be worth mentioning."
This can be used as an implicit criticism, suggesting that other traits which are lacking and could lead to the belief that the remedy lies in promoting specific aspects of Western European behaviour. Becoming captive to a particular theory brings the risk of being blinded to the third element - the causal factor - which is easily overlooked. It could be plausibly argued that it is economic wealth which allows for both individualism and a healthy aviation industry..." (Flight International, 1994c)

The author highlights the sensitivity of culture as a factor in aviation safety discussions and highlights one of the risks of this subject. That is of judging cultural difference in terms of what the host culture does right and what other cultures do wrong. He also touches on another subject that is often related to national differences, but does not strictly come under the classification of culture; that is the effect of economic wealth.

Boeing’s attempt to correlate Hofstede’s cultural indeces accident rate represents a tentative first step. However, the results are rather primitive and seem to lack the necessary academic integrity. Whilst it is difficult to make judgment without sighting the original data, the scattering of datapoints of the two graphs (see figures 5.1.2.4 and 5.1.2.5) seems to make the trendlines seem optimistic at best. In another letter to Flight International (1994b), “...the graphs of accident rates against ‘power distance index’ and ‘individualism’ do not support the simple proportional relationships indicated by the straight lines drawn through the points. More worrying is the assumption that a correlation implies causality...”This is a fact that cannot help convince either the academic or industrial community and risks doing more harm than good. In the same issue of Flight International, Johnston, one of the most respected experts in this area, warns that, “...cultural influences and regional safety are sensitive matters. There is virtually no definitive research upon which to base interventions.” (Flight International, 1994b) Nevertheless, the Boeing study remains ground breaking and is afforded some integrity by virtue of their international market. Cultural sensitivities are very relevant to a manufacturer of the magnitude of Boeing which can only lend credibility to their investigations into the influence of culture on safety.
5.1.3 National Cultural Traits of Australia

Although previous sections have provided an overview of the national cultural differences that have been observed through empirical research around the world, it is necessary to summarise those cultural traits which may be seen to be 'Australian'. This is necessary so that similarities and differences between the national and industry / organisational cultures can be recognised in the next section of analysis.

5.1.3.1 Australia versus the Rest of the World

The stereotyped Australian is a loud individual who 'is not backward about coming forwards, says what he likes and likes what he says'. The Crocodile Dundee or Sir Les Patterson image is an endearing if not an enduring one.

Trompenaars (1993) asked a series of questions in his research into cultural diversity which produced information of relevance to the aviation industry. None of the data was collected as particularly aviation-specific, but there is much to be learnt from his observations. The areas of individualism and power-distance are clearly illustrated through the following questions in terms of their variability.

For instance, the author examined the effect of national culture on corporate culture in terms of how managers perceived their leaders. This gives an impression of the relative hierarchy and therefore the role that individuals are expected to play. By asking the question; 'What makes a good manager?' Trompenaars plots the percentage of respondents who opted '...to be left alone to get the job done':

![What Makes a Good Manager?](image)

*Figure 5.1.3.1 Adapted from Trompenaars, 1993*
Australians firmly believed that the manager was responsible for doing a particular job rather than presiding as a ‘father-like’ figure over his subordinates. In the more familial cultures such as Turkey, Venezuela and China, the role of leaders as ‘...floating on seas of adoration’ (Trompenaars, 1993) and buoyed by the loyalties of their subordinates is clear. It is also reflected in organisational structures, which the author likens to isosceles triangles, where these countries demonstrate the steepest hierarchies. Australia on the other hand reflects a relatively flat hierarchy, a fact which has been examined further within this research.

The importance of the flat hierarchy for aviation safety lies at two levels; namely on the flight deck and within aviation organisations. Both represent similar group dynamics although the former is probably the easiest to recognise as being present. The key issue is one of communications both in terms of integrity and speed. Aviation represents a time critical operation with few opportunities for trial and error. Crew Resource Management highlights three aspects of behaviour that are vital to safe flightdeck operation; namely command, control and communication. The need for effective command dictates that communication gradients should not be perfectly flat (i.e. no leader) and yet the need for open communication requires the command situation not be too much of the other extreme. An excessively steep communication gradient may delay or even prevent the flow of information which may be time or safety critical.

These principles also apply within organisational dynamics. Indeed, just as the original CRM courses derived much of their material from the business world, so the principles that aviation relates to as CRM can be shown to apply in reverse. Of course, that is not to say that organisational processes have been evolved from CRM principles, even though advocates suggest that the next generation of CRM is ‘corporate’ or ‘company’ resource management. Such an effect remains at the planning stage although Ansett Australia does intend to introduce company-wide CRM-type training in 1998.

Open communication by itself does not entirely capture the cultural identity that anecdotal evidence attaches to Australia. It is the directness of style which is often focused upon although it is arguable that open communication within Australia is direct in style. However, as this is not necessarily the case for other cultures where communication channels may be open, albeit with much direct language use, it is worth considering as a separate issue.
Trompenaars (1993) highlights the cultural tolerance to direct communication through a reasonably obscure question. Respondents from 38 countries were asked what they would do when faced with the following problem:

A boss asks a subordinate to help him paint his house. The subordinate, who does not feel like doing it, discusses the situation with a colleague.

The colleague argues: “You don’t have to paint it if you don’t feel like it. He is your boss at work. Outside he has little authority.

The subordinate argues: “Despite the fact that I don’t feel like it, I will paint it. He is my boss and you can’t ignore that outside work either.”

The results (shown for a selected 18 countries) were documented as follows:

<table>
<thead>
<tr>
<th>Country</th>
<th>Australia</th>
<th>Netherlands</th>
<th>UK</th>
<th>West Germany</th>
<th>USA</th>
<th>Italy</th>
<th>Japan</th>
<th>Canada</th>
<th>Poland</th>
<th>Pakistan</th>
<th>Mexico</th>
<th>Hong Kong</th>
<th>Malaysia</th>
<th>Egypt</th>
<th>Singapore</th>
<th>Indonesia</th>
<th>Nepal</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage who would refuse to help the boss.</td>
<td></td>
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</tbody>
</table>

Australia ranked the highest (96%) demonstrating not that Australian’s were unhelpful, but rather that it was culturally acceptable for them to decline if they really did not want to help. The likelihood that a manager would consider the refusal to be an insult or act of insubordination is low and neither would he suffer from a loss of face. Discussions with various groups of Australians about this graph reveals that the decision would very much come down to whether the boss was thought to be “a mate” or a not. The critical factor not being the
ascribed rank or position of the manager, but whether he had earnt the respect and friendship of the subordinate. Knowing that it is acceptable to say no allows the decision to be more directly influenced by ‘softer’ issues such as friendship.

In terms of aviation, the Trompenaars graph may be interpolated to support the premise that “Australians do not defer to authority” (Green, 1993). That is to say that individuals do not defer to authority for authority’s sake, rather they maintain a healthy disrespect for it which allows decisions which are perceived to be fallible to be questioned.

The history of modern Australia spans over 200 years and it is beyond the scope of this thesis to explore the area in great detail. However, there are a few issues which have stood out as being relevant to flight safety by crafting certain aspects of national culture. This is not to say that the link has been formally established. Indeed as Patience (1991) points out, “In Australia the recognition of culture as a critical force shaping consciousness and action has not been widespread. It is largely confined to history and remains relatively untheoretical, particularly in sociology which is one discipline one might most expect to have taken up this theme.”

Of the work that has been done, Patience cites Ward’s The Australian Legend (Ward, 1982) as perhaps the best known historical interpretation of Australian culture. “This offers a picture of an egalitarian culture shaped by the bush, mateship, self-reliance, toughness practical inventiveness, and coloured by a larrkin irreverence for most authority.” The emphasis appears to be on “mateship” with a commensurate discrimination against “non-mates”. The definition of non-mates generally encompasses those who “...do not easily slot into the category of Anglo-Celtic male” including Aborigines and women”. Mateship is not just about the ‘easy-going’ and friendly image which many Australians would like to project. Indeed, mateship is very much about groups rather than an ‘open membership’ policy of friendliness. This is possibly a situation which leant itself to an efficient airline industry and yet one that could also ultimately have a destructive effect.

Historically, as White (1981) writes, “The emphasis was on masculinity and on masculine friendships and teamwork, on ‘mateship’ in Australia”. The flight decks of multi-crew aircraft also tended to be almost exclusively male domains. A shared love of flying and a cultural context that allowed flight deck crew of different ranks to be mates tended to support the objectives of crew resource management long before anyone coined the phrase. This is a crucial issue that is worth noting; that many aspects of culture exist and have existed well before they have ever been labelled. Indeed some of the resistance to cultural change spans from practitioners who do not recognise the existing culture and attempt to teach ‘old dogs news tricks which are in fact old tricks with new names. Australians in particular, renowned for their “...forceful behaviour and drive” (Johnston, 1993b), do not generally warm to being taught things they already know. Polite deference to authority in terms of listening to things they already know is certainly not an Australian trait. However, that having been said, it is also an Australian trait to believe in giving people ‘a fair go’.

More simply, the attitude seems to be, ‘listen to what they have to say and if it is rubbish, tell them!’
Exploring the issue of authority and communication

The perceived distance between manager and subordinate in Australia is expected to be low, according to Hofstede's (1980, 1991) and Trompenaars (1993) work and through the anecdotal evidence supplied by expert witnesses.

One method which was designed to explore this relationship on the flight deck, particularly in terms of the Captain (manager) and First / Second Office / Flight Engineer (subordinate) relationship was inspired by a study which originated from the RAF Institute of Aviation Medicine. Beaty (1995) and Taylor (1991) both refer to the study of military crews which revealed that the following words were used to describe other crew members:

<table>
<thead>
<tr>
<th>Captains describing co-pilots</th>
<th>Co-pilots describing captains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competitive</td>
<td>Over-confident</td>
</tr>
<tr>
<td>Over-confident</td>
<td>Arrogant</td>
</tr>
<tr>
<td>Strong personality</td>
<td>Abrasive</td>
</tr>
<tr>
<td>Obstructive</td>
<td>Bad tempered</td>
</tr>
<tr>
<td>Obnoxious</td>
<td>Unpleasant</td>
</tr>
<tr>
<td>Bolshie</td>
<td>Sarcastic</td>
</tr>
<tr>
<td>Difficult</td>
<td>Over-critical</td>
</tr>
<tr>
<td>Unco-operative</td>
<td>Not easy to get on with</td>
</tr>
<tr>
<td>Bored</td>
<td>Intransigent</td>
</tr>
<tr>
<td>Lazy</td>
<td>Pig-headed</td>
</tr>
<tr>
<td>Number-chaser</td>
<td>Unpredictable</td>
</tr>
<tr>
<td>No sense of humour</td>
<td>Aggressive</td>
</tr>
<tr>
<td>Minimiser</td>
<td>Disagreeable</td>
</tr>
<tr>
<td>Complainer</td>
<td>Martinet</td>
</tr>
<tr>
<td>Lethargic</td>
<td>Tyrannical</td>
</tr>
<tr>
<td>Resentful</td>
<td>Autocratic</td>
</tr>
<tr>
<td>Bullying</td>
<td>Authoritarian</td>
</tr>
<tr>
<td>Talkative</td>
<td>Incompetent</td>
</tr>
<tr>
<td></td>
<td>Overbearing</td>
</tr>
</tbody>
</table>

As can be seen, the comments represent varying levels of negativity and are used by the authors to highlight the problems of the (male) pilot's ego. Whilst only a limited amount of information exists about the original study, it does give a quite negative impression on the relationship between crew-members. Whilst some would argue that an individual's feeling would not affect their 'true professionalism', that assumes that everyone acts professionally all of the time; a fact which is obviously untrue or human factor accidents would never take place. The feelings that an individual has towards superior or subordinates will affect the way they communicate and even the way they perform; both factors may also prove to be safety critical.
By asking crew members to describe other ranks in a repeat of the RAF study, the objective was to examine the perceived relationship between ranks to explore the power-distance effect. The responses were voluminous and provided research material which was both unexpected and demanded disproportionate resources. Simplistic analysis is included here to demonstrate the general results. Further research is required and results will be published as a separate paper.

Simple analysis of the words which were used to describe other ranks produced a list similar to the RAF study ranking the following:

<table>
<thead>
<tr>
<th>Top 20 Words to describe Captains</th>
<th>Top 20 Words to describe other crew members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional</td>
<td>Professional</td>
</tr>
<tr>
<td>Experienced</td>
<td>Competent</td>
</tr>
<tr>
<td>Competent</td>
<td>Keen</td>
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<tr>
<td>Knowledgeable</td>
<td>Friendly</td>
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<tr>
<td>Skilled</td>
<td>Helpful</td>
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<td>Capable</td>
<td>Supportive</td>
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<tr>
<td>Helpful</td>
<td>Knowledgeable</td>
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<tr>
<td>Approachable</td>
<td>Enthusiastic</td>
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<tr>
<td>Confident</td>
<td>Capable</td>
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<tr>
<td>Friendly</td>
<td>Eager</td>
</tr>
<tr>
<td>Responsible</td>
<td>Conscientious</td>
</tr>
<tr>
<td>Dedicated</td>
<td>Willing</td>
</tr>
<tr>
<td>Managers</td>
<td>Skilled</td>
</tr>
<tr>
<td>Skilled</td>
<td>Dedicated</td>
</tr>
<tr>
<td>Leaders</td>
<td>Responsible</td>
</tr>
<tr>
<td>Conscientious</td>
<td>Experienced</td>
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<tr>
<td>Fair</td>
<td>Inexperienced</td>
</tr>
<tr>
<td>Reliable</td>
<td>Reliable</td>
</tr>
<tr>
<td>Diligent</td>
<td>Young</td>
</tr>
<tr>
<td>Keen</td>
<td>Motivated</td>
</tr>
</tbody>
</table>

In the case of Captains, all of the top twenty words may be considered to be positive, describing as they do, both aptitude and attitude. Certainly most of the terms describe features which are desirable in aircraft Captains such as experience, knowledge, capability and aspects of leadership. Approachability, helpfulness and fairness are also traits which appear to concur with the anecdotal evidence regarding Australian aviation and national cultures.
The words used to describe junior crew members are also ostensibly positive. Competency, enthusiasm and the ability to support are all traits which would be encouraged by a good commander. The inclusion of ‘inexperienced’ and ‘young’ as the closest the top twenty came to negativity may simply reflect an objective description rather than insinuating a deficiency.

Words used to describe management may be expected to be rather more negative than towards co-workers, as is the nature of the job. However 12 of the top 20 words may be seen to be positive and only four were truly negative. The term ‘professional’ ranked as the top description for every position which is a reflection of the perceived function of all involved in flight operations.

<table>
<thead>
<tr>
<th>Top 20 Words to describe Managers</th>
<th>Top 20 Words to describe themselves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional</td>
<td>Professional</td>
</tr>
<tr>
<td>Experienced</td>
<td>Competent</td>
</tr>
<tr>
<td>Overworked</td>
<td>Dedicated</td>
</tr>
<tr>
<td>Approachable</td>
<td>Capable</td>
</tr>
<tr>
<td>Competent</td>
<td>Experienced</td>
</tr>
<tr>
<td>Knowledgeable</td>
<td>Conscientious</td>
</tr>
<tr>
<td>Helpful</td>
<td>Keen</td>
</tr>
<tr>
<td>Hard Working</td>
<td>Friendly</td>
</tr>
<tr>
<td>Dedicated</td>
<td>Reliable</td>
</tr>
<tr>
<td>Responsible</td>
<td>Responsible</td>
</tr>
<tr>
<td>Ambitious</td>
<td>Enthusiastic</td>
</tr>
<tr>
<td>Aloof</td>
<td>Approachable</td>
</tr>
<tr>
<td>Conscientious</td>
<td>Diligent</td>
</tr>
<tr>
<td>Distant</td>
<td>Safe</td>
</tr>
<tr>
<td>Fair</td>
<td>Skilled</td>
</tr>
<tr>
<td>Arrogant</td>
<td>Confident</td>
</tr>
<tr>
<td>Self Serving</td>
<td>Fair</td>
</tr>
<tr>
<td>Capable</td>
<td>Knowledgeable</td>
</tr>
<tr>
<td>Managers</td>
<td>Hard Working</td>
</tr>
<tr>
<td>Out of Touch</td>
<td>Average</td>
</tr>
</tbody>
</table>

In describing themselves, pilots were not expected to be unduly modest which would explain why all of the top 20 descriptions were positive. Words focus on ability (professional, competent, capable, diligent, safe etc.) or on attitude (dedicated, conscientious, approachable and enthusiastic).
5.1.3.2 Myths of National Culture

Observing differences in national culture is an activity which is prone to significant unscientific biases. These may range from lighthearted stereotyping to rather more serious racism. While there may be some truth behind these anecdotal perceptions, their value in scientific study should be observed with some caution. Stereotyping may be based on personal experience (which in turn may be somewhat limited) or even a projected image from the media and can be a source of both entertainment and misinterpretation.

Australian icons tend to be based on a romantic bushman image propagated through a number of movies. The most successful must be Paul Hogan’s ‘Crocodile Dundee’ who delighted audiences with his shrewd, yet seemingly innocent view of the world. On arrival in New York, Mick Dundee is observed riding in the back of a taxi which stops at a set of traffic lights. At this point the hero leans out of the car and introduces himself to two men who are stood chatting at the side of the road; “G’Day; Mick Dundee from Australia - I am in town for a few days; I’ll probably see you around?” The two men look at each other suitably bemused, enhancing the image of Australia as a small country where everyone knows everyone.

However, even this incident has some aspects pertinent to aviation safety. Australia is a small community especially when compared to the USA or Europe. There are a relatively small number of key players in the aviation industry which can either be a good thing (in terms of close communication) or a bad one in terms of the strength of adverse individual influence or lack of experience.

Numerous Australian films have painted a picture of the strength of the ‘genuine Aussie battler’ and their fight against the system. Patience’s (Ward, 1982) “...larrikan irreverence to authority” is clearly demonstrated in films such as ‘Strictly Ballroom’, ‘Muriel’s Wedding’ and ‘The Castle’. It is an unsurprisingly romantic image and has as much to do with the way Australia would like others to perceive it to be, as it is a truthful image. This has helped create an image of a small-town mentality which tends to ignore some of the great innovative achievement of the Australian nation.
Qantas - the American Airline?

In the recession of the early 1990's when Domestic regulation being reformed in Australia and Qantas was preparing to become a public company, a movement began to review whether the airline should undergo a name change. Although the word Qantas was, for many, synonymous with Australia, there were also some who believed that the word confused people. Although strictly an acronym for 'Queensland and Northern Territory Aerial Services', Qantas has become a word in its own right as the only one with a 'Q' not followed by a 'U'.

A survey of customer attitudes was conducted both within Australia and overseas which uncovered a significant yet surprising fact from the USA. That was that not only were the American public fiercely patriotic towards their own airlines, but that a significant proportion believed Qantas was in fact an American airline. The conclusion was that a name change would risk a substantial loss in American traffic rather than any increase.

Australia's view of the world

The other aspect of cultural stereotyping is that it works both ways. Whatever the image different countries have of Australia, there are similarly interesting perceptions held by the Australians. The impression of straight-laced Brits which seems to be summed up by actors such as Anthony Hopkins, Laurence Olivier, Sean Connery or Hugh Grant sits alongside images of Americans as hard-talking individuals like John Wayne, Tom Cruise or Harrison Ford. That having been said, the multicultural nature of Australia, and particularly its aviation industry reduces the effect of a lack of experience. Expertise within the industry is drawn not only from Australians, but a large number of ex-patriots. Although Qantas will only recruit staff with Australian citizenship, they have encouraged and assisted international staff, especially flight crew, to relocate and naturalise.

Whilst it has been suggested that culture can remain invisible until it is compared to another, it must also be noted that perceived differences can be based on stereotypes or at least limited exposure. As a consequence it is easy to perceive cultural superiority, or indeed be led to believe a cultural inferiority. In the former case, it is tempting to view developing nation's safety records with some contempt and risk ignoring the fact that similar basic issues may exist as latent defects in both aviation systems. For example, the VH-INH B747 accident at Sydney Airport (BASI, 1996) was partly the result of very basic issues, namely training and communication. In the latter case, of cultural inferiority, there seems to be a mood within Australia to look towards the USA and Europe for expertise, a movement which is not always justified. Whilst CASA has made a commitment to harmonising its regulations with the American FAA and European JARs, some caution is warranted for fear of the 'grass is always greener' factor. Former CASA Director, Keith (1997) warns that "...in my opinion, the FAA today is in a distressed state, not dissimilar to the Australian regulator in the 1990s."
5.1.4 Organisational Culture

Reason (1993) defines corporate culture as "...the set of unwritten rules that govern acceptable behaviour within and outside the organisation. It emanates from the strategic apex of the company and colours all of its activities". Mitroff and Kilman (1984) define organisational culture as "...a set of shared philosophies, ideologies, values, beliefs, expectations, attitudes, assumptions, and norms", whereas Jackson (1960) more simply states that "cultural norms refer to the set of unwritten rules that guide behaviour" which is closer to Reason's definition. Every organisation has its own unique culture and even sections of the same company may have specific traits or ways of operating. At its simplest, organisational culture is concerned with 'the way we do things around here'. Kroeber (1952) makes the point that "...culture is learned and transmitted through groups and individuals in society". In other words, organisational culture is self perpetuating and not solely dependent on the individuals who form that organisation.

According to Trompenaars (1993), "the organisation... is a subjective construct and its employees will give meaning to their environment based on their own particular cultural programming." The culture of that organisation is "...shaped not only by technologies and markets, but by the cultural preferences of leaders and employees." Certainly in a new company or one undergoing significant high level restructuring, the key employees will adopt traditions or ways of behaving that are already familiar to them. Mental images of 'this is the way we did things at company x' or 'this is the way we should have done things at company x' will have a strong influence.

5.1.4.1 Organisational Culture and Aviation

Lauber (1993) examined a series of high technology accidents for evidence of an influence from organisation's culture. He cites the examples of the Ro-Ro ferry, Herald of Free Enterprise, the Clapham Junction Railway disaster and the loss of an Embraer 120 near Eagle Lake, Texas. The legal action against P & O management as a result of the 1987 Herald of Free Enterprise disaster broke new ground when it was ruled that a body corporate could be responsible for manslaughter when perhaps there were employees who felt by placing the blame upon the assistant bosun, they were safe from accountability. Fortunately, the court looked beyond the active failure of the mariner, who was asleep in his cabin when he should have closed the bow doors, and examined the latent defects that allowed such an error to lead to a disaster. The Public Inquiry had been most explicit in detailing where the fault really lay; "All concerned in management, from the members of the Board of Directors down to the Junior superintendents, were guilty of fault in that all must be regarded as sharing responsibility for the failure of management. From top to bottom, the body corporate was infected with the disease of sloppiness." (DOT, 1987) It is most unlikely that a collection of faulted individuals came together by chance. Similar attitudes to safety within an organisation reflect the organisational culture and is perpetuated through the subtle influence of 'how we do things around here' or in the recruitment of subordinates in the image of their superiors.
5.1.4.2 Safety Culture

A review of literature which covers safety and organisational culture, will find this term used quite commonly, particularly in American texts. Meshkati (1997) contends that the term was first introduced following the Chernobyl nuclear power plant accident and is used extensively by a number of industries including chemical processing. Reason (1997) points out that “Few phrases are so widely used yet so hard to define as ‘safety culture’.” He further explains that “...there is nothing mystical about it. Nor is it a single entity. It is made up of a number of interacting elements that have enhanced ‘safety health’ as their natural by-product.”

It is important that there is some sort of definition to establish whether there is a real difference between a ‘safety culture’ and a ‘safe culture’. As Wood (1993) puts it, “Is it our corporate attitude toward safety or is it the safety programme itself?”. Should the concept of safety culture be kept separate from the overall culture of an organisation and if so, is this not a self defeating definition? That is to say, is it possible for an organisation’s overall to be considered healthy even its safety culture is not and vice versa? Indeed, closer investigation of works on safety culture suggest that the authors are in fact examining the safety focussed aspects of an organisation. The danger here being that aspects of corporate operations that may in fact have safety consequences may not be perceived to do so unless they fall under the more obvious definitions of ‘safety programmes’.

Westrum (1997) writes that “Around every technological system there is a human envelope of protection. This envelope is made up of those who originate, operate, and maintain the system, and together they form the protective elements that keep the system intact and safe from harm. This envelope may be thick or thin, seamless or faulted, but this envelope protects the system from harm.” While he avoids referring to this ‘human envelope’ as the safety culture of an organisation, it represents the meeting of organisational and safety cultures. Maurino (1992) suggests that “...the design and corporate culture of an organisation exert powerful influences on how safely it functions. Pilots, controllers and other operational personnel do not act in a vacuum - instead they mirror the policies and practices of the organisations to which they belong.”

For example, the subject of commercial pressure in placing unreasonable demands on operating staff has started to have real safety consequences in air transport operations. In the context of the Australian domestic airline market this has been demonstrated where the commercial sides of the airlines battle for customers they have started to offer more and more in the way of service add-ons. Even on short domestic sectors, business and first class passengers have been led to expect their coats to be stowed by the flight attendant, pre-take off drinks and a choice of newspapers, and an on-time departure. On busy flights or those attempting to catch up time from an inbound delay, flight attendants have been known to be still carrying on their duties in the cabin during the take off run. This has now become a safety issue, but the systemic problem began as a corporate attitude (priorities of customer service) and became a ‘safety culture’ issue at a later date.
Wood (1993) describes organisations with strong safety programmes as displaying seven basic cultural traits. The most important of these being the involvement of management from the top. This is, of course, a basic premise to the success of most organisational operations and not exclusively the domain of safety programmes. The concept of Total Quality Management (TQM), which has been adopted with great success particularly in the freight logistics industry, relies very heavily on this sort of management, yet can hardly be described as a safety programme. Or could it? If the efficiencies which are strived for in TQM are really met then they will have a commensurate safety benefit - good safety is essentially the same as operational efficiency.

Doak (1993) describes American Express' corporate aviation safety culture as being broken down into five areas:

- Beliefs
- Corporate Attitude
- What Was in Place
- Plan
- Action

Doak also describes how the "...safety consciousness existed at the highest level in the corporation, including the chairman." But is this really an element of a safety culture? Surely this is a confusing expedition into semantics? A safety culture is not a mutually exclusive component of an organisation's culture; it is an important descriptor of one of its attitudes.

O'Leary and Pidgeon (1995) argue that a "...good safety culture is characterised in four ways;"
O’Leary and Pidgeon (1995) also raise an interesting idea for assessing the safety culture of an airline through the company’s attitude towards incident reporting. In addressing a comment from ICAO’s Stephan Corrie that “It’s too bad that we need to have confidential reporting programmes”, the authors have interpreted the statement to mean that “...in an ideal world, reporting systems would exist within a culture in which line pilots would be able to discuss their technical, operational, crew and personal problems directly with their managers.” In other words, the fact that airlines have to set up confidential systems is symptomatic of a level of distrust between employees and management which may restrict the flow of safety information. It also causes problems with the reluctance of management to accept and act on information from anonymous sources which cannot be verified. (In some cases this can also be abused by management as an excuse for not acting on a report).

If communication lines were open enough for problems to be reported without the need for confidentiality, then the time needed for safety problems to be resolved can be reduced and the number of reports may increase. Indeed, both British Airways (Hunt, 1994) and AirServices Australia (Guselli, 1995) highlight with pride the increased number of incident reports within their respective organisations. They are not the result of an absolute increase in reportable incidents, instead they reflect an increasing level of trust in the system as a method of communication and the ease of reporting which has been enhanced through redesigned forms.

The argument against the existence of a safety culture separate to that of corporate or organisational culture is based upon the difficulty of delineating between safety and non-safety actions. Indeed it is this difficulty that can be found to be the critical error in decision making in many accidents. When decisions are known to have a direct impact on safety, the choice process works quite differently to when they are not known to have a direct effect. It is often only in retrospect or during formal accident investigation that safety critical actions or decisions are highlighted as such. Attempts to separate safety culture from organisational culture are difficult enough following an incident and therefore are all but doomed to failure in the predictive sense.

Using the four aspect of safety culture as highlighted by O’Leary and Pidgeon (1995), it is possible to demonstrate just how similar it is to organisational culture;

1. **It originates at the level of strategic management:** Organisational culture is also highly dependent on leadership. Cultural change originates from strategic management through policy decisions and support (or otherwise) for particular projects. Charismatic leadership from individuals such as Victor Kiam (Remington), Richard Branson (Virgin) and Bill Gates (Microsoft) can set the culture of organisations in both a positive and negative sense. An inefficient and unhappy organisation is one which will contain latent defects; the precursors for all accidents.

2. **Concern for safety is distributed and endorsed throughout the organisation:** Although this statement appears to be specific to safety culture, a second glance will pose the question
as to what constitutes “concern for safety”. Whilst explicit safety concerns such as Occupational Health and Safety posters, training programs and audits may be the most obvious concerns, there are countless areas which impact upon safety which are not directly obvious. A good example is in the area of excess baggage, where check-in agents are often encouraged to turn the other cheek to weights above the limit (20kg for economy and 30kg for business class), especially for frequent flyer or business passengers. This has become institutionalised and now passengers expect the extra which has a potential follow on affect on ground handling staff (Occupational Health and Safety) and aircraft handling (Flight Safety).

3. There is a clear set of flexible and effective norms and rules which govern safety behaviour:- Once again, although this refers specifically to safety behaviour and therefore apparently suggests the difference between safety culture and corporate culture to be their remit, the problem is one of defining boundaries. Attempting to separate norms and rules which govern safety is a near impossible task not least because apparently minor or insignificant actions can interact with a complex series of factors to cause accidents. Remembering that accidents are, by definition, unexpected events, part of the danger of trying to highlight safety behaviour rules is not anticipating the compound effect. Actions which are safety critical to one employee may not appear to be so for others. For example, a flight attendant may not realise that the flight deck crew should not be disturbed part way through a checklist, even on the ground after a flight, until they are made aware.

4. There is ongoing pro-active reflection on unsafe events and incidents and about safety in general:- The follow up to incidents is another apparently safety specific action, but as such, it is not so different from standard commercial practice of review. A proactive response to all incidents, whether they be operational, safety, financial or even disciplinary is as much a function of good organisational procedure as it is a specific safety concern.

Although the O'Leary and Pidgeon definition is safety specific, all of the four elements also relate to organisational culture which is ultimately responsible for the portion that is referred to as safety culture. However, to separate the two is to make definitive judgments about what is and what is not a safety issue and this is the source of many safety problems in the past. “Safety is influenced by culture, which dictates priorities, and by pride. “The culture can partly be national - affected by the respect in which aviation is held in the culture.” (Flight International, 1994d) In other words, safety isn’t a culture in itself, rather it is a condition defined by multiple levels of culture. If the concept of a safety culture is something which focuses the corporate mind towards the importance of safety, then it is a good thing. However, if there is a risk that it separates the issue of safety from general operation efficiency, then it should be discouraged as they are not mutually exclusive from each other.
5.1.4.3 **Industry Culture**

The existence of national and organisational cultures seems to make the existence of an industry culture a likelihood, although there are few studies that have ever tried to examine this mid-range. Traditional arguments against such a phenomena include the apparently transferable skills of managers who seem equally able to work in say manufacturing, retail and transportation. Whether this is true or not is the source of some debate and may actually be the first pointer to the existence of 'professional cultures' which hold together industries to create a 'virtual' industry culture.

For instance, there are professional qualifications for pilots, maintenance engineers, and accountants that are identical whether the employee belongs to Qantas or Ansett, but then in the case of the latter category, the skills would be similar whether they worked for an airline, a manufacturer or a retailer. Nevertheless, there are certain traits even within that job that would make an 'airline accountant' different to a non-airline accountant.

The above schematic highlights the way different organisational or professional cultures may overlap within and outside of an industry. In this example, the industry culture, aviation will encompass a number of different organisational cultures (A and B) - in this case these may represent Ansett and Qantas. Within those groups may be a set of professional cultures - in this example they represent pilots, maintenance engineers and accountants. Although pilots and aircraft maintenance engineers are only found working within aviation (in the strict sense of...
their profession), the accountants in this example may also reasonably work outside of aviation in, say, an electronic firm (C), which in turn has its own organisational culture (and possibly industry culture along with other electronics firms.). Although this may seem complicated at first glance, the concept is quite simple - that there are many layers of culture which are not mutually exclusive and can affect organisations in many ways. In terms of the very simplistic statement that organisational culture is concerned with ‘this is the way we do things around here’, the presence of professional and industry cultures requires the statement to be modified on occasion to ‘this is the way we do things around here. Some of it is also what they do around there.’

Defining aviation industry culture is a difficult job and one that has not successfully been done in any form other than anecdote. It is a task that requires significant experience of more than one industry and more than one organisation within each industry. There are also national differences to be expected, only some of which relate to national culture traits. Differences may be a function of physical geography - distances involved, weather conditions and terrain for example.

Nevertheless, there are certain traits of the Australian aviation industry that have become apparent during the course of this research that may be of interest.
5.1.5 The relative safety of aviation

In exploring the possibility of a relationship between culture and safety within the aviation industry, it is important to try and establish whether any phenomenon is the result of a national, industry, organisational culture, or indeed a mix of all three. One way of doing this is to ask the question, Is Australian airline safety above average because of a 'safe' national culture? In other words, do Australians have an inherent aversion to risk and therefore a low level of risk acceptability?

Ideally, the researcher requires a set of activities which are similar in nature and measurement between countries for which there is readily available data for a stable period of time. Although various measures of risk exist, the use of fatalities as a measure is the most sensible for analysis. A fatality is a strict definition which is easily recorded - levels of injury are difficult to define and open to subjective interpretation.

The transport industry provides a number of readily published statistics of accident rates, especially for car travel. Solomon (1993) publishes fatal accident rates for 26 countries which demonstrate considerable variation between countries, especially when normalised against the number of registered cars. Unfortunately, a complete set of data for more countries is not available and this means that it is difficult to try and attach any cultural significance to the results. The extreme outlier represented by Egypt may prove to be not such an extreme if more third world nations were added to the series.

![Automotive Deaths Per 100,000 People per Year](Image)
It is also the case that Egypt has very poor regulation of road safety; the driving test is only a few minutes and involves driving only a few metres forward and backwards. There are a comparatively low number of cars and a relatively high proportion of these vehicles have been involved in fatal accidents.

Indeed, if statistics for general accident rates are shown, Egypt appears relatively safe;

![Accidental Deaths Per 100,000 People per Year](image)

**Figure 5.1.5.2 Accidental Deaths for 26 Countries Solomon, 1993**

Australia does not stand out as being particularly safe and is situated amongst relatively ‘similar’ nations, both in terms of economic status and culture. It is certainly not a particularly unsafe nation in terms of accidental death rate, especially compared to some of the more developing industrial nations such as Hungary and Cuba. However, whilst the above graphs may be used as a guide, they are not necessarily 100% accurate as the process for recording an ‘accidental’ death may vary between nations.

A study of road accident fatality rates conducted by the Transport Accident Commission (TAC, 1995) of Victoria, Australia looked at accident rates for eight countries. The results placed Australia as shown in figure 5.1.5.3 below;
The Australian rates are relatively unremarkable compared to the other seven countries. Fatalities per 10,000 vehicles (1.8) are marginally worse than the United Kingdom (1993) and marginally better than the USA (2.0). In terms of fatalities per 100,000, Australia (10.9) fares somewhat worse than the UK (6.8), but significantly better than the USA (15.6) and New Zealand (17.1). The reasons behind this are complex and involved (including quality of infrastructure, terrain, speed limits etc.) and beyond the remit of this thesis. However, road safety statistics rate amongst some of the most easily comparable statistics and therefore help to illustrate a simple point. That is that Australia in general does not stand out as a particularly ‘safe’ nation, either in terms of road safety or in accidental deaths cumulatively. Neither is it a particularly dangerous nation, especially when compared on a World scale.

Concentrating on accidental deaths within Australia, a difference in attitude to death by various causes may give some indication as to whether safety-consciousness is a cultural trait. Lane (1964) examines the value of life as determined by society through a number of hazards and the resources allocated to counteract them. Eleven events are compared on the grounds of the hazard, countermeasure (and its use) and cost per life saved. Two of the hazards are diseases (polio and tuberculosis) and five are related to aviation accidents. The rest are other accident types. Although the figures are now over thirty years old, they provide a useful historical indicator of the relative costs and allocation of resources in Australia at that time.

Lane’s figures (see table 5.1.5.4) demonstrate the diversity of costs of life that exist even within a single nation. The spectrum of values is from £3,200 to £3,000,000 (1964 costs); a range of one thousand fold. This provides a graphic demonstration of the fact that society attaches different values to death depending on the method rather than the outcome. The author
comments that; "It is apparently acceptable to be drowned but bad to be eaten by a shark; its apparently acceptable to be killed in a bus accident but bad to be killed in an plane accident; it is bad to be crippled by poliomyelitis, but in order if the crippling is caused by an automobile." Further observation by Lane (1973) notes that, "tractors in this country (Australia) kill about three times the number of people as are lost in civil aviation accidents, by a mechanism which has been shown to be almost totally preventable, but no-one takes much notice."

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Countermeasure</th>
<th>Use</th>
<th>Cost (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poliomyelitis</td>
<td>free immunisation</td>
<td>in force since 1956</td>
<td>8750</td>
</tr>
<tr>
<td>death by accident to motorcyclists</td>
<td>compulsory wearing of crash helmets</td>
<td>in force in Victoria since 1961</td>
<td>3200</td>
</tr>
<tr>
<td>death by accident in particular type of training aircraft</td>
<td>compulsory modification to aircraft of this type</td>
<td>rejected proposal</td>
<td>4300</td>
</tr>
<tr>
<td>death by accident to car occupants</td>
<td>compulsory fitting of seat belts</td>
<td>legislation rejected in one state</td>
<td>8000</td>
</tr>
<tr>
<td>death by accident to road users</td>
<td>improved street lighting</td>
<td>piecemeal application</td>
<td>8000</td>
</tr>
<tr>
<td>pulmonary tuberculosis</td>
<td>case finding, free treatment, financial support for sufferer and family</td>
<td>in force</td>
<td>13,800</td>
</tr>
<tr>
<td>death by shark attack</td>
<td>reduction in shark population by regular meshing</td>
<td>in force at Sydney beaches since 1937, elsewhere recently</td>
<td>14,000</td>
</tr>
<tr>
<td>passenger death in airliner accidents</td>
<td>aft-facing passenger seats</td>
<td>rejected by industry</td>
<td>2.8 x 10^5</td>
</tr>
<tr>
<td>death due to burning in airliner accidents</td>
<td>automatic fire-inerting of engine nacelles</td>
<td>rejected by industry</td>
<td>7.6 x 10^5</td>
</tr>
<tr>
<td>death by drowning of passengers of airline coming down in the sea</td>
<td>carrying of dinghies etc. on overwater flights</td>
<td>standard practice</td>
<td>1 x 10^6</td>
</tr>
<tr>
<td>death by burning in airliner accidents close to airport</td>
<td>full-time firecrew at airports</td>
<td>current Australian practice</td>
<td>3 x 10^6</td>
</tr>
</tbody>
</table>

Figure 5.1.5.4 Hazards and Countermeasure Costs Lane, 1964

Aviation, it seems, attracts a disproportionately large amount of expenditure on safety measures which may only save a comparatively small number of people. Not only that, but
there is also a clear difference in the acceptability of various causes of death. Whilst no accidental death may be considered acceptable in moral terms, there is a point where the balance between risk exposure and countermeasures are balanced by socio-economic forces. This balance is, in reality, rarely zero, but neither is it the same for different causes. The Air Safety Regulation Review Task Force (1990) also comments on the considerable disparity in risk acceptability between road and air transport within Australia.

"The fact that the Australian community continues to accept a very high road toll without undue protest is implicit acceptance of the number of fatalities and the associated cost. Statistics published by the Bureau of Transport and Communications Economics for 1988 show fatalities at 2886 at a cost of $1382 million (AU) or $479,000 per fatality. Total costs including injured medical services, legal, insurance, police and vehicle damage totalled $6180 million. Perhaps public acceptance is related to the fact that total Australian fatalities of 2886 in 1988 is only marginally higher than the 1960 figure of 2605?"

Lane (1994) notes the significant drop in accident rates for various transportation methods between the 1960's and 1988 in Australia. In doing so, he also presents the significant difference in fatal accident rates between each mode:

<table>
<thead>
<tr>
<th>Mode</th>
<th>1960's Rate</th>
<th>1988 Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airline</td>
<td>0.06</td>
<td>0.00</td>
</tr>
<tr>
<td>Bus</td>
<td>0.33</td>
<td>0.04</td>
</tr>
<tr>
<td>Passenger Car</td>
<td>1.81</td>
<td>0.86</td>
</tr>
<tr>
<td>General Aviation</td>
<td>10</td>
<td>3.57</td>
</tr>
<tr>
<td>Motorcycle</td>
<td>22</td>
<td>13.75</td>
</tr>
</tbody>
</table>

Figure 5.1.5.5 Fatality Rate per 100m occupant-km Lane, 1994

All of the accident rates have improved over the period; a function of improved technology, but the level of improvement is disparate, as is the ‘acceptable’ accident rates which have been set by socio-economic forces. Airline accident rate was already low (0.06) and has been reduced to zero (albeit based on a small statistical sample). The 1988 car fatality rate (0.86) is only 47.5% of the 1960’s figure (1.81) and the 1988 General Aviation figure (3.57) is only 35.7% of the 1960’s level (10). Motorcycle fatalities remain very high in 1988 (13.75), only a 37.5% drop from the 1960’s figure (22). It is interesting to note that not only have all the rates reduced, but that the ranking of fatality rates has remained the same. Motorcycle riding remains the most dangerous transportation method, followed by General Aviation (skewed perhaps by its training role) and then passenger car travel.

Notwithstanding this, an air of caution is required when comparing safety statistics between modes of transport. Lane’s chosen measure of 100 million passenger kilometres is valid and allows easy longitudinal analysis of changes over time within each mode. However, it is easy
to get a false perception of relative risk as each mode has a different profile; in terms of journey length, frequency, distance. Accident risk for aircraft, for example focuses primarily around the take off and landing phase so long cruise phases, especially by modern aircraft such as the B747-400 and A340 tends to smooth aircraft accident rates when scored against time or kilometres. At the other end of the spectrum, transport modes such as cars and motorcycles may travel comparatively short distances (in kms or time) yet are exposed to an equally high risk throughout the journey. This can make the accident rate seem extraordinarily high when measured with large units such as 100 million kilometres or hours.

There are a number of theories as to why commercial aviation may be seen to have a 'disproportionately' low accident rate, or indeed other transport modes a comparatively high accident rate. Smith (1992) examines the way that the media treat aviation safety suggesting it to be "...subjective and emotive... probably because their prime objective... is to make money for shareholders." Noting that 20 deaths on the roads over a weekend would hardly rate a mention in the media, the author highlights the fact that in the last 20 years, 60,000 Australians have died on the roads and yet no-one has ever died in a commercial jet airliner. A significant point may be that if accident rates were measured in journeys rather than absolute numbers of accidents, the perception may be rather different. Indeed in other arenas that is exactly what happens. The accident rate for the commercial jet aircraft fleet appears to have been stable since the early 1970's which, whilst not ideal, appears to demonstrate stability. However, if this rate were expressed solely in terms of the absolute number of accidents or the absolute number of fatalities, the picture may seem much more gloomy.

The media's focus seems based on the impact and visibility of large scale accidents and the apparently widespread morbid fascination in such accidents which sell newspapers. However, Smith (1992) also suggests that one of the reasons for 'hype' surrounding air safety is because of the staff working in aviation themselves. Another explanation for the hype is that some of those who earn a living from aviation, including pilots, air traffic staff and maintenance personnel, have long realised that an emotive statement to the media in relation to air safety is often the best way of ensuring high salaries and the continuation of inefficient practices.”

Smith’s rather inflammatory remark places the blame for “...emotive reaction to aviation safety” on the world aviation industry for failing to adequately communicate the risk effectively. The argument is simplistic and does not adequately address what is a complex issue. At an address to the 1997 Risk Engineering Society Conference (Smith, 1997), Smith blamed ‘excessive expenditure on safety at the Lucas Heights nuclear research facility’ on the inability of their risk engineers to adequately communicate the true risk of operation. This, according Smith, had led to the deaths of numerous Australians as nuclear power had taken more than its fair share of the ‘safety dollar’.

In doing so, the author seems to underestimate the forces of the public and government. Whilst public perception of safety is influenced heavily by the media, it is also influenced by a series of other factors which are discussed below.
5.1.5.1 Risk Perception and Acceptability

The safety (or risk-taking) behaviour of an individual is highly dependent upon a unique (and, arguably, dynamic) set of factors. Put rather more simply, "People respond to the hazards they perceive." (Slovic, Fischhoff and Lichtenstein, 1980) While the outcome of any risk taking decision is not directly related to an individual's perceived risk, it is this perception on which decision making is based. Indeed, even at policy making level, the meeting of perceptions have an extremely powerful impact on the result. For example, objections to the building of nuclear facilities tend to be disproportionate if solely compared to the hazards calculated through quantitative risk assessment (QRA). It is the fear and dread of catastrophic events that has a significant effect on the perception of risk. "If ...perceptions are faulty, efforts at public and environmental protection are likely to be misdirected" (Slovic et al. 1980).

Although Slovic et al. tend to highlight the negative aspect of the above statement i.e. where faulty perceptions lead to an economic inefficiency, this thesis poses the question as to whether an overestimated perception of risk has in fact afforded a greater margin of safety and therefore contributed to a good safety record. In other words, has a pessimistic perception of risk led to overcompensation in safety measures with a commensurate overall level of assured safety?

Slovic, Fischhoff and Lichtenstein's deep analysis of risk perception lays a very useful foundation for examining the subject. The authors suggest a number of judgmental (heuristic) biases which can affect the individual’s risk evaluation process. The include the following;

a) Availability: As frequently occurring events are easier to imagine, less frequent events tend to suffer from inaccurate recollection. This is a process which can be further effected by publicity such as the fear of shark attacks following the release of the 'Jaws' movies or a heightened awareness of aviation safety following a high profile air disaster.

Slovic et al. concluded that in general "...rare causes of death were overestimated and common causes of death were underestimated. A study of 41 causes of death revealed that accidental death causes were also overestimated, as shown in the following table;

<table>
<thead>
<tr>
<th>Most Overestimated</th>
<th>Most Underestimated</th>
</tr>
</thead>
<tbody>
<tr>
<td>All accidents</td>
<td>Smallpox vaccination</td>
</tr>
<tr>
<td>Motor vehicle accidents</td>
<td>Diabetes</td>
</tr>
<tr>
<td>Tornadoes</td>
<td>Stomach cancer</td>
</tr>
<tr>
<td>Flood</td>
<td>Lightning</td>
</tr>
<tr>
<td>Botulism</td>
<td>Stroke</td>
</tr>
<tr>
<td>All cancer</td>
<td>Tuberculosis</td>
</tr>
<tr>
<td>Fire and flames</td>
<td>Asthma</td>
</tr>
<tr>
<td>Venomous bite or sting</td>
<td>Emphysema</td>
</tr>
<tr>
<td>Homicide</td>
<td></td>
</tr>
</tbody>
</table>

Figure 5.1.5.6 Estimates of Death Causes Slovic et al. 1980
Overestimated events tended to be "...dramatic and spectacular" whereas "...unspectacular events which claim one victim at a time and are common in nonfatal form" tended to be underestimated. Aviation accidents involving large commercial aircraft tend to be both dramatic and spectacular and result in a large loss of life in a single event. Accidents which fall into this category are rarely nonfatal events.

b) Overconfidence; A function of the process of heuristics is a generally misplaced confidence in judgments based upon them. Slovic et al. (1980) assign this to "...people's insensitivity to the tenuousness of the assumptions on which judgments are based." There is a tendency by convinced more by the medium of communication of risk (e.g. through media impact) than the information which is contained. Personal experience can heighten awareness of specific risk at the expense of skewing judgment on other risks.

Overconfidence can also arise where experts underestimate risks, especially in complex or high technology systems or where effects are chronic or cumulative. For example, the designers of the DC10 underestimated the effect of the rear cargo-door blowing off on the flight controls of the aircraft. The trust in the aircraft on account of the Douglas reputation and Regulatory certification was sufficiently high that the aircraft was bought in large numbers. Confidence in the design was knocked severely following several incidents and a fatal accident.

c) Desire for Certainty; All technologies involve a certain gamble and their relative attractiveness is a function of the possible gains and losses associated with them. Ways of confronting this uncertainty include either denial (a source of overconfidence) or to "...outlaw the risk". An example of the former may be car travel where in spite of accidents statistics which confirm its relative unsafety as a transportation mode, perception of the risk is low. An example of the former is nuclear power where perceived risk is so high that denial is not possible and risk-taking attitude tends to be more directed towards its removal.

A desire for certainty may also be affected by cultural factors, as represented by Hofstede's (1980, 1991) Uncertainty Avoidance Index. The two areas of research have not been linked to date and would make an interesting future research project. A desire for certainty in risk taking seems likely to be based on a more general attitude towards uncertainty avoidance.

d) It Won't Happen to Me; A function of overconfidence, which is demonstrated in attitudes to driving (Svenson, 1979) and other risks. Direct personal experience which has been mishap free, supplemented by media exposure to others who have suffered accidents has the effect reassuring individuals that they are safer because of their own exceptional skill. As this particularly applies to driving, where the individual is under control, it also applies in reverse to flying as a passenger in a commercial airlines where as a passive participant. 'it might just happen to me'. Arguably the level of skill is reversed; car driving requires a single simple test whereas aviation requires recurrent training and checking.
5.1.5.2 Boeing 737 G-OBME - A case study in risk taking

To suggest that the majority of air transport accidents have been the result of 'faulty risk perceptions' or poor risk-taking decisions may seem to be a somewhat inflammatory remark at first glance. Surely no-one ever 'takes risks' in safety critical situations? But of course, individuals do take such risk-taking decisions as a matter of routine. For example, in January 1990, British Midland B737-400 G-OBME crashed at Kegworth, UK. The aircraft had developed an in-flight defect in one of its two engines and the crew shut down what they thought was the damaged engine. (In fact they had selected the wrong engine.) A diversion was made to East Midlands Airport (which happened to be the airline maintenance base) and upon final approach, the single remaining running engine broke up. The aircraft lost altitude and collided with terrain short of the runway threshold with the loss of 57 souls. The risk-taking decisions which may now be seen to have been faulty in that incident include:

<table>
<thead>
<tr>
<th>Risk Taking Decision</th>
<th>Made by?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are two-engined aircraft safe for passenger transport?</td>
<td>(regulator)</td>
</tr>
<tr>
<td>Is the 737-400 a reliable and safe aircraft?</td>
<td>(regulator / airline)</td>
</tr>
<tr>
<td>Were the crew adequate trained to be released to the line?</td>
<td>(airline)</td>
</tr>
<tr>
<td>Were the crew confident enough in their ability to detect faults?</td>
<td>(crew)</td>
</tr>
<tr>
<td>Was the aircraft warning system adequate for fault detection?</td>
<td>(manufacturer)</td>
</tr>
<tr>
<td>Was the engine of adequate design?</td>
<td>(manufacturer)</td>
</tr>
<tr>
<td>Did the errant engine need to be shut down immediately?</td>
<td>(crew)</td>
</tr>
<tr>
<td>Should the crew have made a visual inspection in flight?</td>
<td>(crew)</td>
</tr>
<tr>
<td>Was a diversion to the nearest airfield (Birmingham) necessary?</td>
<td>(crew)</td>
</tr>
<tr>
<td>Should passengers / cabin crew questioned the PA announcement?</td>
<td>(pax / crew)</td>
</tr>
</tbody>
</table>

Some of these decisions represent a simplification of complex procedures such as aircraft certification. For example, the Boeing 737 had been certified by a number of airworthiness authorities such as the American FAA and UK CAA. These processes involve a complex series of physical tests including destructive and non-destructive testing of materials and flight tests where aircraft performance is measured against a series of predetermined criteria. However, even this process can make an ill-judged final decision in deciding 'is the risk of allowing this model of aircraft to fly acceptable?' In the case of the original Comet series aircraft, this decision was found to be fallible when two airframes were lost in mysterious circumstances. When a cause could not be found for two high-profile accidents, the UK CAA took the step of revoking the aircraft's certificate of airworthiness until such time as a cause became apparent. The eventual discovery of metal fatigue which had been effected by the use of square windows in a high speed pressurised fuselage represented an area of aeronautical engineering without expertise. The deficiencies in the certification process were on account of a lack of knowledge rather than an error or mistake. This illustrates an important facet of risk taking - that is the concept of the unknown which is particularly important in fast developing technologies such as aviation.
Other decisions in the above scenario represent active risk-taking decisions such as 'Were the crew confident enough in their ability to detect faults?' and 'Was a diversion to the nearest airfield (Birmingham) necessary?'. The flight crew had recently completed a conversion course from the Boeing 737-300 series (electromechanical display) to the -400 (LED display) series aircraft. Their competency was assessed by instructors and training pilots and there was also a self assessment point where the flight crew had to confront their own ability to operate this new series of aircraft. When the aircraft developed a rough running engine on a B737, it was procedure on the -400 series to use the LED vibration dials to diagnose which engine was at fault. On the earlier series of B737 (-100, -200, -300) this gauge was notoriously unreliable and crews were advised not to rely on them for diagnosing engine faults. Instead a trial and error solution was used which involved easing the throttle back on either engine to see if the rough riding ceased. Unfortunately, in the G-OBME example, this technique was applied as the flight crew had not been trained to utilise the new instrument. This meant that when the healthy engine was throttled back, the aircraft’s autothrottle system was disengaged and the deficient engine was fed with additional fuel which temporarily cured the vibration. This misled the flight crew into believing that they had shut-down the correct engine. The crew believed that the risk of their training letting them down was sufficiently minimal as to be acceptable. They further decided that the risk of making a longer diversion to East Midlands Airport (which was their maintenance base) was no less acceptable than making the diversion to Birmingham. In the event, the distance flown may have had no influence on the outcome, but the terrain on approach may have been significant in terms of the survivability of the accident. (The aircraft collided with a steep motorway embankment and broke up.) If the crew had held enough information about the incident (i.e. that the engine they were using would break up on approach) such that they would be able to choose which airport to divert to, then arguably, the accident would not have taken place. It is impossible to suggest that this risk taking decision was fallible even though the ramifications of the choice could have been less serious if they had selected to divert to Birmingham.

Finally, some of these decisions represent the sort of subtle risk-taking decisions which are made almost subconsciously on an hour to hour basis. In the context of being dissected after the event, they are often decisions that may seem very obvious, but this is rarely the case at the time these choices are made. In the case of the announcement made by the Captain which informed the cabin that there had been 'some trouble with the right engine' when a number of passengers and cabin crew had witnessed torching or sparks from the left engine, the decision regarding whether to speak up and question the action was answered quietly within the confines of the individuals' minds. Confirmation bias could have persuaded the passengers that they actually heard 'left' instead of 'right'; Perhaps the engines are labelled facing backwards (in which case the left engine would be right) and so on? May be it was a slip of the tongue by the Captain - surely he knows how to fly the aircraft? No-one questioned the action except in their minds where they all concluded that the risk was acceptable. In hindsight, the decision was fallible, but entirely understandable.
5.1.5.3 Reasons for Variation in Risk Perception

Slovic, Fischhoff and Lichtenstein's first study (1980) of perceived risk concluded that both experts and laypeople "...differ systematically in their perceptions, ...particularly in regard to the probability and consequences of catastrophic accidents." They add that "Cognitive limitations, based on media coverage, misleading evidence, and the anxieties generated by the gambles life poses cause uncertainty to be denied, risks to be misjudged, and judgements to be believed with unwarranted confidence". In other words, the supply of poor information regarding risks has the expected consequence of fallible decision making. The power of media coverage is echoed by Kone and Mullet (1994) who found in favour of a "...practically totally determinant effect of the media in risk perception". Is attempting to answer the question as to whether differences in risk taking behaviour solely a result of the information that has been provided, it should be asked whether if supplied with similar levels of information, would two individuals make the same decision about risk acceptability?

Research conducted by Flynn, Slovic and Mertz (1994) to examine the influence of gender and race on the perception of environmental health risks took the unusual step of examining the characteristics of the 'risk perceivers'. Although some work had previously differentiated between the perceptions of men and women, the authors are only able to cite one study which look at racial differences. That study by Savage found that "...blacks felt more threatened by whites by each of four hazards: commercial aviation accidents, home fires, automobile accidents and stomach cancer."(Flynn et al. 1994) What makes up the categories 'black and white' is undefined. Flynn et al.'s attempt to examine the effects of race on the perception of environmental health risks used a population of 1512 Americans which were divided up as either Hispanic, white, black, Asian or American Indian. Any study which delves into issues of race and ethnicity relies on self-definition and as such, the answers could not take account of what generation white or black Americans might be.

The findings of the Flynn et al. study were that non-white males and females are much more similar in their perceptions of risk than are white males and females. As such, white males stood out, not least for consistently avoiding rating hazards as posing a 'high risk'. As risk avoidance behaviour is largely based on perception, it may be the case that white males accept higher levels of risk or narrower safety margins. A study of 38,829 male versus female pilot error accidents in 1986 found that not only were "...females significantly safer pilots as far as accident rates were concerned ...but they also kill themselves off at a significantly lower rate when they do have pilot-error accidents." (Vail and Ekman, 1986). Whether this is a link to risk perception or a function of other factors such as the recruitment process or the motivations involved in working in a predominantly male dominated environment is open to speculation and therefore suggested as a subject for future research.

Kone and Mullet (1994) summarise attempts to examine perception of societal risk in different countries by highlighting differences between the USA, Soviet Union, France, Poland, Norway and Hungary. (See Mechitov and Rebrick, 1990; Teigen, Brun and Slovic, 1988;
Englander, Farago, Slovic and Fischhoff, 1986; Karpowicz-Lazreg and Mullet, 1993; Goszczynska, Tyszka and Slovic, 1991.). In attempting to explain the significant differences the authors mention a discounted hypothesis which suggested that a deciding variable was the size of the country involved. They also offer the hypothesis that the active variable was the influence of the media. Responses from the former communist bloc countries (Soviet Union, Hungary and Poland) where accidents were rarely reported appeared to support the view that perceptions were related to media coverage. This was further supported by the authors’ study of differences between Burkina Faso and France, the former being a Soviet satellite.

The power of the media in heightening a perception of risk may not be a bad thing in terms of aviation safety, regardless of how frustrating it may be for operators to see them appear to make ‘something from nothing’. In Australia, the media reaction to aircraft incidents and accidents is traditionally high profile. Whether this is a function of a general lack of competing news or a more general high expectation of safety in aviation is debatable, although the latter seems more plausible. Following the Monarch and Seaview accidents and the incident involving Ansett B747 VH-INH at Sydney in 1994, a number of features appeared in newspapers and on current affairs television programs about the apparent demise of aviation safety in Australia. Articles which talked of “The aviation scandal” (The Age, 1995) and which suggested that Australia’s safety record had “...flown into turbulence” (Herald Sun, 1994) were commonplace. As the Sydney Morning Herald seemed to most aptly capture it; “By World standards, the crash landing of an Ansett B747 at Sydney Airport in October was not a disaster... But by Australian standards, where air safety within the big companies is not so much a matter of pride as a basic characteristic unquestioned by the travelling public, the crash was the worst incident in recent memory.” (Sydney Morning Herald, 1994)

The intensified media profile assured public consciousness of aviation safety matters remained high. As such, aviation safety has also remained high on the political agenda, a fact which precipitated the “...broad strategy to improve air safety (regulation) in Australia” which was announced by the then Minister for Transport, Laurie Brereton. (HORSCOTCI, 1995) Indeed it was a high public and political consciousness of an apparent decline in aviation safety standards that prompted the House of Representative Standing Committee on Transport, Communications and Infrastructure to conduct its Inquiry into Aviation Safety in 1995.

If the media in Australia is guilty of heightening the public’s perception of risk in aviation, then it seems likely that it is a contributory factor in lowering the societal acceptability of risk in this area. As a consequence, the level of resources which are allocated to counteracting perceived risk in aviation are likely to be higher. For example, when the Australian Civil Aviation Authority existed as a Government Business Enterprise between 1988 and 1995, it was tasked with recovering all of its costs from its users. This involved commercial services within the CAA cross-subsidising the safety regulatory function. When the Civil Aviation Safety Authority was created in 1995 with the devolution of commercial service provision to the new Airservices Australia, it became funded directly from the Government as a single-function safety regulatory authority.
The major importance of risk perception is its power as a driver of risk taking; a process which involves balancing perceived hazard and benefit against the risk countermeasures required to achieve an acceptable level of risk. This level is then referred to as safety, unless in retrospect the balance is judged to have been wrong.

The Council for Science and Society (CSS, 1977) suggested that an individual’s acceptability of risk is governed by a number of considerations including:

- Whether the risk is voluntary
- Whether the effect is immediate
- Whether there is an alternative
- Whether it is experienced occupationally
- Whether the consequences are reversible

These may provide a model to examine why acceptable risk for Australian commercial aviation may be ‘artificially’ low, especially when compared to other transport modes (such as road) and why, as a consequence, safety countermeasures provide an additional margin of safety. To consider commercial aviation against road travel in Australia:

For the five aspects mentioned in the CSS model, acceptable risk is consistently low. In other words, safety countermeasures are demanded at a high level which in turn has an effect on the magnitude of safety margins.
The risk profile for car travel is rather different with four out of five categories accepting a higher level of risk than civil aviation. The rationale for this profile is as follows:

1) Whether the risk is voluntary; Long distance travel by air is judged to be a necessity by virtue of the distances involved in travelling both interstate within Australia and overseas. International passenger traffic is almost exclusively by air, although technically only 35% of interstate trips are by air (BIE, 1994). The latter figure does not discriminate length of trip and is probably skewed by the large proportion of the population which lives near to the borders of Queensland, New South Wales, Australian Capital Territory and Victoria. The only alternative for international travel is sea transport which takes several weeks to reach most destinations. As such international travel, whether it be for trade or for leisure purposes depends on aviation, and is therefore an involuntary risk.

Additionally, internationally air travellers are passive participants in the transportation whereas a high proportion of car travellers are active participants (i.e. drivers) or able to directly influence the performance or behaviour of the driver. The apparent lack of direct control is one of the most commonly cited reasons for fear of air travel and is another reason why flying may be considered to be an involuntary risk. Individuals may perceive that if they were in control of a passenger aircraft, they would accept lower risk in certain situations, although in practice, their lack of technical knowledge and experience accounts for this difference.
2) Whether the effect is immediate; In both car and commercial air travel, the risks tend to be immediate (with the exception of perhaps radiation or air pollution) from collisions. Such catastrophic risks tend to be more feared than the chronic threats of, say, heart disease, not least because a direct causal link between activity and outcome is easily apparent. As such the level of acceptable risk is lower for all transportation methods.

3) Whether there is an alternative; Linked to the voluntariness of risk taking, there is virtually no alternative to aviation for international travel from Australia and interstate travel is limited by time because of the vast distances involved. Low numbers of alternatives reduce the level of acceptable risk as that activity becomes less voluntary. Car travel has a number of reasonable alternatives depending on the journey to be undertaken. These range from walking and cycling through public transport (bus, suburban rail, tram, ferry) to interstate alternatives such as rail or air (subject to time constraint). As such, the level of acceptable risk generally associated with car travel is higher.

4) Whether it is experienced occupationally; The CSS (1977) found that risks which were experienced occupationally tended to be at a lower level of 'riskiness' than those experienced at other times. Aviation may be seen to have two groups of participants; namely the operators (flight crew) and the customers. The former are obviously experiencing occupational risk whether it be in the form of working in a potentially hazardous environment or in terms of their expected role in, for example, evacuating a stricken aircraft. The situation with customers is less clear. Business travellers may need to fly as part of their occupation whereas holiday travellers do not. Notwithstanding this, it may be argued that those who do experience occupational risk in aviation are in a strong position to demand a lower level of acceptable risk.

Historically, the high number of early accidents and incidents associated with aviation meant that the occupation of pilot was one with a high associated risk. As the vast majority of people involved in aviation were either pilots or at least from a flying background, the demands for improved reliability and safety were loud. This was particularly the case in Australia where the terrain was very unforgiving to lost or damaged aircraft, especially in terms of its vast distance and sparseness of population. This historical factor is possibly one of the reasons that risk acceptability in commercial aviation operation within Australia is relatively low.

Occupationally induced risk in car driving exists in some instances (such as travelling sales representatives, limousines etc.), but in general, car travel is not associated with occupational risk. Even when a car is used to travel to and from work, it is not classified as an occupational risk and as such, the high proportion of leisure use accounts for a higher acceptance of risk. This is one of the reasons why a relatively high level of drink-driving deaths are tolerated by society.

5) Whether the consequences are reversible; Some risks attract consequences which may be reversible over time. One example is car travel where injuries from non-fatal accidents are predominant and will heal over time. In 1988 in Australia, only about half a percent of road accidents were fatal. (BTCE, 1992) Commercial airline accidents on the other hand, whilst rare events, tend to be fatal 50% of the time (Schiavo and Chartrand, 1997). Risk acceptability is set at a much lower level when consequences are believed to be irreversible.
5.1.5.4 Perception of Risk for Different Activities

Section 4.1 of the questionnaire aimed to explore the issue of risk perception. Although the results were not as definitive as expected, they do illustrate a few issues that are pertinent to this case study. As this questions covers a far reaching area of research, further analysis of the data will be presented as a separate paper.

Expectations

Well structured research often utilises existing methodologies or established research tools such as questionnaires. Originality is maintained through the collection of different datasets, time series data and the synthesis of different research elements. However, every so often there is a need to experiment with new and untested research tools to try and discover innovative methodologies. There is no guarantee that they will work, especially when used in association with human subjects, but if they do then they provide the basis for valuable new research tools.

Questionnaire Design Rationale

Accident statistics are freely available in significant samples for transport safety. Motorcycling is generally accepted to be a more dangerous form of road transport than car travel although as both use the same form of highway, certain variables are eliminated for easier comparison. Hence a difference in accident rate can be narrowed down to factors pertaining to the vehicle or the operator. Previous studies of driver safety have highlighted a disparity between an individual’s perception of how safe they drive compared to everyone else. In other words, “I am an above average driver, the majority of drivers are of a lower ability than me”.

Two levels of air travel are considered to examine the question of different levels of acceptable (or ‘affordable’) safety. The issue of control is explored by including the distinction between flying as pilot and as passenger.

Smoking legal drugs (tobacco), drinking alcohol and smoking illegal soft drugs are included as examples of social pastimes that may be expected to have little to do with professional training and more to do with individual personality. They represent voluntary risk taking with chronic consequences i.e. long term and primarily effecting the individual.

Australian rules football / rugby league, snow skiing, rock climbing and freefall skydiving all represent active sports with varying levels of participation and following. Australian rules football and rugby league are games played by most children and commonly followed through later life while the other three sports tend to have a more exclusive participation / following. Australian rules football (AFL) is a vaguely similar game to rugby league but the following of each game is particularly regionalised within Australia. The expert panel involved in questionnaire design suggested that respondents from New South Wales may not really understand what AFL is or answer in an extreme way. (‘Only girls from Victoria play AFL’).
4.1 For the following activities, we would like you to mark how risky you consider each one would be to you personally if you participated:

a. Motorcycle riding  
b. Car Travel (self driving)  
c. Car Travel (other driving)  
d. Flying as a passenger in a light aircraft  
e. Flying as the solo pilot of a light aircraft  
f. Flying as a passenger in a commercial airliner  
g. Flying as the pilot of a commercial airliner  
h. Cycling  
i. Smoking 20 cigarettes a day  
j. Drinking 20 pots of medium strength beer a week  
k. Smoking 'soft drugs' e.g. cannabis  
l. Australian rules football / rugby league  
m. Snow skiing  
n. Rock climbing  
o. Freefall skydiving

Figure 5.1.5.11 Question 4.1 from Main Questionnaire

Results and Analysis

The results were split into six categories to represent the following groups;

- Australian Airline Pilots (Qantas and Ansett)  
- Australian Civil Air Traffic Controllers  
- Australian Military Air Traffic Controllers  
- Australian Military Transport Flight Deck Crew  
- Australian General Public (Rotary sample)  
- British Airline Pilots

Not all groups were asked to answer all categories. For example, only pilots were asked to rate their perception of the risk of flying a commercial airliner. The question regarding flying as passenger of a commercial airliner lacks any useful data from the Australian Civil ATC which is a great disappointment. This was because Airservices Australia made the decision to retype their questionnaire forms into corporate format and did not submit a proof for approval before distribution. The forms were therefore erroneously printed to include a question regarding how risky they considered ‘flying as a passenger in a light commercial aircraft’ to be. This new wording changes the meaning of the question to render the data unreliable.
a. Motorcycle riding;

Rated as a significantly more risky activity than car driving, which is not a surprise. Air Traffic Controllers display a slight difference in attitude over pilots and especially the general public which may point to

b. Car Travel (self driving);

Generally ranked as a low risk and only marginally higher than flying as a passenger in a commercial aircraft by all six groups. Military ATC actually consider this activity to be safer. This may relate to the high exposure to car travel (see earlier notes.)

c. Car Travel (other driving)

No surprises here in that car travel is perceived to be more risky when someone else is driving. This corroborates with previous studies and is related to the concept of being in control. All six categories record similar responses (mean 2.59 to 2.97).
d. Flying as a passenger in a light aircraft;

Perception of travelling as passenger in a light aircraft ranks as a consistently higher risk than car travel. Even though Smith (1992) rated commuterline air travel to be 15 times more safe than road travel and charters to be twice as safe, recent events have obviously changed overall perceptions of risk.

e. Flying as the solo pilot of a light aircraft;

In general, the risk profile was lower than for flying as a passenger, which is in line with the results for car travel. Civil ATC are notable in considering the risk to be higher (mean of 3.44 instead of 3.21), but this may be a reflection of their lack of currency.

f. Flying as a passenger in a commercial airliner;

This was recorded as being a low risk by all categories, although military air traffic controllers perceive a greater risk (mean of 2.71 as opposed to a range of 1.58 to 1.80). The reason for this is not clear and is worthy of further investigation.
g. Flying as the pilot of a commercial airliner;

This represented the lowest risk of the list with Australian commercial aircrew rating it the lowest (mean of 1.45) of the three groups. Whilst this is similar to the British pilots response, the difference may reflect the operating conditions in both regions.

h. Cycling;

Although higher, the perceived risk exposure is not significantly different to the results for car travel (other driving). In practice, cycling is much more dangerous and as such, this response may further support the importance of control in influencing risk perception.

i. Smoking 20 cigarettes a day;

Smoking cigarettes, whilst is represents a chronic risk rather than the catastrophic risk of transportation modes ranks as the highest perceived risk for all groups. This is probably a function of the high level of publicity which has surrounded the hazards of smoking over the last decade or so. The power of the media in affecting risk perception is clear.
j. Drinking 20 pots of medium strength beer a week;

The hazards of alcohol, particularly in regard to drink-driving are more publicised in Australia. A fact which is borne out by the British sample who rated the risk of drinking to be significantly lower (2.88) than the five Australian samples (mean 3.40 - 3.80).

k. Smoking 'soft drugs' e.g. cannabis;

The perception is that smoking soft drugs is less risky than habitual smoking, but is still rated as a quite high risk (mean 3.82 to 4.36). Military ATC suggest the lowest risk, although the reasons behind this can only be speculated at this point.

l. Australian rules football / rugby league;

Generally a similar reaction from the six groups to this as an activity with an above average level of risk. The two military groups rate the lowest (pilots, 3.35; ATC, 3.38) which is possibly a reflection of the different culture from which they are recruited.
m. Snow skiing:

Similar results for skiing which is actually more hazardous than AFL / rugby league. (See Slovic et al. 1980). The difference may be accounted for by lack of personal experience and relatively low coverage of injuries and deaths caused by skiing compared to the more professional spectator sports such as football.

n. Rock climbing:

This activity is perceived to be much more dangerous than the previous two categories. Whilst it has a better safety record than football in terms of injuries, it represents a risk with potentially more catastrophic consequences i.e. the risk of death is higher which affects overall risk perception.

o. Freefall skydiving:

Rated similarly highly to rock climbing, but included because it is a sport that is likely to be well known to aviators. However, there is no major difference between their opinion and that of the general public. This may be an indication of how even limited experience may not be enough to alter general risk perceptions.
The issues highlighted by this section have been covered fairly briefly as each of them warrants a significant amount of extra research from the point of view of risk perception. However, they do seem to support the theoretical aspects of risk perception discussed elsewhere in this section. The difference in perception between the risk of car travel, light aircraft and commercial aircraft travel are particularly interesting and may reflect the intense media coverage of aviation safety around the time of the survey. Nevertheless, a lack of discernable difference between the Australian and British pilots may also be of some significance in suggesting that the reaction to events such as Monarch and Seaview in terms of heightened risk perception are not as dramatic as may be first thought.

The perception of car travel being more dangerous when someone else is driving and in turn is more dangerous than flying in light aircraft is something that will change very slowly or based on direct experience.
5.1.5.5 Factors Influencing Risk Taking Behaviour

Eight areas were selected to investigate what factors were perceived to influence an individual's ability to take risks. The questions reflected the influence of money (positively and negatively), differing severities of outcome, the influence of other people and level of understanding. The function of this question, like 4.1 was somewhat speculative and few expectations were held about the results.

4.2 To what degree do the following factors affect your willingness to accept particular risks?

For each activity, please circle between 1 (No Effect) and 5 (Major Effect).

a. How much you are paid to accept that risk.
b. Whether the risk could incur a financial penalty to you.
c. Whether the risk could involve some injury to you.
d. Whether the risk could result in your death.
e. Who else is also accepting that risk.
f. Whether your risk taking increases the risk to your family.
g. Whether your risk taking increases the risk to other people.
h. How much you understand about the risks of an activity.

Results and Analysis

There was little agreement regarding the matter of payment although most of the answers tilted towards a low effect of payment on risk acceptability (mean 2.22-2.66). This trend is not as apparent for air traffic controllers (mean 3.10-3.21) which are occupations which are both highly paid and stressful. While the same may be argued for pilots, the latter is a more participative, and therefore
possibly more enjoyable occupation. This finding relates to the CSS’s (1977) suggestion that occupationally experienced risk promotes a lower level of acceptable risk.

b) Whether the risk could incur a financial penalty to you;

The threat of financial penalty all seemed to affect the six groups in similar ways with means of 3.11 to 3.72. Money as a motivator is evidently a little stronger in persuading an individual not to take risks than in persuading them to accept additional risk.

c) Whether the risk could involve some injury to you;

Risk of injury brought a high level of uniformity (mean of 4.08 to 4.41) of agreement that the risk of injury had a high or major effect on risk taking decisions. Even military pilots and air traffic controllers demonstrate no significant difference in their attitude.
d) Whether the risk could result in your death;

Risk of death was a category which brought the clearest consensus of opinion (mean 4.6-4.78) which is what may be expected in countries where individuals believe that they have strong control of their own destiny (such as the UK and Australia). This question would be an interesting one to test in more collectivist countries or ones with different religious backgrounds.

e) Who else is also accepting that risk;

Although all six categories answered similarly (mean 2.72 - 2.90), there was little agreement within the groups. This may represent the opposing scales of mateship and individualism which have led to apparent indecision as to how much someone else taking a risk will affect an individual’s choice. A development of this question may examine who has what effect.
f) Whether your risk taking increases the risk to your family;

Once again, a high level of uniformity and agreement that increased risk to an individual’s family would have a high or major affect on risk taking decisions (mean 4.40 to 4.65). In retrospect, this question should have separated the risk of injury and that of death to allow comparison with 4.2c and d. A number of pilots measured the safety of their colleagues by the standard ‘would they let their family fly with them’.

g) Whether your risk taking increases the risk to other people;

Increased risk to others was judged to have a high effect (mean 4.19 to 4.33) although not as high as when risk taking affects a family member.

Injury, whether it be to self, family members or others was judged to be a far greater motivator than the threat of financial penalty. In training terms, this may suggest that an approach of illustrating the human cost rather than punitive measures.
h) How much you understand about the risks of an activity;

Understanding risk is something which can allow safety margins to be reduced with a commensurate resource saving, if done correctly. What Slovic, Fischoff and Lichtenstein (1980) refer to as ‘dread’ is often associated with a lack of understanding about a particular risk (e.g. nuclear power). Although the effect is barely significant, it may be noteworthy that both British and Australian commercial pilots felt that an understanding of the risk had a major effect on their risk taking behaviour. This would sit comfortably with images of commercial airline pilots being precise individuals who work to strict standard operational procedures. As such, it is suggested that while this graph gives only a lose indication, the experiment might be usefully reproduced on pilots from different operators and different operating cultures.

This section of analysis did not produce the sort spectacular differences that might have been hoped for. However, they did cover reasonably homogeneous groups in terms of occupation or culture. In fact, the similarity of the groups may be more important than their difference. That is to suggest that risk taking decisions are not necessarily related to occupation, rather more generic features such as exposure to information through the media as mentioned above. The data do not suggest that faced with the same information, the six groups would all make the same decision, rather that the mental processes of consideration are similar. The important variable would therefore likely be the availability of information. A fact which returns to Slovic et al.‘s (1980) comments that, “People respond to the hazards they perceive. If perceptions are faulty, efforts at public and environmental protection are likely to be misdirected”. Bearing this in mind, the crucial determinants become issues such as education training, information quality and flow and the more subliminal forces of organisational, industry and national culture.
5.2 Training

"Flying an aeroplane is a learned skill. Learning is so involved in perception, thinking and memory that it is impossible to put it in a tight compartment. One psychologist has described learning as ‘the process of being modified, more or less permanently, by what happens in the world around us, by what we do, and by what we observe’.” (Beaty, 1995) As such, it is difficult to evaluate the quality and effectiveness of training for an entire aviation system without very in-depth analysis. The background of employees in an RPT airline is varied and even the comparison of airline level training is difficult because of the numerous variable involved in the process of training and learning. Nevertheless, there are a number of issues of importance that relate to training which have had an impact upon safety in Australian aviation.

5.2.1 Recruitment

Would-be airline pilots within Australia only had three major (now two) RPT carriers to aim for during their flight training. Although all three majors have run cadetship schemes at some point in their history, they have not been the main source of pilots. Australian Airlines, for example, only had two cadet intakes which were in the late 1960’s although Qantas did run a quite extensive cadetship program with 14 courses commencing between 1963 and 1970. (Stead, 1995)

As such, the main route to the airlines is through general aviation or the military. Baker (1988) estimated the traditional source of Australian Airlines pilots to be approximately 60% from the military, 35% from the armed forces and 5% from other airlines.

Selection was difficult, particularly as the recruitment process developed in line with increased competition. Whereas selection in Qantas before 1960 relied on flying experience, and interview and medical examination, it has since developed to include a battery of psychological testing. Whereas candidates in the 1960's needed fulfil the following direct entry requirements:

- Commercial Pilot's Licence
- 500 hours minimum command experience (experience commensurate with age)
- Multi-engine time
- First class instrument rating

These had extended by the 1980’s to include senior commercial pilots licence theory subjects / rating and a twin-engine endorsement (with exception for military fighter pilots).

This change reflects not just an increased awareness of the attributes required in a good candidate, but also the increased availability of pilots to choose from. It is clear that one of the by-products of a large number of potential recruits is the ability of the employer to select a higher calibre of employee.
Recruitment is perhaps a more important concept than training as even the best training system needs quality candidates if it is to hope to do its job properly. "Training is one thing, but the pilot must be trainable and have the potential of developing in due course into an aircraft commander." (Davenport, 1988)

CASA stipulate a minimum requirement for pilot selection which is exceeded by Qantas at a cost of $230,000 per annum. (Lewis, 1997) A pilot will represent a long term investment which will require expensive training (thought to be in excess of $2 million to Captain in Qantas at present). The slow speed of progression through ranks may mean that without adequate selection tests, a 'bad investment' may be difficult to spot. Davenport (1988) observes that the position of Second Officer in Qantas means that "...it may be three to four years before inherent flying deficiencies become apparent." Recruitment is important to the Australian major carriers and their commitment is highlighted by their work on the development of customised psychological testing instruments. (see Alexander and Stead, 1993)

As most of the pilots who apply to join the major RPT carriers have paid their own way through training, there is no doubting their commitment. To accumulate sufficient hours and experience to be considered for employment, they will have had to spend a period of time flying charters, bank-runs and / or instructing, often in very inhospitable terrain. "The majority of airline pilots from Australia paid their own way through local flying schools, then went into the real world to sink or swim. This experience just may be one reason why that country has, at least to date, such an enviable safety record." (Flight International, 1991). Indeed, even Qantas cadets were sent out to 'fly bush' upon graduation to gain much needed experience. In spite of anecdotal evidence regarding 'good flying weather' and 'flat terrain', the hazards of General Aviation flying within Australia are significant. The level of accidents in this sector is high; averaging between 1.0 and 1.5 fatal accidents per 100,000 hours per year. (C of A, 1997) Whilst aviation is a well respected career in Australia, it does not carry the same social status that it does in other cultures. Individuals become pilots because they want to, not because society ascribes a high level of respect to that profession. The slow route of experience which involves the 'serving of time' in the harsh operating environment of General Aviation or the Armed Forces has a naturally selecting effect on those wishing to become RPT pilots.
5.2.2 Evaluating Training Effectiveness

It is all but impossible to compare the training regimes of different airlines for a number of reasons. These include variations in:

- recruitment policy
- training style
- line flying environment
- technology (aircraft / simulators)
- organisational culture

As such, it is impossible to say that training at airline X is only half as good as at airline Y because the courses are only half the length. It may be that recruitment at airline X specifies a higher standard and has a greater emphasis placed on 'on the job' learning. For the latter to happen requires an ingrained commitment which forms a definitive aspect of the operating culture. In other words, it has to be possible for different members of the crew to help train each other. "Not every airline will subscribe to the need to develop a training culture within the organisation" (Beaumont, 1997). Indeed some airlines would positively discourage training being done by anyone other than official training staff for fear of a lack of standardisation. The counter-argument within Qantas would be the strict adherence to standard operating procedures that is the cornerstone of their operation. The position of Second Officer, who is carried on all flight lasting over eight hours, fulfils a dual role as 'cruise pilot' and as officer in training. Whilst the S/O may have many hours of flying experience (including a minimum of 500 hours in command), they will stay in the position for about 2-3 years watching and learning from the other line crew members. By the time they reach First Officer, they will have received an unusually high amount of experiential training.

Comparative evaluation tools are limited and regulatory licencing procedures for monitoring standards examine basic compliance and not any 'additional quality'. Instruments such as the NASA/UT 'Line - LOS checklist' (Helmreich, 1991; Hines and Helmreich, 1997) have only been used quite recently and tend to focus on a particular aspect of performance such as CRM skills. In applying such a tool, Helmreich (1991) was surprised to observe "...great variability among crews operating the same type of aircraft" even in the comparatively highly regulated USA. Although the NASA/UT have conducted extensive testing using the 'LLOS checklist', it does not provide a comparative tool that can be used easily. Observers need to be trained and standardised and fly with numerous crews on numerous sectors which make it a very expensive process. The checklist has never been used in Australia and therefore comparative data is not available.

There are no easily available primary markers currently available to support the view that training within the Australian RPT system is above average. However, a lack of accidents would seem to support a consistently high level of skill. Boeing observe that flightcrew error has been the primary cause in around 70% of accidents (Lautman and Gallimore, 1987) and
whilst no training regime could currently claim to be able to prevent all of these factors, the disparity of accident rates between carriers suggest that more effective training is possible. "Flight crew members are highly disciplined professionals and they respond to emergency situations in the manner in which they have been trained." (Doss, 1992)

Australia's reputation for good RPT safety is based on a lack of accidents. Based on a breakdown of accident statistics from around the world, it is flight crew performance which stands out as the single greatest primary cause. As such, if failures to the Australian safety net were to occur, this is the area which is most likely to be deficient. The lack of accidents suggests a strength in the effectiveness of crew training and the training of support staff such as engineering and maintenance and air traffic control.

5.2.3 Level of Training

Terrell (1988) comments that one of the main elements of safety management within Qantas is the issue of training. As such Qantas has invested in training facilities which include;

- Advanced flight and ground simulators which expose crews to realistic emergency conditions too dangerous to practice in an aircraft.
- Emergency procedures training in which evacuation procedures are taught to pilots and cabin attendants.
- Maintenance training simulators for personnel involved in the line maintenance of aircraft.

Australian Airlines and Ansett Australia also have high-fidelity flight simulators based in Melbourne along full sized high-fidelity B737 cabin simulators. Where equipment is only held by one airline, co-operative agreements exist to allow staff from the other airline to use it. Some of the subsidiary airlines are also now getting flight simulators with recently arrived Dash-8 and Saab 340 units.

The level of training is not just about the equipment which is available, but is a function of pre-employment experience, formal ab initio training and on the job training. It is supplemented by the use of CRM training, LOFT exercises and Emergency Procedures training.

Controlling the effectiveness of training is a very strict standard operating procedure culture, which is particularly evident in Qantas. The effect of personality and leadership style is minimised by strictly following the book procedure and feeling able to speak up if this is not
done. The Qantas or Ansett ‘way of operating’ is made clear from the recruitment stage, through training and in normal line operations. “Right from the beginning it is important to ensure the applicant understands the company’s goals and company’s culture... it is a serious business. Teamwork and crewmanship are taught in the first few days”. (Davenport, 1988) “Individual and group behaviour of crewmembers forms the tone of cockpit operations... The degree of self-discipline and procedural discipline affect the overall cockpit environment and in turn, determines the level of risk at which the flight crew operates.” (ICARUS, 1994)

A low turnover of staff within the major carriers, a function of good working conditions and the prized nature of jobs, means that pilots in all positions have a high average level of experience. ‘Career First Officers’ are quite normal in Qantas as are First Officers with more flying experience that Captains from other major carriers around the world.

5.2.4 Experience and Currency

As mentioned above, competition for employment with the major RPT carriers is intense and as such, they are able to make selections based on the most compatible experience. This does not necessarily equate to employing new recruits with the highest hours, especially in Qantas where ab initios may have comparatively low numbers of hours. Indeed, secondary level carriers such as Eastern Australia and Kendell generally demand higher numbers of flying hours as new recruits will go straight into flying aircraft as First Officers. Qantas, on the other hand has the ability to train and standardise its new intake through the ‘apprenticeship’ Second Officer position; a rank which a crew-member may find themself in for 2-3 years.

International Operations: International services out of Australia, previously the exclusive domain of Qantas, but now joined by Ansett Australia, represent probably the longest average sector length of any airline in the world (Learmount, 1987). The advent of long range aircraft in the form of the Lockheed Constellation, Boeing 707, 747 and 767ER has been the result of demand from carriers such as Qantas. Indeed, long range variants of the Constellation (L1049G), B707 (-338C) and B747 (-B) were built at the request of Qantas (Gunn, 1988).

Early long-distance services were limited by aircraft range and services such as the ‘Kangaroo Route’ to London via Asia required several stops. For example, when the B707-138 commenced the service between London and Sydney, it would make intermediary stops at Rome, Istanbul, Tehran, Delhi, Bangkok, Singapore, Jakarta and Darwin. Qantas’ B747SP-38 Classic aircraft have a range of 10,200 km and the advanced B747-400 series aircraft have a range of 12,300 km. As such, this allows long-haul routes to be operated with zero or one stop. Long sectors such as Sydney to Los Angeles (12,054 km), Singapore to London (10,873 km) and Melbourne to Johannesburg (10,312 km) mean that for long-haul crews, the opportunity to handle to the aircraft at take-off or landing is comparatively rare. Indeed, they find that the opportunity will only arise once or twice in a month.
The threat is a lack of experience, especially in terms of local conditions such as weather or complicated approach procedures. The counter-argument is that the situation is mitigated by the use of simulators (each crew-member has a simulator check three times per annum) and a heightened awareness of safety threats that comes with a lack of recent experience. Additionally, the openness of communication which exists within the flight crew supplements the available experience of any individual crew member.

Nevertheless, this hazard should be acknowledged, especially as Ansett Australia expands its International operations and as longer range aircraft such as the B747-200X, A330/340, A3XX series become available and open up new route opportunities.

**Domestic Operations:** Although Australia's domestic carriers are faced with long distance 'international length' routes, the range of destinations for each aircraft type is relatively limited. For example, domestic B767-200s operated by Ansett Australia and Qantas may find themselves limited to the trunk ports of Perth, Adelaide, Melbourne, Sydney, Brisbane and Cairns. Even the more flexible types such as the B737 (AN and QF) and A320 (AN) will find themselves limited to about 14-15 destinations Australia wide with an average sector length in excess of the average of 1.6 hours cited by Boeing (1996).

Experience of operating into these key airports is high amongst domestic RPT carriers, assisted by a higher than average pilot utilisation rate than comparable airlines;

<table>
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<tr>
<th>Pilot Utilisation 1992</th>
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<tr>
<td><strong>Airline</strong></td>
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<td>Australian</td>
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<td>Aerolineas Argentina</td>
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<td>Aviaco</td>
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Figure 5.2.4.1 Pilot Utilisation (Domestic) BIE, 1994

However, this is balanced out somewhat by the longer than average stage length operated in Australia (BIE, 1994) which dilutes the number of cycles which makes up the total hours flown. Notwithstanding this, the low number of destinations means that crews become very familiar with their routes. Whilst there is an ever present hazard of overconfidence, the approaches to major airports in Australia are, on the whole, straightforward and a high level of experience is the norm.
Both Qantas and Ansett pay particular attention to their check and training and quality assurance systems which are currently the best-practice techniques for ensuring standards are achieved and maintained. However, check pilot training is not required by CASA, yet Qantas and Ansett both conduct such training at a cost of $1.35 million per annum in the former case (Lewis, 1997). A Flight Standards section within Qantas monitors the output of both trainers and the trained. Comprising a Director, three pilots and an engineer, the Flight Standards section had the authority to take anyone off line up to the level of Training Captain. This is separate to Flight Operations (FLOPS) and is unlike other airlines which call FLOPS, Flight Standards without it having the same function.

Whilst check flights are the subject of regulation, CASA requires only two check flights per crew per annum (one simulator and one route check), but Qantas exceed this by 100%. Crewmembers are required to undertake three simulator checks per year at a significant cost of $12 million per year. (Lewis, 1997)

5.2.4.1 Continuous Fleet Monitoring

One of the difficulties of assessing training effectiveness is the so-called Hawthorn effect whereby the behaviour of an individual under observation performs differently to normal. Simulator exercises and check flights are designed as assessment tools and with failure potentially meaning loss of licence and loss of earnings, the need to perform perfectly is heightened. Even ‘non-jeopardy’ assessments such as CRM LOFT missions or the NASA/UT Flight Management Attitudes Questionnaire (FMAQ) are liable to suffer from individuals ‘performing for the camera’. What is required to supplement these assessment methodologies is a way of monitoring performance and behaviours continuously.

One of the solutions is the use of Quick Access Recorders (QARs) which contain Digital Flight Data Recorder information for all flights. These tapes/disks are analysed by the airline for trends from predetermined exceedence limits. The advantage is two-fold as the system is capable of tracking both recurrent deviations by individual crew members or recurrent deviations at a particular location or on a particular aircraft type. It is not a punitive system, rather a training tool which picks up occurrences that might be overlooked by the standard training and checking system.

Qantas introduced a flight data monitoring system progressively from 1987 which is now being expanded to encompass the domestic operations inherited from the merger with Australian Airlines. Ansett Australia is now in the progress of implementing a similar system.

Early successes include the discovery of fleet-wide over-rotation at take-off on the B747-400 fleet which was causing the speed to bleed-back at the most critical part of climb. The problem highlighted deficiencies in the conversion training from B747 Classic which was subsequently amended before a tail strike or worse occurred. Although the use of QARs is a relatively new development in the Australian system and therefore has only played a limited role in the
successful historical safety record, such a system is representative of the commitment to training development that exists, particularly in Qantas. Indeed, without the right culture within the airline, such a system (which is still quite unusual by world standards) could not have been implemented as smoothly as it was. Former Qantas General Manager, Operations, Alan Terrell suggested that the system was "...one of the best things that Qantas ever did" (Terrell, 1995) and that one of the critical elements was the positive role of the pilots' union (AIPA) which was unusual in "...its commitment to maintaining standards and conditions" (Terrell, 1995). In other words, the establishment of such a system may be as much an indicator of organisational attitude to safety as the results of it once it was up and running.

5.2.5 Joint Flight Crew Training

Training in the areas of aviation human factors and CRM has been developing steadily since the early 1980's, when a number of key accidents highlighted the human fallibility of the aviation system (Cooper, White & Lauber, 1980; Helmreich & Foushee, 1993). Statistics suggest that human error is found as primary cause in the overwhelming majority (70-80%) of aircraft accidents (Boeing, 1996; International Air Transport Association, 1992), and all aviation accidents can be found to exhibit some form of human error as causal factor. The emphasis in finding a training solution to this problem was originally focused on the flight deck of aircraft, with early CRM courses known as cockpit resource management training. These programs embraced the maxim best articulated by Dr John Lauber in his definition of CRM as "the effective utilisation of all available resources - information, equipment and people - to achieve safe and efficient flight operations" (Lauber, 1984). The shortfall of such courses, and of the application of this definition is apparent with the benefit of some years of hindsight: they only addressed part of the problem, that which related solely to crew members working within the cockpit. In doing so they ignored the valuable contribution to safety and efficiency to be made by the inclusion of other personnel, particularly cabin crew, as an integral part of a flight's operating crew.

The exclusion of cabin crew from the core operational team is still widely practised today. While most airlines have now altered the nomenclature of their courses to reflect the fashionable transition to crew rather than cockpit resource management, for many companies only the name has changed, and CRM remains as a form of cockpit crew, rather than total crew, training (Hayward, 1995, 1997). This results in broad differences in the safety attitudes and knowledge of crew members (Merritt, 1993). However, in recent years, a greater understanding of the multiple causes which lie behind complex industrial accidents (Reason, 1990, 1991, 1993, in press) has led to a recognition that human factors knowledge and attitudes are important in all aspects of the aviation system. The case for including cabin crew as an integral component of a flight's operating crew is now well established (Hayward, 1993, 1995). The British Midland B737 accident at Kegworth (UK Air Accidents Investigation Branch, 1990) and that involving an Air Ontario F-28 on take-off at Dryden, Canada (Moshansky, 1992; 1995; Maurino, Reason, Johnston, & Lee, 1995) are classic case studies of the perils of
ineffective use of all available resources, and have been used to justify the integration of crew Emergency Procedures (EP) training at some air carriers (Baker & Frost, 1993; Chidester & Vaughn, 1994; Hayward, 1993). The salient feature of each of these accidents is that the operating crew were acting as two crews - one running the cockpit and the other the cabin - rather than one. This resulted in failure on the part of the cabin crew to inform the cockpit crew of vital information which may have prevented these accidents. This failure is an outcome of inappropriate technical training (National Transportation Safety Board, 1992; Transportation Safety Board of Canada, 1995; Chute & Wiener, 1996), which is in turn contributed to by a lack of awareness of the type and level of knowledge held by cabin crew, and misunderstanding of the roles and responsibilities of crew members.

Australian Airlines introduced a two-day Annual Proficiency Check Course (APCC) in 1991 which ran until the airlines merger with Qantas (where it continued under a new title). Developed from the original crew resource management ‘Aircrew Team Management’ program which was introduced in 1985, the course brought together 16 flight attendants and four technical crew for two days. The effect was significant; “Crew member cohesion and support developed where little previously existed, mostly out of ignorance generated by each group training in isolation.” (Baker & Frost, 1993)

The significance of this type of training is two-fold. Firstly the role of flight attendants as part of the operating crew is elevated such that interaction no longer stops at the cockpit door. This is not simply about making the aircraft a happier place to work (even if this has proved to be one side effect), rather extending the knowledge, skills and attitudes of all of the aircraft’s flight crew such that the safety net is widened. Even in the first two years of APCC, the trainers noted a difference in feedback from crews complaining about each other in the first year to relating more positive incidents of support (Baker & Frost, 1993). Although there are no comparative scientific appraisals of cabin crew knowledge, skills and attitudes currently available, the importance of the Australian Airlines (and subsequently Qantas and Ansett courses) is highlighted by a number of secondary indicators. These include the fact that the Australian course was one of the first in the world and the region is the only one in the world to have a Cabin Safety Working Group (which operates under the Australian and New Zealand Societies of Air Safety Investigators).

The second significant issue is the fact that both organisational and national cultures have allowed this type of training to take place. The role of flight attendants is something which means different things to different airlines. In the Australian carriers, the primary role of flight attendants is safety. “The basics that Qantas requires in the flight attendants must be safety.” (Jensen, 1988) Anecdotally, this has sometimes appeared to be at the expense of service quality. One expert witness suggested that ‘as a passenger on Qantas, he would be lucky if he got a cup of coffee thrown at him, but he knew damn well that in an emergency, the flight attendants would be there to throw him down the evacuation slide’.
The Australian Bureau of Industry Economics examined the performance of the Australian aviation industry in 1994 and examined differences in costs between the Australian carriers and their international competitors. Figure 5.2.1 lists salary levels for 1992 and demonstrates the difference between pilots and cabin crew. Although difference between locations may be expected because of the cost of living, this does not account for the level of disparity between pilot and cabin crew salaries. However, this may give an indication of the difference of role which is expected from each carrier; a factor which may well be cultural.

<table>
<thead>
<tr>
<th>Airline</th>
<th>Pilots Salary (US $)</th>
<th>Cabin Crew Salary (US $)</th>
<th>Cabin Crew as % of Pilots Salary</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Nippon</td>
<td>161,223</td>
<td>52,798</td>
<td>32.75</td>
</tr>
<tr>
<td>Swissair</td>
<td>191,352</td>
<td>48,515</td>
<td>25.35</td>
</tr>
<tr>
<td>SAS</td>
<td>125,643</td>
<td>59,625</td>
<td>47.46</td>
</tr>
<tr>
<td>Northwest</td>
<td>117,954</td>
<td>26,978</td>
<td>22.87</td>
</tr>
<tr>
<td>Delta</td>
<td>113,645</td>
<td>31,569</td>
<td>27.78</td>
</tr>
<tr>
<td>United</td>
<td>117,981</td>
<td>34,145</td>
<td>28.94</td>
</tr>
<tr>
<td>American</td>
<td>99,254</td>
<td>23,439</td>
<td>23.62</td>
</tr>
<tr>
<td>Cathay Pacific</td>
<td>241,881</td>
<td>30,104</td>
<td>12.45</td>
</tr>
<tr>
<td>Qantas</td>
<td>95,464</td>
<td>35,691</td>
<td>37.39</td>
</tr>
<tr>
<td>Air Canada</td>
<td>90,979</td>
<td>32,514</td>
<td>35.74</td>
</tr>
<tr>
<td>Continental</td>
<td>65,143</td>
<td>20,470</td>
<td>31.42</td>
</tr>
<tr>
<td>British Airways</td>
<td>106,464</td>
<td>29,408</td>
<td>29.62</td>
</tr>
<tr>
<td>Singapore</td>
<td>96,990</td>
<td>15,877</td>
<td>16.37</td>
</tr>
</tbody>
</table>

Figure 5.2.5.1 Airline Average Wages (US $) 1992  Source, BIE, 1994

The Scandinavian carrier, SAS has the lowest disparity with cabin crew earning 47.46% of the pilots salary. These represent feminist cultures where the emphasis is on quality of life and care of the weak. (Smith, Dugan and Trompenaars, 1994) The ‘anglo’ carriers in the US, UK, Canada and Australia all tend to be reasonably similar with cabin crew earning between 22.87% (Northwest) and 37.39% (Qantas) of the pilots salary. Finally, the Asian carriers have the greatest difference with Cathay cabin crew earning 12.45 and Singapore earning 16.37% of the pilots salary. These cultures are ones where male and female roles are traditional and strongly enforced; pilots are male and flight attendants are female. The role of cabin crew also tends to be aimed particularly at customer service and as such personnel tend to be recruited to be ‘pretty young things’ rather than as part of the safety team. The salaries reflect the difference in attitude and expectations towards the role of cabin crew. It is worth noting that behind SAS, Qantas cabin crew are paid the largest proportion of pilots salaries which correlates with the emphasis placed on their safety role.
5.3 Communications

The primary language of Australia is English which is also the preferred language of International aviation. As previously mentioned, it was the opinion of a series of expert witnesses that one of the most important factors behind Australia’s apparently good record was in the openness and unambiguity of communications. Cultural theory suggests that the low power-distance index rating for Australia would translate into ease of communication between ranks. The high level of individualism would also suggest that communication would tend to be direct which may mean by-passing formal communication channels where necessary.

To test the directness of communications within Australia, the following survey question was constructed:

**2.12 A senior manager introduces a new company rule you consider to be unsafe, which of the following statements best describes your actions?**

1. I would simply ignore the new rule; its my life.
2. I would complain about the rule to my colleagues.
3. I would complain about the rule to my union representative.
4. I would complain about the rule to my fleet manager.
5. I would complain directly to the manager responsible for the rule.

A further variation of the question was included for the military transport crews to represent the different operational environment:

**2.11 A senior officer introduces a new operating rule you consider to be unsafe, which of the following statements best describes your actions?**

1. I would simply ignore the new rule; its my life.
2. I would complain about the rule to my colleagues.
3. I would complain about the rule to my Wing Commander
4. I would complain directly to the officer responsible for the rule.
5. I would obey the rule as it is my job to obey the rules.

The answers are presented as follows;
The majority answer was quite clear. Qantas recorded 65% and Ansett Australia recorded 74% for the response that crew members would complain directly to the manager responsible. This is the answer predicted by anecdotal evidence before the survey. Max McGregor, Manager of Operational Safety for Ansett Australia suggested that in the event of the introduction of new operational rules, it was not uncommon for crew members to head straight for senior managers' offices if they disagreed with its philosophy. The difference between the Qantas and Ansett response may be explained by the geographical distribution of crews who may find themselves away from home base for up to two weeks at a time and therefore unable to approach senior management directly. It is also a much larger organisation with a commensurately larger management structure.
The true significance of the results only becomes apparent once compared to the British airline used as a comparison. Asked the same question as the Australian carriers, the response was as follows;

![Figure 5.3.3 Answers from British Airline Pilots](image)

Only 22% of British crew members would go directly to the manager responsible, demonstrating a marked tendency towards adhering to company hierarchy. This matches indications from existing cultural research although the magnitude of the disparity is greater than was expected. It is frustrating that the research did not have the resources to encompass comparative research groups from cultures which appear at the extremes of Hofstede’s cultural grids. This does, however, lay the groundwork for future research and it is hoped that these results provide a good basis for that work.

The majority of British pilots (46%) would go to their fleet manager whereas only 10% of Qantas Crew and 5% of Ansett Australia crews would claim to do this.

Another interesting indicator is the number of crew members who would action their grievance through the union. Only 5% of Australian crew members would utilise this channel in the first instance compared to 13% of British Crews. This points to the loss of faith suffered by the Australian pilots in their unions following the 1989 pilots dispute. (The strike led to a large number of domestic pilots losing their jobs.)

The British also seem more inclined to complain to their colleagues (8%) than the Australians (Qantas; 3%, Ansett; 2%). This would seem to fit with the cultural stereotype of ‘whingeing poms’ or rather of the slightly lower level of individualism that Hofstede’s grid assigned to the British over the Australians.
What is of concern is the high number of British airline pilots who claim that they would ignore the rule; a staggering 10%. This is in contrast to 0% from Qantas and 1% from Ansett. This suggests that the Australians are not willing to accept dangerous operational procedures without doing something about it. They will not ignore rules which is to be expected in the light of comments regarding the strict adherence to standard operation procedures.

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Which of the following best describes your actions? (RAAF Transport Crews)
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![Bar chart showing responses from RAAF Transport Pilots](image)

Military transport crews were expected to return a different set of answers and the question was constructed in such a way as to take account of this. The majority of pilots, again would go directly to the officer responsible for the new operational rule. Such direct communication is supported for flight safety matters and not considered to be insubordinate. The fact that 37% of the transport (generally non-combat) crew members would be prepared to obey rules they considered to be unsafe marks the contrast between military and civilian operations. Nevertheless, such a result was greeted with considerable surprise by the collection of Air Commodores and Acting Chief of Air Force Staff during the feedback stage of this research. This represents an organisational culture trait within the military that is not unexpected whereby junior rankings are expected to follow orders. However, the distinction between such compliance and the reaction to operational procedures (rather than tactical or strategic commands) is significant. Flight safety matters within the RAAF and Australian Defence Force (ADF) in general have received growing attention in recent years, not least in response to the loss of a B707 in a training accident in 1991 (DFS, 1994) and the Army Blackhawk Helicopter disaster in 1996. In the former accident, the instructor attempted to simulate an asymmetric two engine failure (both engines on the same wing) in the air which led to the subsequent loss of the aircraft and all of the crew.
5.3.1 Crew Resource Management Training

Crew Resource Management (CRM) first developed in the late 1970's as cockpit resource management through programmes run by United Airlines and KLM Royal Dutch Airlines. The original objective was to improve management of the cockpit especially following the 1977 Tenerife Air Disaster where the KLM Chief Training Pilot had taken the decision to take off in fog without air traffic clearance. Although the CVR tape revealed some concern from the subordinate crew within the KLM flight deck, there was no attempt to get the Captain to abort take-off and the ensuing crash claimed the lives of 583 souls. Original courses were based on business management training programmes (Härtel and Härtel, 1995) and have become ever more aviation specific over the last twenty years. The original courses also focussed almost exclusively on resources within the cockpit (Flight Safety Foundation, 1995) whereas modern courses aim to include “...extra-cockpit resources such as flight attendants and maintenance, air traffic control and dispatch personnel”. The latter development is now recognised in the working definitions of CRM.

Helmreich, one of the most respected experts in CRM, defines it as “the effective coordination and utilisation of all available resources in the service of flight. These resources are both inside and outside the aircraft and are both material and human, including especially the knowledge, judgment and decision-making skills of all crewmembers”. (Helmreich, 1987) In explaining the components of training required to achieve successful resource management, Diehl (1991) suggests, “Such programmes stress the importance of proper communications, division of responsibilities, leadership and teamwork”. The author contends that the synthesis of CRM and ADM (Aeronautical Decision Making) create an agenda of five key areas for instruction, namely:

- Attention Management
- Crew Management and Communications
- Stress Management
- Attitude Management
- Risk Management

However, one of the principle difficulties that has yet to be overcome in CRM training is how to assess the effectiveness of different courses or components of courses. Although the Flight Safety Foundation (1995) suggest that “...the importance of CRM has been demonstrated repeatedly in the performance (both positive and negative) of flightcrews during accidents”, there are actually very few metrics available. (Conclusion of Royal Aeronautical Society Human Factors Group, 1996). There are a number of anecdotal examples of aircraft that have been saved through the propitious use of CRM skills which are worth noting. For example, probably the most cited case involved a United Airlines DC10 which crash landed at Sioux City, Iowa with survivors, following what would previously have been deemed to be an unsurvivable loss of all hydraulic control lines.
However, most of these stories lack the sort of comparative data that may be required by the strict rules of empirical research. For example, the loss of B737 G-OBME at Kegworth, England in 1990 following the shut-down of a healthy engine is often held up as an example of where CRM could have saved the aircraft. While in theory this is probably true, it is impossible to make such a simplistic statement as ‘this accident would not have occurred if the crew had received CRM training’. The fact that crew members have been through a particular training course is no guarantee that they will take on board and actively use those skills. Returning to the example of the United Airlines DC10 crash at Sioux City; while the Captain of the aircraft now tours the world extolling the virtues of CRM as a way of operating, there were several factors involved in that accident that make it an extraordinary example. Firstly, the three man crew were augmented by an off-duty Check and Training Captain who administered the crucial thrust control and secondly, the performance of the crew was proved to be beyond any expectations. Following the accident, a number of other crews (all of which came from the same training background) were faced with a similar sequence of events in the flight simulator and none of them were able to land (or crash-land) the aircraft as successfully as the original crew. Whether this was a function of the individuals involved or the effect of adrenaline etc. on the actual day is beyond the realms of measurability.

Notwithstanding this, the general feeling is that CRM training is of very great value to the aviation industry. This is reflected in the number of programs which are now in place with major airlines and the move by certain regulatory authorities including the UK CAA to make the provision of such training mandatory. The 1997 Civil Aviation Safety Authority (Australia) Regulatory Review Process looks set to mandate some form of CRM training in all airlines involved in commercial flying. Prior to this, both Ansett and Qantas have established CRM training programs and more recently, Regional carriers including Eastern Australia, Kendell and Hazelton Airlines have been involved in setting up their own programs. It is now becoming standard practice to supplement CRM training for technical crew with courses that include flight attendants or pursers. This is sometimes done as part of recurrent emergency procedures training e.g. Qantas or as specific courses e.g. Ansett’s CAPS - Captains and Pursers CRM course. More recently moves have been afoot to introduce CRM or Human Factors type courses for Air Traffic Controllers (Airservices Australia), Engineering and Maintenance Crews (Qantas) and Ramp Staff (Qantas and Ansett).

Some of the problems that have been encountered when trying to translate the principles of CRM from its original host anglo culture indicate that certain aspects may need revision or change. For example, following successful introduction of CRM training to the major US carriers, an attempt was made to sell the training course to Asian airlines with the American trainers. Many of these countries represent areas of high power distance and collectivism (see Hofstede, 1990) and when faced with an American lecturer (who was therefore empowered by his position) telling them that communication within the flight deck should be open and without loss of face should a junior rank feel it necessary to correct his senior officer, then the crew members happily agreed. Although the initial thoughts of the course leaders was that the ideas were being accepted ‘because they made sense’, it was found that as soon as the senior
officers became empowered back in the aircraft then the system returned to the original 'the Captain is always right'.

As a further example, trainers that have worked in the South American countries (Argentina, Peru etc.) have complained that CRM training has empowered First Officers to such a level that followership is becoming a problem and all of the Captain's actions are being questioned. (ERAU CRM Developers Group Discussion).

However, an important question is how dependent upon the organisational culture of the host airline or indeed national culture of the host nation, the success of CRM training actually is? To answer this, it is necessary to look at the fundamentals of what such training is trying to achieve and in simple terms, that is a shift in attitude away from working as a set of individuals to performing as a team. Ansett's Ramp Resource Management course teaches its staff that it is better to be part of a champion team than to be a team of champions.

Does this shift in emphasis from individual performance to group performance go against the strong cultural dimensions of individualism or power-distance? This is a question which is difficult to answer without significant multi-cultural investigation. However, it is worth asking some of the questions here, partly to encourage further research and also to suggest explanations for the variability in acceptance of CRM.

**Individualism; (How an individual perceives themself relative to the rest of society)**

This dimension may explain more about the need for CRM training than just its variability of success. Highly individualistic nations ascribe success to the performance of the individual rather than of the group. Even in areas where group performance is supposed to be very important such as in sport teams, there is a tendency to elevate key individuals. For example, the level of hero worshipping for individuals such as Alan Shearer (UK, Soccer) or Michael Jordan (USA, Basketball) highlights this process. Although civil aviation has long since required multi-crew on large aircraft, it still bases flight training solely on individual performance. This is not necessarily a bad thing, but has implications for the ease of introduction of training such as CRM.

Wolfe's (1979) legendary work 'The Right Stuff' which charted the progress of USAF Test Pilots up to the implementation of the Apollo Space Program, has been largely responsible for highlighting an industry stereotype known as 'the right stuff'. This description captures the 'gung-ho' macho mindset of a group of pilots who believed that 'the right stuff' was either something they naturally had, or didn't. Those who were killed in flight, for whatever reason, were deemed to have the wrong stuff. Whether this was a strategy for dealing with grief or hiding fear is a matter for psychology to tackle, but it has become the epitome of what CRM is trying to cure. Recruitment still attracts this model of pilot, not least because the recruitment process has not evolved to select out such traits and interviews are often conducted by a generation of pilots which remain cynical to the benefits of CRM.
Does individualism affect the ability of pilots to work as a team and thereby embrace the principles of CRM? If that question could be answered then it may give some light as to how much CRM is needed in different airlines or countries. It is possible that some of the cynicism towards its introduction is based upon already applying the principles in normal operations.

On an observation flight between Singapore and London on a Qantas B747-400, the Captain was heard to explain that he thought "...CRM was a load of crap". As the observer remained on the flight deck for most of the sector, he looked for signs of good or bad CRM. The Captain was not aware that he was under such examination and neither was the exercise conducted using an evaluation tool (such as NASA/UT’s Line LOS Checklist). However, it was clear that in normal operations, the Captain was embracing the principles of CRM admirably. This included open and friendly communications with a new female Second Officer who was part of the four-strong crew. Whilst it is impossible to suggest that this behaviour would necessarily be replicated under a high pressure, safety critical situation, it did highlight the possibility that the principles of CRM were being used as standard ‘airmanship’ and as such was not something he needed re-teaching. This represents one of the lesser referred to side-effects of CRM; that is the risk of alienating the believers. Helmreich (1992) refers to ‘Boomerangs’ - non-believing pilots who do not respond to CRM training and as such, perhaps an awareness of ‘positive boomerangs’ - believing pilots who do not respond to CRM training, is required?

Power-Distance; (How a subordinate perceives themself relative to their manager)

CRM attempts to improve team performance through the opening of communication channels. This is achieved through the training of ‘appropriate assertion’ and other related communication techniques. Crew members are made aware of the technicalities of style from the role of body language and written word, to the use of empowered phraseology such as ‘Captain, you must listen!’ which is used by Qantas as a final level of assertive upward communication. Cultural research has demonstrated that the process of communication between ranks is not just dependent on the structure of formal communication systems, but also the cultural context it operates within. The concept of Hofstede’s Power-Distance index is based on national culture difference rather than organisational and yet indicates the relative ease of which communications can occur.

Australia records a low Power-Distance ratio such that questioning of authority is not necessarily disrespectful or causes loss of face. This is in contrast to countries such as Japan or China where respect for seniors can literally become a situation of life or death. In an incident where the Captain of a Japanese DC-8 decided to kill himself by flying his aircraft into Tokyo Bay, the First Officer is known to have politely requested the Captain not to do so as crashing the plane may damage the company’s aircraft or harm the passengers in First Class. At no point did the First Officer attempt to take over the controls or even raise his voice and the aircraft subsequently crashed.
An important aspect of organisational culture within Qantas was the empowerment of junior crew members through standard operational procedures (SOP’s). The most frequently cited example is often considered to be reflective of national cultural traits, although deeper investigation suggests this is only part of the explanation: Qantas has always carried Second Officers (S/O’s) on the flight decks of its international jet aircraft (B707, B747, B767) to fulfil several roles. These included training and the accumulation of flying hours and as relief pilot in the cruise phase on long distance routes. The Second Officer is a licenced air transport pilot, but will only fly the aircraft in cruise until reaching the rank of First Officer (F/O). A test of the power gradient on the flight deck is the ease of which junior crew members can speak up if they believe their senior crew members have made a mistake. A number of expert witnesses highlighted the fact that junior crew members on Australian flight decks are able to speak up in this way without fear of reprisal or causing loss of face to the senior crew member. (Lewis, 1995; Green, 1994)

The reasons for this appear to be two-fold. Namely that cross checking of senior crew members by the second officer was proceduralised within standard operational procedures as being part of their role and that the national culture context was relaxed enough to allow this rule to work. Although Terrell (1995) suggests that the rule was introduced partly “…to give Second Officers something to do...” in long, uneventful cruise phases, there was an early recognition within Australia of the benefits of a skill which CRM has tried to encompass; namely that of cross checking of crew members actions. Ashford (1994) highlighted the fact that in 54% of 118 large-jet accidents, there was inadequate cross-checking by other crewmembers.

Due to the mix of domestic and international flights that Qantas now operate, especially using the B767, the role of the Second Officer no longer explicitly dictates that the cross-checking of flying pilots. However, it is a practice that is firmly entrenched in the company’s culture and done as a matter of routine. This is a good example of where an aspect of company culture has been established over time and remains in place even after written procedure has been changed. The procedure of cross checking did not disappear from print because it was thought to be obsolete or incorrect, but because the activity was now inherent to the way that a Qantas Flight Deck was operated. It is reinforced by the CRM training process and attitudes of senior crew members.
5.3.2 Organisational / Industry Structure

A significant factor which both affects, and is affected by communications is the structure of organisations, and indeed, the industry that a particular organisation may find itself operating within. As there are very few unknown accident types, only variations on original themes, it seems fair to assume that repetitions occur because individuals possess incomplete or inaccurate information. There are few unsolved accidents so why does the industry keep making them?

Short term, selective memory is not unique to the aviation industry. Beaty (1995) highlights the "...need to look at mistakes in a much wider context instead of in constrained and separated specialist enclaves with little communication between. ...Individual expertise in the different environments of air, sea, road, rail and ground are of course essential, but a connection between them and a cross-fertilisation of information on the pivot of a corporate understanding of human factors needs to be established." This is because not only are similar, systemic and organisational failures occurring across different modes, but also there are lessons that have already been learned elsewhere which do not need recreating. Reason's (1992) examination of organisational accidents derived from a general psychology background to see the same sort of latent defects and active failures occurring in accidents as diverse as the Bhopal Union Carbide Chemical Works Disaster, The Challenger Space Shuttle loss and the Kings Cross Underground Station Fire.

The quality of communications at organisational level are affected by a number of different variables, not least the structure of the organisation. The format and quality of formal communication channels is important and yet the informal communication structure can also be of vital importance. Trompenaars' study of cultural diversity in business (Trompenaars, 1993) suggested that organisational structures could be expressed using simple triangles. The height of the triangles gives a graphical representation of how individuals perceive the company they worked for. Steep triangles represented those organisations with a steep hierarchy of many levels of management where communications may become stifled by the grades they need to transcend. Studies of CRM in different cultural environments demonstrate how national cultural traits have directly affected the hierarchical structure on the aircraft; a process which is replicated within the rest of the operation.

The issues here are twofold; namely the effect of national culture on hierarchy and communications and the effect of organisational structure (which in turn may be directly influenced by national culture.) The former has been discussed in considerable detail in previous sections. The safety (efficiency) message in the case of organisational communications is a simple one; that the corporate structure must be set up to facilitate and encourage open communication. FAA Assistant Administrator for System Safety, Christopher Hart (Male, 1997) "...believes that the only way of further reducing airline accident rates is the sharing of safety information." In other words, the expertise is generally in place, it is just not
communicated to the right people at the right time.

However, even if communication channels appear to be in place, the integrity of data needs to be assured. Bent (1997) suggests that "Without data, you are just another person with an opinion" and yet all too often 'fact' is apparently borne out of enough people saying the same thing (Braithwaite, 1997). While a commitment to the goal of 'safety first' may be common, the level of commitment varies between individuals and organisations. Accidents only occur when decision makers have perceived risk taking decisions to be acceptable in terms of safety. "People respond to the hazards they perceive." (Slovic, Fischhoff and Lichtenstein, 1980) and consequently if these "...perceptions are faulty, efforts at public and environmental protection are likely to be misdirected." Perceptions are the result of a number of direct and indirect processes that range from formal education to observations and life experiences. Whether right or wrong, it is often perceptions that risk taking decisions are made on.

Efficient and effective communication is the key to avoiding misperception. Efficiency is assured through establishing channels of communication in the organisational structure and the way in which communication is encouraged. Qantas' (1995) Crew Resource Management course suggests the following list of effective communication rules, some of which translate directly to the question of organisational structure;

a) Be descriptive, specific and non-judgmental in reply
b) Choose an appropriate time and place
c) Tailor the length and content of communications to suit the occasion
d) Create an environment which encourages people to communicate
e) Avoid ambiguity

Figure 5.3.5 Rules of Effective Communication Qantas, 1995

a) Be descriptive, specific and non-judgmental in reply: This reflects the need for any communication to contain the correct information and is a function of both formal communication systems (such in incident reporting forms) and the organisation culture in the form of precedence. Judgmentalism may also be a function of this and can be influenced to a degree by traits of national culture.

b) Choose an appropriate time and place: Formal communications structures such as forums or meetings may provide an appropriate time and place, but need support to be arranged and should be backed up with other informal channels. For example, communication between Ansett and Qantas Safety Departments is continuous regardless of when official forums such as the Australasian Flight Safety Council may meet. This process can be hampered by geography - Australian Airlines and Ansett were based in Melbourne and Qantas in Sydney although advances in telecommunications and the availability of travel have helped this. More of a problem exists when dealing with international concerns such as airframe or
engine manufacturers and other operators. This has always been the case in Australia which from the start of European settlement depended on Europe and the USA for a technological lead. However, the extreme delay in communication at this early stage forced the need for self-dependency which in turn had an effect on how the Australian industry dealt with problems. Expertise within the Australian system was developed to cope with both the spatial separation and time-zone differences which exist.

c) **Tailor the length and content of communications to suit the occasion;** One of the main problems for effective communication is making sure the important aspects of the message get through. In transport operations, this becomes even more important when information may be time critical. For example a go-around command or collision avoidance call may need an instantaneous reaction and the aviation industry has constructed standard phraseology to allow this to happen. As English is the common language of aviation, there is an extra margin of safety afforded to individuals where English is their first language. For example in the 1977 Los Rodeos accident where two KLM and Pan American B747’s collided on the runway, the First Officer uttered a non-sensical reply to the Air Traffic Controller when asked about his status. The Controller had instructed the KLM B747 to hold at the departure threshold, but the KLM Captain elected to take-off without clearance. The phrase “We are now at takeoff” was intended to mean “We are now taking off” whereas the controller interpreted it as “We are now ready for the takeoff”. (Cushing, 1994).

Airlines train both standard phraseology for use with technical communications (such as to the air traffic control tower) and in other situations. Qantas ensure that junior crewmembers feel empowered to speak up in a conflict situation through aspects of its CRM training course. Appropriate assertion is taught as a skill and supplemented by a ‘last resort’ power phrase which is “Captain, You must listen!” whereby any crew-member can guarantee the attention of the aircraft captain. Similar phrases exist for use in other situations such as hijacking. Such a proceduralised approach is the exception rather than the norm and is reflective of the need to support practices with official procedure.

d) **Create an environment which encourages people to communicate;** Even where a formal structure is put in place to facilitate effective communication, organisational practices can mean that the objective is not met. For example, mandatory incident reporting can suffer from lack of reporting when individuals perceive that the process does not offer them anything in return (i.e. lack of feedback). Encouragement may be in the form of financial support e.g. to attend conferences, working groups or forums or may be through training courses such as CRM or Operational Teamskills (Ansett’s version of company wide CRM type training) where the need and methodology for inter- and intra-group communications are highlighted. Openness in communication is a strength in Australia and within the Australian aviation industry which exists at a cultural level. As such it may the environment which encourages communication may be invisible, except under close comparison.
e) Avoid ambiguity; Ambiguity can be the result of incomplete knowledge or understanding or may be the result of poorly phrased or translated messages. It can be avoided through attention to detail in ab initio and recurrent training, a developed systems knowledge and through structured communications protocol. The latter may be in terms of form design for written systems or standard phraseology for verbal communications. Whereas English speakers have an advantage in the fact that it is the preferred language of aviation, it is also an ambiguous language. “Ambiguity is an ever present source of potential (air-ground) misunderstandings.” (Cushing, 1994) Simplified standard operational procedures are designed to reduce this risk although experience with the introduction of SIDs (Standard Instrument Departures) and STARs (Standard Arrival Routes) demonstrated that unless standard procedures are exactly that, they are prone to misinterpretation. Australia is certainly not immune to risk from deficient communication as recent accidents have shown. It is important for operators to recognise the strengths of the existing system and fortify them if safety is to be maintained.

As mentioned above, organisational structure plays an important role in facilitating communication and therefore in assuring operational effectiveness. Over and above this is the role played by the industry structure which may be influenced by a number of geographic, economic and social factors.

5.3.2.1 Industry Structure

Australia represents a small population divided over a large surface area which in turn has led to one of the lowest areas of population density in the world. The entire population of Australia is roughly equivalent to the number of people contained within the London M25 Orbital Motorway on a week day spread over a land mass roughly equivalent to continental USA. As such it is relatively unique and has an aviation industry which is commensurately different. This is not simply a feature of the historical influences of geography and demographics, but also the influences of political phenomena such as the two airline policy and economic forces. To what degree the structure of the aviation industry has played a role in safety is difficult to quantify, yet is worth consideration to better understand the mechanisms of systemic safety.

Communication between the major carriers on matters of safety has always been good. (Lewis, 1994; McGregor, 1994) Although Australian Airlines (and latterly Qantas) and Ansett were always in competition, their safety professionals worked together, not least because of their geographical isolation from other similar carriers and aircraft manufacturers. Co-operation existed on a formal level through bodies such as the Australasian Flight Safety Council and the Australian Society of Air Safety Investigators and at an informal level between individuals from each carrier. Ansett Manager, Flight Safety, Australian Airlines Manager, Flight Safety and Qantas, Head of Safety and Environment would talk to each other all but every day, even at times when their relative commercial departments were locking their corporate antlers.
When an Ansett BAe 146 suffered a four engine roll-back in unusually warm air at high altitude near Meekatharra, WA, the Ansett Manager, Flight Safety not only contacted the Regulatory Authority, but also contacted his opposite number at Qantas. Regional services operated on behalf of Qantas by Airlink utilised BAe 146 aircraft and both Ansett and Qantas voluntarily imposed a maximum operating ceiling on the aircraft type well before the CAA made any such recommendation. This is but one example of similar positive action well before the regulator made a move.

Their is a friendly rivalry in existence between the two safety departments which allows them to co-operate rather than conspire. When the Ansett B747-300 VH-INH landed at Sydney Airport with its nose wheel retracted in full view of the Qantas Safety Department, there was a genuine rush to communicate the news to the Ansett Manager, Flight Safety. Once it had been established that no-one had been injured, the communications became perfect examples of Australian ‘larrakin irreverence’.

Unfortunately, communication within and from the CAA was severely damaged by the reforms of the late 1980's and early 1990's. Within the organisation, the reaction was one of “...uncertainty, fear, resentment and antagonism towards senior management and between CAA staff.” (HORSCOTCI, 1995) These were hardly the best conditions for good communications at a time when both the organisation and the aviation industry were experiencing severe change. Westrum (1995) writes that “aviation organisations require information flow as much as aircraft require fuel.” Infighting within departments about management positions was rife, particularly in the Safety Regulation and Standards (SR&S) division and between air traffic controllers and flight service officers. One of its former chief airworthiness surveyors, Laurie Foley commented that “...the culture of the organisation is the basic problem. ...Until you change the basic culture of the organisation, you won’t fix the problem. The recipe might have changed, but the ingredients have stayed the same.” (The Australian, 1995)

Direct communications from the Board Chairman, Dick Smith were extreme examples of the Australian cultural trait. A number of CAA employees, who wished to be deidentified, cited examples of receiving phonecalls from the Chairmen telling them to do something. When they tried to explain why items were technically impossible, their protests fell on deaf ears. Arthur Jeeves, an airworthiness inspector with the CAA told the HORSCOTCI that staff who did not share Smith’s vision were told that they should leave. “His dictum was both fundamentalist and amateurish but he had the support of the minister of the day and the die was cast. Those who dissented were virtually driven out.” (Herald Sun, 1995)

Poor communications between the CAA and industry were highlighted in the Seaview and Monarch accidents as findings in the BASI investigations. In the case of the Monarch accidents the report stated that “Latent organisational failures identified within the CAA included ineffective communications between the local CAA District Office and Monarch.” (BASI, 1994). In the Seaview accident, the report observed that in relation to the surveillance
activities of the CAA, "deficiencies were treated in isolation from those which had previously been identified" (BASI, 1996). One of the reasons for this was likely to have been the fact that "CAA district offices displayed significant differences in their respective operating practices". These examples highlight the incoherence of an organisation in poor health and are perfect examples of the precursors or latent defects highlighted in the Reason model (Reason, 1990).

Hayward (1997) illustrates the three distinctive patterns of aviation organisations as suggested by Westrum (1993, 1995) (pathological, bureaucratic and generative) using a chart of basic organisational communication styles.

<table>
<thead>
<tr>
<th>Pathological</th>
<th>Bureaucratic</th>
<th>Generative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information is personal</td>
<td>Information is routine</td>
<td>Information is seen as a key</td>
</tr>
<tr>
<td>personal power</td>
<td>Responsibility is</td>
<td>resource</td>
</tr>
<tr>
<td></td>
<td>compartmented</td>
<td>Responsibility is</td>
</tr>
<tr>
<td></td>
<td></td>
<td>shared</td>
</tr>
<tr>
<td>Responsibility is shirked</td>
<td>Messengers are listened to</td>
<td>Messengers are</td>
</tr>
<tr>
<td></td>
<td>if they arrive</td>
<td>trained</td>
</tr>
<tr>
<td>Messengers are shot</td>
<td>Bridging is tolerated</td>
<td>Bridging is rewarded</td>
</tr>
<tr>
<td>Bridging is discouraged</td>
<td>Organisation is just and</td>
<td>Failure leads to inquiry /</td>
</tr>
<tr>
<td></td>
<td>fair</td>
<td>learning</td>
</tr>
<tr>
<td>Failure is punished or</td>
<td>New ideas are present</td>
<td>New ideas are</td>
</tr>
<tr>
<td>covered up</td>
<td>problems</td>
<td>welcomed</td>
</tr>
<tr>
<td>New ideas are actively</td>
<td></td>
<td></td>
</tr>
<tr>
<td>crushed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 5.3.6 Basic Organisational Communication Styles Redrawn from Hayward, 1997

Activities within the troubled CAA represented a pathological style; information became personal power in the course of infighting and power struggles within the SR&S and air traffic services divisions. Messengers were metaphorically shot if they disagreed with the high level changes and directives and failure was covered up either through naivety, overwork or the desire not to be the messenger of bad tidings.

On the other hand, communications within the major airlines tended more towards a bureaucratic or generative system. Information as a key resource is embraced through the principles of crew resource management which in turn has been shown to be as much a function of organisational culture as it is a separate safety initiative. A good example of how failure leads to inquiry / learning is provided by the Qantas Engineering and Maintenance Department. Human Factors incidents are examined through a 'no-blame' inquiry. Following
an incident, personnel who may have been involved are invited along to a hearing which is made up of management representatives from Engineering and Maintenance and the Safety Departments, and the trade union. The interview is designed solely to establish what went wrong so that reoccurrence can be prevented through retraining or change of procedure. It is a process that is entirely separate from any investigation that may be conducted by BASI and is predominantly used for events which would not warrant a formal investigation by the Bureau. The system works because it is non-punitive in nature and allows all concerned to express ways to prevent future incidents. In this way, new ideas can be communicated between shop floor and management.

More recently, BASI has introduced a proactive safety program for regional airlines called INDICATE (Identifying Needed Defences in the Civil Aviation Transport Environment) which allows airlines to "...critically evaluate and continually improve the strength of their safety system" (BASI, 1996). This is accomplished by the use of focus groups and has been successfully implemented at Kendell Airlines (a wholly owned subsidiary of Ansett Australia) and is to be introduced at a number of other regional carriers in 1997. The importance of this issue is that it highlights organisational traits that needed to be present for airlines to agree to participate in the first place. Generative organisations welcome new ideas, information is seen as a key resource and failure leads to inquiry and learning (Westrum, 1995). The fact that Kendell and therefore its parent company, Ansett was prepared to participate (and actively support) the INDICATE program is evidence of a Generative organisational communication style.
5.4 Political Influence

Aviation importance as a transport mode within Australia is second only to road transport (BIE, 1994) and boasts an output which is as large as both rail and water transport combined. In 1992 the air transport industry employed 36,000 people with an additional 7,800 people employed in industries supplying services to the industry (e.g. airports and navigation). At $4,430 million (1990 prices), the output of the air transport industry in 1992-93 represented 1.2% of Gross Domestic Product (GDP).

It is an industry which is primarily involved in the movement of passengers, but with an important role in moving high value, time sensitive freight; a sector which has been growing at approximately 20% per annum. In terms of domestic travel, air represents only 35% of all interstate trips (BIE, 1994), yet it accounts for just under 100% of international trips (BTR, 1993; ABS, 1993).

The monopolistic position of aviation as the mode of international passenger travel assures a high political profile for aviation. This is the case in most developed industrial nations, especially in terms of medium and long range trips, but particularly so for Australia because of its size and distance from other countries. International trade is highly dependent on air travel because of this reason, as is domestic interstate business which is "...a relatively intensive user of domestic passenger airline services." (BIE, 1994)

This section highlights some of the political issues behind aviation safety in Australia whilst attempting to avoid becoming distracted by micro political issues which may be linked indirectly with safety. As such, the priority of aviation in Australian political life is considered, as is the role of the regulator; a subject of vociferous debate within Australia over the last few years. The role of the Bureau of Air Safety Investigation is also considered, not least because of its uniquely proactive approach to aviation safety.

5.4.1 Priorities for Aviation

A high priority for aviation is Australian society has been assured through historical and geographical reasons. These included the profile of Australia's trading partners, which were concentrated mainly in the North Atlantic, and the so called 'tyranny of distance' that existed both within Australia and in terms of its international location. Aviation brought the opportunity for a high speed transport link that could not be achieved by any mode of land transportation and as a result made its success a very political issue. Aviation has become depended upon within Australia to a level which is unusual amongst developed nations. Not only does geography dictate a strong trade need, but it has also made the provision of services such as the Royal Australian Flying Doctors Service a fundamental part of the social structure.
The high level of political interest can be noted through regulatory issues such as the ‘Two Airline Policy’ and the strong intervention surrounding the Monarch and Seaview crashes. Both of these issues will be discussed within this section.

However, it is first worth noting the position of air transport as a modal choice within Australia. As it is Business travellers who account for the largest proportion of RPT-level airline income and therefore also possess a great deal of political weight, it is worth considering their views regarding aviation’s attributes within Australia.

In 1993, the Bureau of Industry Economics (BIE, 1994) surveyed 84 members of the Business Council of Australia regarding the most important aspects of aviation services. The results are summarised as follows;

### Business Assessment of Attributes of Air Passenger Services, 1993

(average scores out of 10, ascending scale)

<table>
<thead>
<tr>
<th>Aspects of service quality</th>
<th>International</th>
<th>Domestic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Importance</td>
<td>Australia</td>
</tr>
<tr>
<td>Safety</td>
<td>8.3</td>
<td>8.2</td>
</tr>
<tr>
<td>Timeliness on arrival</td>
<td>8.2</td>
<td>6.9</td>
</tr>
<tr>
<td>Timeliness on departure</td>
<td>7.8</td>
<td>6.9</td>
</tr>
<tr>
<td>Flight time</td>
<td>7.4</td>
<td>7.1</td>
</tr>
<tr>
<td>Comfort</td>
<td>7.4</td>
<td>7.6</td>
</tr>
<tr>
<td>Clearance time: baggage</td>
<td>7.3</td>
<td>5.4</td>
</tr>
<tr>
<td>Clearance time: check in</td>
<td>7.2</td>
<td>6.1</td>
</tr>
<tr>
<td>Fares</td>
<td>7.2</td>
<td>5.0</td>
</tr>
<tr>
<td>Frequency of service</td>
<td>7.1</td>
<td>6.6</td>
</tr>
<tr>
<td>Clearance time: immigration</td>
<td>7.1</td>
<td>6.0</td>
</tr>
<tr>
<td>Clearance time: customs</td>
<td>6.9</td>
<td>6.0</td>
</tr>
<tr>
<td>Airport services and facilities</td>
<td>6.5</td>
<td>6.2</td>
</tr>
<tr>
<td>Courtesy of staff</td>
<td>6.4</td>
<td>6.7</td>
</tr>
<tr>
<td>Liability coverage</td>
<td>5.7</td>
<td>5.9</td>
</tr>
<tr>
<td>Claims procedures</td>
<td>5.2</td>
<td>5.6</td>
</tr>
<tr>
<td>Average</td>
<td>6.4</td>
<td>6.4</td>
</tr>
</tbody>
</table>

Figure 5.4.1.1 Redrawn from Bureau of Industry Economics, 1994

Safety was rated very highly in both importance and Australia’s performance. For international travel it was considered to be the most important factor and the ranking indicates a high level of satisfaction. For domestic travel, the importance of safety was considered to be the third most important factor being clearance time: check in and timeliness of arrival. Australia’s performance for safety was rated above its importance ranking, second only to clearance time: check in.

There is an apparent disparity between the importance ranking of safety for domestic and international travel. While both score very highly, time issues become more important for domestic travel. This may hint towards expectations regarding safety within Australia which are higher than for certain overseas routes or carriers.
5.4.2 Role of Regulator

The Australian Government took control of civil aviation in 1919 (the Americans did not start until 1926) and in its early years was the responsibility of various departments including the Department of Defence, Department of Civil Aviation and Federal Departments such as Transport and Aviation. (Keith, 1997) The first Controller of Aviation, Colonel Horace Brinsmead, was appointed in 1921 to "...bring order into this new method of transport, which unless controlled and given guidance and orderliness, could set itself back many years." (Buddee, 1978) The Civil Aviation Branch operated within the Department of Defence until 1938, when the Department of Civil Aviation (DCA) was created. The DCA controlled civil aviation in Australia until 1973, when it merged with the Department of Transport. (CASA, 1997) In 1982, responsibility for civil aviation was removed from the Department of Transport, placed under a new Ministry and re-named the Department of Aviation.

Australia was a founding member of the International Civil Aviation Organisation (ICAO) and has been represented on its council since its inception at the 1944 Chicago Convention. It is also a foundation member of the South Pacific Air Transport Council. (Buddee, 1978). Australia has generally based its national requirement on the US Federal Aviation Regulations (FARs) and the UK British Civil Aviation Requirements (BCARs) and the differences are quite minimal. (Dunn, 1988) Reasons for not adopting regulations directly from the much larger US FAA include the concept of Grandfather rights whereby "...aircraft and their derivatives can remain in production almost indefinitely and still only be required to meet the original design standards" (Dunn, 1988) For example, this applied to the Boeing 737 which was launched as the -1/200 series as a non-glass cockpit aircraft and evolved to the glass cockpit -4/500 series.

The 1977 Domestic Air Transport Policy Review (Department of Transport, 1979) noted that "...there had been little debate on the role of the Government in safety regulation". Industry Commentators tended to focus primarily upon the economic considerations of the regulatory structure. Advocates for the deregulation of the domestic air transport industry suggested that "the Australian regulatory system can be criticised for its lack of competition, minimal innovation, poor consumer choice, and high costs and fares" (Albon and Kirby, 1983; Kirby, 1979; Forsyth and Hocking, 1980; Findlay, Kirby, Gallagher, Forsyth, Starkie, Starrs and Gannon, 1984). However, minimal coverage is given to the safety implications of the existing system and any proposed shift towards US style deregulation. Findlay et al. (1984) acknowledge that "...statistics regarding air safety must be interpreted with care..." yet base their argument against "...exaggerated claims of some commentators that deregulation will necessarily result in a lowering of air safety standards" on the following logic;

"In 1980 the total accident rate for certificated carriers was 0.221 accidents per 100,000 hours, the best result on record. In 1982 the rate was only 5% higher and the second best result of the last decade. In terms of fatalities per 100 million passenger miles flown, the average for the period 1977 to 1982 was less than half the average for the period 1971 to 1976. Similarly, in 1982 the commuter industry recorded the lowest total and fatal accident rates in the eight years for which statistics have been available."
The summary carefully ignores the general improvement in air safety that may be expected over time. This includes the effect of the introduction of human factors training from the early 1980's and the introduction of Ground Proximity Warning Systems (GPWS) in the late 1970's. As controlled flight into terrain (CFIT) remains the largest cause of fatalities in aviation, the impact of prevention strategies such as GPWS on the accident record cannot be ignored. Whilst the figures do not support any doomsday scenario regarding degradation of safety within the deregulated system, they do not paint a convincing picture of improvement either. Lowering of air safety standards does not necessarily equate to hard statistics in the form of accidents. A deeper examination may show an increase in regulatory violations and a general trend towards reduced margins of safety.

The 1977 Domestic Air Transport Policy Review (Department of Transport, 1979) also notes that within Australia, "...the safety and expedition of aircraft operations is dependent on many factors including the nature, reliability and integrity of the aviation infrastructure." The authors add that "Because the infrastructure forms an essential part of the operation of the air transport industry, the Government, through its development and provision of most of the infrastructure, can exercise a significant degree of regulation on the industry." Such a statement remained almost unique in emphasising the regulator's safety role when discussing economics. The experiences of the 1990's to be discussed below indicate some of the shortsightedness that seemed to go hand in hand with the focus towards economic regulation.

The Civil Aviation Authority was created in 1988 by moving airport responsibility to the newly created Federal Airports Corporation (FAC). In 1990, the CAA became a Government Business Enterprise which was tasked with covering its own operating costs. This was done through fees collected for airways and terminal use and an avgas levy for private pilots. Although the capital investment afforded through this restructuring was dramatic (capital investment increased threefold during the first year), it was not without some severe organisational shrinkage. During the first year alone $57 million was paid out in severance settlements. (Proctor, 1993) This equated to the closure of five air traffic control towers and the replacement of face-to-face weather briefings at small airports with telephone and fax links. The 1991 Review of Resources sought to streamline the CAA further by over 50% from 7,332 in 1991 to 3,641 in 1996. In the Safety Regulation and Standards Division this meant it would lose over 40% of its staff within seven months - from 727 employees to 434. (HORSCOTCI, 1995)

The repercussions of the Review of Resources (RoR) were significant and far reaching. The HORSCOTCI (1995) review noted that it "...challenged entrenched power structures and cultures within the Authority", but the effects in terms of safety were planted as latent defects in an hitherto safe system. The change in focus towards core businesses and to reduce the cost for its 'customers' was to result in the revision or removal of regulations. All this occurred at a time when the organisation was enduring significant 'shrinking pains' in terms of individual's roles and a general crisis of confidence.
Whilst there is general consensus that a review of resources was necessary to reduce red tape and excessive bureaucracy, "...the overwhelming reaction to the changes from within the CAA was one of uncertainty, fear, resentment and antagonism towards senior management and between CAA staff." (HORSCOTCI, 1995)

![Review of Resources - Planned Staff Requirements](image)

Figure 5.4.2.1 Redrawn from HORSCOTCI, 1995

The Air Safety Regulation Review Task force released its second report on Air Safety Regulation Issues in May 1990 (CAA, 1990) and made grave warnings about the current Australian situation;

"There are currently limited national directions in regard to surveillance procedures and methodology and Regions are left largely to themselves as to the depth and direction this activity takes. No surveillance training is carried out and the quality, scope and techniques used depends mainly on individual talents and abilities of operational staff."

The Terrell Report (CAA Board Safety Committee, 1993) observed that "...the RoR reductions were initiated at the same time as the Division and industry were facing a period of unprecedented and rapid change which required the Division to be at a peak of effectiveness and able to lead the industry through the transition period. RoR documents and the outcome of this study indicate that cuts in the Division’s resources were made without regard to this imperative." In assessing this period of the CAA’s existence, the HORSCOTCI (1995) report described feelings towards it as representing "...the ‘dark ages’ of aviation safety regulation in Australia or the ‘slash and burn’ period of safety regulation. This was the period when (Dick) Smith was chairman of the CAA."
On 6th July 1995, the Civil Aviation Act was amended to create two bodies from the old CAA; namely the Civil Aviation Safety Authority (CASA) and AirServices Australia. The former body is an independent safety regulatory authority while the latter responsible for airspace management and the provision of navigation and RFFS facilities. CASA is no longer a Government Business Enterprise and is entirely funded through the Government. This change, in response to the Monarch and Seaview accidents "...sent a clear signal that the Government wanted the appropriate focus given to air safety." (Keith, 1997)

5.4.2.1 Unable to Regulate? - Two Case Studies

The following case studies demonstrate how the emphasis of the now defunct CAA has been found to have been misplaced. Whilst both accidents had a number of contributory factors behind them, they also demonstrated similar problems with the ability of the CAA to carry out its function as regulator.

Example One; Piper Chieftain at Young

On 11th June 1993, Piper Navajo Chieftain aircraft VH-NDU struck terrain and crashed on approach to the aerodrome at Young, NSW with the loss of seven souls. The aircraft was operated by Monarch Airlines as an regular public transport service. The subsequent investigation by the Bureau of Air Safety Investigation (BASI) highlighted numerous deficiencies within the airline and the regulator and became the catalyst for the launch of the House of Representatives Standing Committee on Transport, Communications and Infrastructure's Inquiry into Aviation Safety in the Commuter and General Aviation Sectors (HORSCOTCI, 1995).

In line with BASI's policy not to specify a primary cause, they published 34 findings and 8 significant factors which described the events behind the accident. Although the accident appeared to be a classic controlled flight into terrain (CFIT) accident during an unstabilised approach, BASI highlighted a number of organisational deficiencies within both the airline (significant factor 7.) and in the regulatory activities of the CAA (significant factor 8.).

The findings specific to the CAA are documented below (BASI, 1994);

### BASI - Selected Findings - Monarch

29. *Latent organisational failures identified within the CAA included;*

a. a difference between the corporate mission statement of the Authority, which placed a clear primacy on safe air travel, and that of the Safety Regulation and Standards Division which appeared to emphasise the viability of the industry as its major concern

b. poor planning of flight operations surveillance
c. poor division of responsibility

d. inadequate resources, which restricted the ability of the CAA to conduct regulatory activities concerning the safety of flight operations

e. ineffective communications between the local CAA District Office and Monarch

f. poor control of the management of Monarch surveillance

g. poor operating procedures, particularly the practice of issuing AOCs for an indefinite period.

Monarch represented an airline which was operating at the threshold of the law. On the evening in question, the crew were not checked out to fly the route and the aircraft had several unservicabilities. However, this was not unusual to the normal operations of that airline and yet it was licenced to operate by the CAA. Gaps in the regulator’s surveillance and enforcement capabilities afforded the opportunity for an airline with a poor attitude to safety to take advantage of the system. Whilst this says a great deal about the regulatory regime at the time, it also points to the effect of organisational culture within Monarch Airlines.

**Example Two; Rockwell Commander en route to Lord Howe Island**

On 2nd October 1994, Seaview Airlines Rockwell Commander 690B VH-SVQ crashed between Williamtown and Lord Howe Island with the loss of nine souls. Although the flight was planned as RPT flight CD111, it was not licenced to operate the service by the New South Wales Air Transport Council. Although “...factors that directly related to the loss of the aircraft could not be determined” (BASI, 1996b), mainly due to the fact that there were no survivors, no CVR or DFDR and only a small proportion of wreckage recovered, BASI did publish 37 findings. As was the case with the Monarch Investigation, several of these referred to the responsibilities of the Regulator, CAA.

The Seaview accident was the last straw in terms of political and public dissatisfaction towards aviation safety. The effect of this accident was exacerbated by media attention and the fact that two of the deceased were a newly-wed couple flying out to their honeymoon on Lord Howe. In a country with as small a population and as high a value of life as Australia such events have a major effect.
BASI - Selected Findings - Seaview

17. Airworthiness directives issued by the Federal Aviation Administration and Civil Aviation Authority did not correctly specify the engine modifications to be completed before allowing flight in icing conditions.

20. The Civil Aviation Authority had not followed its published procedures in monitoring service bulletins.

24. Seaview Air was not licensed by the New South Wales Air Transport Council to operate regular public transport services from Williamtown to Lord Howe Island.

26. The required airworthiness-related inspections of facilities, staff and equipment were not completed prior to the air operators certificate upgrade.

27. Ramp checks were carried out in response to events or breaches of regulations by the company, rather than as a check on the safety health of the company.

28. The surveillance that was conducted did not ensure compliance with a number of applicable regulations.

29. Surveillance checks had not been conducted since the operator was granted the low capacity regular public transport air operators certificate. However, checks were planned for 10 October 1994.

30. There was inadequate follow-up of deficiencies which were identified in Seaview Air's operations prior to the issue of a low capacity regular public transport air operators certificate.

31. Deficiencies were treated in isolation from those which had previously been identified.

32. Civil Aviation Authority district offices displayed significant differences in their respective operating practices.

33. The certification of low capacity regular public transport operators was almost entirely based on the approval/acceptance of various manuals. In this case the operator was not required to demonstrate to the Civil Aviation Authority that the Organisation and its employees would/could operate according to the standards laid down in the manuals.

34. The Civil Aviation Authority had no internal procedure to review the issue of air operators certificates.

Figure 5.4.2.3 Redrawn from BASI, 1996b
Not only was the Captain of the Seaview flight (which was operating with a single crewmember) not correctly licenced, but neither was the service. The aircraft was in excess of its maximum take-off weight and had been incorrectly modified to allow continuous flight through icing conditions (which was forecast for the route on that day). As with all accidents, there were multiple causal factors, but so many of them were preventable through effective regulation, surveillance and enforcement.

Following these incidents, Phelan (1994b) recorded Industry leaders’ perceptions of the problems within the CAA to be;

- An unwieldy and large unenforceable rule structure which weakens the regulation, surveillance and enforcement process
- The conflict of interest between revenue-raising and standards-setting and policing functions within one authority
- Administrative and political conflicts of interest because various agencies will remain responsible to the same minister
- A need, in any new authority, for specialists with operational, commercial and technical expertise, to replace career public servants in management, and political appointees at board level.

In spite of all of the political drama surrounding the Australian regulator and the perceived direct effect on aviation safety, Chalk (1987) challenges the emphasis on regulatory powers in the first instance as an explanation for the high level of safety in aviation. He argues that the view that “...the regulatory standards that the state imposes on airlines and aircraft manufacturers ensures their adherence to safe design and operating procedures” do not account for the level of safety. Instead, Chalk believes in “...various market mechanisms” which, in the case of aircraft manufacture, includes product reputation. However, the structure and mandate of any regulatory body is also part of this market mechanism because ultimately it is responsible to the state it represents. In the case of the Australian CAA / CASA, Board members are political appointees and and senior management positions are decided by the Board and the Minister for Transport. Reorganisation within CASA came in the face of fierce public and political criticism, not least in response to a perceived drop in safety standards.
5.4.2.2 The CAA Crisis of Confidence

The House of Representatives Standing Committee on Transport, Communications and Infrastructure’s Inquiry into Aviation Safety in the Commuter and General Aviation Sectors (HORSCOTSI, 1995) was the product of a severe crisis of confidence with, and within, the civil aviation authority. Two major accidents involving commuterline aircraft (Monarch and Seaview) had raised public awareness of aviation safety to a very high level. In his response to the publication of BASI’s report into the Monarch disaster (BASI, 1994), Minister for Transport, the Hon. Laurie Brereton “...announced a broad strategy to improve air safety regulation in Australia”. (HORSCOTSI, 1995) This consisted of two major features; namely the creation of CASA and the House of Representatives Inquiry.

However, although the inquiry made a wide range of recommendations which are now being implemented such as through the 1997 Regulatory Review Process and the collection of safety indicators, the crisis of confidence in the ability of CAA / CASA will take some time to resolve. This process will not be helped by the recent appointment of Dick Smith as Deputy Chairman to the CASA Board and the resignation of both CASA Director, Leroy Keith and two Board members in September 1997. This followed a tactical move by Smith in the absence of the recently resigned Minister for Transport, the Hon John Sharp.

Australian flight crews and air traffic controllers were asked a number of questions which related to their current feelings on aviation safety. The first was as follows;

<table>
<thead>
<tr>
<th>3.5</th>
<th>Over the last five years, do you think Australian civil aviation in general has become...?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>More safe</td>
</tr>
<tr>
<td>2.</td>
<td>Remained about the same</td>
</tr>
<tr>
<td>3.</td>
<td>Less safe</td>
</tr>
<tr>
<td>4.</td>
<td>Don't know</td>
</tr>
</tbody>
</table>

This question was circulated at a time following the nose-wheel up landing incident involving Ansett Australia B747 VH-INH at Sydney, the loss of the Monarch and Seaview (BASI, 1996b) aircraft and following the launch of the HORSCOTSI Inquiry. It did precede the publication of the Ansett VH-INH and Seaview accident reports and the conclusion of the HORSCOTSI Inquiry.

The results are documented as follows;
Qantas Airways;

Nearly two thirds of Qantas crew members believed that aviation safety in general had got worse over the last five years. Perhaps more importantly, only 5% believed that it had become more safe. The sobering aspect of this statistic is that with traffic increasing at current rates and the general accident rate staying static since the early 1970's, aviation needs to become safer to keep the absolute number of accidents the same.

Ansett Australia;

A slightly larger proportion of Ansett Australia crew members (67% as opposed to 63%) believed that safety standards had slipped in the last five years in general. Only 3% perceived any improvement with a third (same as Qantas) believed safety levels had remained about the same. This represented a period of time that was long enough to be a realistically stable period of time and yet short enough so as to exclude the 1989 domestic pilots dispute which is still the source of much contention about the quality of foreign crews which operated within Australian during that time.

Whilst it is accepted that the strong negative reaction will be related to the mass of attention that was focussed on aviation safety at the time, it is an opinion expressed from within an educated group which has as much a responsibility for safety as the much maligned CAA. Even at this time, certain airline officials admitted that they had long since been by-passing the Australian CAA for advice in favour of the British CAA.
Over the last five years, do you think Australian civil aviation in general has become...?

More Safe
7%

Less Safe
45%

Remained the same
48%

RAAF

Figure 5.4.2.7 Answers from RAAF Crews

Over the last five years, do you think Australian civil aviation in general has become...?

More Safe
6%

Remained the Same
31%

Less Safe
63%

RAAF ATC

Figure 5.4.2.8 Answers from RAAF ATC

Over the last five years, do you think Australian civil aviation in general has become...?

More Safe
6%

Remained the Same
34%

Less Safe
60%

CAA ATC

Figure 5.4.2.9 Answers from CAA ATC

RAAF Transport;

Although the military crews seemed less pessimistic than their civilian counterparts, the percentage of 'less safe' responses (45%) was still over six times more than those who believed that aviation safety in general had improved.

The lower proportion of 'less safe' responses may be a function of expectations and relatively short corporate memory regarding safety.

RAAF ATC;

Military controllers seem to share the same attitude as both the Ansett and Qantas civilian pilots with close to two thirds (63%) perceiving that civil aviation in general had become less safe in Australia. The closer alignment to civil pilots rather than the military transport crews may be a function of exposure. Military ATC often work in the same facilities as their civil counterparts and will also be responsible for controlling civil traffic.

CAA ATC;

Civilian air traffic controllers produced almost exactly the same results as the civil pilots and military air traffic controllers. In the case of both ATS providers, those who believed there had been an improvement (6%) were in a very small majority.
5.4.3 Response to Occurrences

Accidents or incidents within Australia are investigated by the Bureau of Air Safety Investigation (BASI) which is an agency of the Federal Government's Department of Transport and Regional Development. The function of the Bureau is in line with the recommended practices of ICAO's Annex 13 which were incorporated into Australian legislation through the Air Navigation Act (1920). However, although the aims of occurrence investigation, as specified within Annex 13 are essentially reactive, BASI's role extends beyond that of similar accident investigative authorities overseas such as the British Air Accidents Investigation Branch (AAIB). That is to say that BASI is involved in proactive safety initiatives which are not necessarily related to incidents or accidents which have occurred in Australia.

The Bureau is funded directly by the Federal Government and its Director reports directly to the Minister for Transport and Regional Development. Its function is kept separate from that of the civil aviation authority / civil aviation safety authority and BASI is not tasked with cost recovery. It is a relatively small agency employing some 80 staff who work in Central Office (Canberra) and at small field offices located in Brisbane, Sydney, Melbourne and Perth.

There are certain key traits of BASI which makes it unusual, if not unique on a world scale. These relate to the profile of the BASI team and the way investigations are conducted. Firstly, there are a number of psychologists employed by the Bureau including its Director, Dr. Rob Lee. This has allowed them to look deeply into the human factors issues that are know to lie behind the majority, if not all, of aircraft accidents. Their attempts to move investigation from the traditional 'tin-kicking' technical investigations to a more systemic approach, not least through the help of human factors specialists such as James Reason, have brought critical acclaim from throughout the world. However, such an approach is not without its detractors. President of the International Society of Air Safety Investigators, Richard B. Stone, President of the International Society of Air safety Investigators, suggested that following experience within the American NTSB "...all of us (ISASI) are dissatisfied with past results. Like many endeavours, human factors in accident investigation were oversold."(Stone, 1997)

It is still the case that the NTSB is required to produce a single primary cause in each of its accident investigations. In Australia, the last use of a 'Cause' statement was in 1983 and then BASI listed 'causal factors' until about 1987 after which they just used 'factors' (Mayes, 1997). Disagreement between the Australians and Americans continues with the Canadians positioning themselves more in line with the likeminded Australians than their geographic neighbours. The fact remains that the stable accident rate and seemingly static, if not growing, proportion of 'human error' type accidents point towards the need to concentrate on human factors oriented investigations. Changing the emphasis from 'a cause' to highlighting all of the 'contributory factors' has significant merit in accident prevention and is far more than an exercise in semantics. The fact that it has been achieved first in Australia is perhaps indicative of the way of thinking that exists within that part of the aviation industry.
The UK AAIB’s mandate is different to that of BASI in that traditionally it has not been concerned with proactive investigation. Although this has changed a little in recent years to include the investigation of very serious incidents (such as the oil-starved landing of a British Midland B737 at Luton in 1995), this is done without any psychologists or human behaviour specialists on the staff roll. Expertise is brought in from the Defence Evaluation and Research Agency (DERA) although this was almost exclusively in the form of the late Dr. Roger Green. The Head of AAIB, Ken Smart claims that of approximately 350 accidents recorded in the UK each year (all classes of aircraft), the causes of about 300 could be predicted by the AAIB. However, when pressed as to why the figure remained static whilst being predictable, Smart pointed out that the role of the AAIB was to investigate accidents then communicate findings to the relevant parties. Unlike BASI, the AAIB does not have a proactive role to play in the form of proactive safety programs. The effect of this is difficult to quantify, although the recurrent accident figures may speak for themselves.

In terms of technical investigations, the AAIB and NTSB may reasonably be expected to hold more expertise and experience than BASI which has not had to investigate large scale aircraft accidents. The AAIB has world-class expertise in fire, severe impact and bomb investigations following the Manchester B737, Kegworth B737 and Lockerbie B747 accidents. The NTSB has conducted a series of large scale investigations which have included difficult to access sites such as the Eastern L1011 and Valujet DC9’s in the Everglades and the Birgenair B757 and TWA B747 in the Atlantic. Australia manages to overcome its lack of experience by sending investigators to work with overseas teams on technical investigations. For example, investigators were sent to the Dryden F28 accident, TWA800 B747 accident and the recent Garuda A300 crash. BASI’s expertise in technical areas such as CVR analysis is routinely used around the world which is not only a reflection on their technical ability, but also adds to their operational experience.

It is worth noting the level of response from the Bureau to key incidents which may seem out of proportion compared to the reaction of their counterparts overseas. This may, arguably, be the result of a lack of major accidents and therefore a surplus of resources. However, as the Director must justify his budget on an annual basis to the Minister for Transport it is unlikely that large-scale incident investigations are simply about finding investigators things to do.

A good example is the investigation into the accident involving Ansett Australia Boeing 747 VH-INH at Sydney Airport on the 19th October 1994 (BASI, 1996c). The investigation lasted nearly two years and culminated in an 86 page report which examined issues ranging from the aircraft (10 findings) and flight deck (8 findings) to organisational issues (26 factors) within Ansett. The depth of the investigation was unprecedented except by the fatal accident investigations conducted by Royal Commissioners at Dryden (Moshansky, 1992) and Erebus (Mahon, 1981). The consequences were similarly far reaching, especially within Ansett where the safety Department swelled from one to ten staff members and was accompanied by an intensified commitment to human factors training which will see all employees go through some form of training by 1998.
5.4.4 Economic Factors

Economics has a direct link with aviation safety, particularly in terms of the availability and allocation of resources. "Economics ...has always been a consideration in achieving safety" (Lederer, 1987) Risk taking of any sort includes the estimation of costs which may be in financial terms or in pain and suffering. Economics is concerned with the former, and when armed with a structured cost benefit analysis, also the latter. In a wider context, economics is concerned with profitability and therefore the ability of individual firms to operate.

The effect of market forces on the safety of an airline or other operation is a complex subject which goes beyond the scope of this study. However, there are a number of economic factors which are pertinent to the Australian situation which are worth considering. These include the regulated duopoly which existed between 1957 and 1990 for domestic operations and the state ownership of the single international airline, Qantas.

5.4.4.1 Domestic Airline Regulation

The forerunners of the two major Australian Carriers - Australian National Airways (which became Ansett-ANA and then Ansett Australia) and Trans-Australia Airlines (TAA) (which became Australian Airlines and then Qantas domestic) were tenured into the Menzies Government's two airline policy in 1957. The policy was created to keep an election manifesto promise; that the government established Australian National Airlines Commission's airline - TAA would be forced to operate competitively. Under the agreement, "...regulation of the aviation industry was considered necessary to foster the development and growth of an infant industry in an orderly manner by ensuring the stability of the major domestic airlines." (Evans, 1987)

Under the Menzies policy, which became law in 1952 and was supplemented by the Civil Aviation Agreement Act of 1957, the Australian National Airlines Commission (ANAC) were responsible for the regulation of domestic air routes and the two carriers that operated them. This included dictating which aircraft could and could not be acquired and ensuring that both airlines were similarly equipped. When Trans-Australia Airlines applied to purchase six Vickers Viscount 701's in 1952, they were refused permission by the Government until it was established that Australian National Airways also intended to firm up its optional order for six. Similarly, when TAA attempted to purchase a number of Sud SE-210 Caravelles in 1956, the Commission blocked this as ANA could not afford to upgrade to jet equipment. A compromise was made and both airlines ordered Viscount 816s with ANA becoming the subject of a successful acquisition by Ansett Transport Industries in 1957 to become Ansett-ANA.

In 1958, the Airline Equipment Act became law which required both Ansett-ANA and TAA to rationalise their operations such that on any given route, neither airline received more than half of the traffic. Note that the two airline policy only applied to trunk routes. By 1960 this was supplemented by the 'cross-charter agreement' whereby the Government attempted to equalise the passenger carrying capacity of TAA and Ansett-ANA. This was achieved by Ansett-ANA
swapping two of its DC-6Bs for three TAA Viscount 720s. Neither airline wanted this agreement which represented a very intense level of direct regulation. However, with the Government also deciding that Qantas should cease operations in Papua-New Guinea thereby allowing the domestic carriers in, profits were restored and the policy was declared a success. Both carriers developed strong networks under the strong guidance of the Department of Civil Aviation "...now stretching upwards towards the pinnacle of its efficiency". (Job, 1992)

Proponents of the two-airline policy argued that it protected against a number of problems including (Kirby, 1981);

**Destructive Competition**
- chaos and instability
- destructive pricing
- declining quality standards
- collapse of airline investment
- irrational behaviour

![Figure 5.4.4.1 The Effects of Destructive Competition](Kirby, 1981)

They further argued that a competitive environment would have the following effects:

**Wasteful Competition**
- excess capacity
- re-equipment problems
- parallel scheduling

![Figure 5.4.4.2 The Effects of Wasteful Competition](Kirby, 1981)

These were supplemented by a series of network considerations which are particularly pertinent to a nation of Australia's sparse population. Namely the fear of abandonment of low yield routes through the unwillingness of commercially led airlines to cross-subsidise from trunk routes.

However, these arguments were counterbalanced by criticisms of the duopoly of TAA and Ansett-ANA or indeed, the monopoly of air transport for interstate passenger transport. Such perceptions were ultimately to lead to widespread reform of domestic aviation towards the end of the 1980's.
5.4.4.2 Domestic Aviation Reform

By the mid 1980’s, the rationale of the 1952 and 1957 Acts regarding the ‘Two Airline Policy’ was no longer considered to be valid. The government was pressing for micro-economic reform across Australian industries and the international feeling towards civil aviation was that economic forces could adequately control supply and demand and allow a more liberal attitude towards regulation (BTCE, 1993). In 1985, the Labour administration appointed a committee to conduct an Independent Review of Economic Regulation of Domestic Aviation (IRERDA, 1986). The conclusions of the committee were as follows:

1. Government regulation of aircraft capacity owned “has in effect allowed the airlines themselves to determine their own future capacity levels” while the market-sharing and consultation arrangements have “muted competition” and discouraged the development of new markets.

2. Rate-of-return regulation, practiced by the Independent Fares Committee, has allowed profit of “up to 28 per cent before tax on shareholder’s equity calculated on an historic basis”, but subject to further adjustment for costs disallowed because incurred unnecessarily.

3. This has encouraged employment of excessive capital assets, “reflected in low density (aircraft) seating configurations and relatively low hours of aircraft utilisation”.

4. “On the other hand, load factors are high and the capacity controls have enabled the worst excesses of capacity to be avoided”.

5. Regulatory restriction of output (measured in seat-kilometres) has encouraged the airlines to focus on serving high-yield (business) passengers, and to give relatively little attention to those willing to travel at discount fares for recreational purposes.

6. Fare-determination (based on fully-distributed cost allocations) has been practised in such a way as to average cost differences over aircraft types and over routes of differing densities.

7. The airlines have not offered off-peak fares, and travel on discount fares have only been a modest part of total sales, because of the restrictive conditions associated with discount fares.

8. As a consequence, there has been a lack of alternative offerings in the price-quality spectrum, and less air travel than might be expected in Australian conditions.

The remedial recommendation of the committee was a partial deregulation of the domestic market, but the reaction of the industry was that regulation should be an ‘all or nothing’
situation. Sir Peter Abeles (Ansett Airlines, 1987) argued that, “Put simply, you just cannot be a little pregnant. The only viable alternatives for the future are to continue with the present arrangements or to give open competition a go”. The Hawke administration opted to go for the full withdrawal of economic regulation from the domestic aviation industry. In October 1987, Senator Gareth Evans, Minister for Transport and Communications documented the ground-rules for deregulation and the role the government would play. (BTCE, 1993).

Three years notice was given before the two airline policy could be formally ended to give Ansett and Australian airlines the opportunity to restructure and for new competitors to prepare for service introductions. In July 1988, Qantas (then still fully an international carrier) was given the right to carry the passengers of other international airlines on the domestic sectors of its international services to start to stimulate some competition before full deregulation commenced in October 1990.

5.4.4.3 The rise and fall (and rise and fall) of Compass Airways

The only significant domestic competitor to enter the Australian market since deregulation was Compass Airways which appeared in two forms (referred to as Compass Mk1 and Mk2), ceasing operations in December 1991 and March 1993. Compass Mk1 suffered a number of problems including late delivery of its A300 aircraft fleet, failure of the telephone reservation system to cope with demand and lower than anticipated yields, principally caused by the inability to capture a significant proportion of the business travel market. As Compass Mk1 flew in head to head competition with Ansett and Australian Airlines on the main trunk routes (Adelaide-Melbourne-Sydney-Brisbane) using high capacity aircraft, it suffered from offering lower service frequencies than the big two. Other hindrances included the decision of the big two to match Compass dollar for dollar on price (which brought massive fare reductions) and poor access to terminal facilities (which were owned by Ansett and Australian Airlines).

Compass Mk2 suffered many of the same problems that Mk1 had, although service frequencies were increased by using smaller (MD88) aircraft. A less aggressive approach to pricing was still not looked upon favourably by the existing carriers who matched all of Compass Mk2’s discount fares. None of the three carriers could afford to be the first to raise the fares and when Compass finally folded on the 12th March 1993, both Ansett and Australian Airlines had inflicted serious damage on their cash reserves. Rules on predatory pricing meant that fares could not return back to their original levels once the third player had been removed and in real terms, fares still remain below their pre-deregulation levels.

The failure of Compass Airways indicated some of the unique features of the Australian domestic market that are significant to the thrust of this thesis. Firstly that the economic situation within Australia was such that the duopolistic situation held by Ansett and Australian Airlines had led to artificially high fares. Nevertheless, through a series of barriers to entry and lower than expected passenger yields, the domestic market was unable to support three major carriers. The situation whereby Ansett and Australian Airlines owned the airport terminals is
unusual and although under the new regime of deregulation there is a requirement for these carriers to provide space in their terminals, the complaint of Compass was that (not surprisingly) they were given the worst, least accessible parts of the terminal.

The legacy of the Compass launches has stayed with the aviation industry and had a long term effect on the profitability of the remaining two major carriers. Competition had been fierce with Compass I especially aiming its services at the busiest routes and attempting to steal market share from Ansett and Australian Airlines rather than attempting to open up new markets. Whatever Compass attempted to do in terms of fares was matched by the majors who also enjoyed the strength of established networks, travel agent and booking services and Frequent Flyer programs. However, following the subsequent demise of Compass I which had been a price leader, the second incarnation aimed only to match the prices of Ansett and Australian. In anticipation of Compass II’s start of operations, the major carriers set their discount fares well below, only to raise them as soon as Compass II started flying.

Although full economy, business and first class tickets have risen in cost, doubtless because of Compass’ inability to crack into this lucrative market, discount fares have remained low and also experienced dramatic increase in customers. As such both Ansett and Australian Airlines suffered considerable economic pressure immediately following deregulation which has continued with the expectation for heavily discounted air fares. Public support for Compass as an airline which precipitated fare reductions by Ansett and Australian was high and therefore they risked severe negative reaction if these fares disappeared. Ansett and Qantas Domestic remain in direct competition with roughly equal market share and an almost tit for tat approach towards discount airfares.

One of the most difficult questions to answer is regarding the effect of domestic deregulation on aviation safety in Australia. Reviewing the process of aviation reform, the Bureau of Transport and Communication Economics (BTCE, 1993) observes that “Although many determinants of aviation safety have been documented, no system has been able to accurately predict aircraft accident rates based on changes in safety related factors”. Nevertheless, they do state that “After several years of aviation reform in Australia, including the first two years of deregulated interstate operations, there has been no evidence of an increase in accident rates in the domestic RPT (Regular Public Transport) aviation sector.” (BTCE, 1993) Such a statement remains valid today as the domestic jet RPT sector has still never suffered a fatality and the recent crashes of the 1990’s such as Monarch and Seaview have involved the charter sector and not RPT carriers.
5.5 Luck - What is it and does it exist?

A recurrent theme in the anecdotal explanations of Australia’s good record for airline safety was that of luck. Numerous individuals, who are asked to comment on the reasons behind Australia’s zero fatality record for jet aircraft travel, used the word ‘luck’. Even Dick Smith, former Board Chairman of the Australian CAA (1994) gave ‘luck’ as one of the four reasons he believed to be responsible for their success.

Luck is defined by the Oxford English Dictionary as “supposed tendency of chance to bring a succession of favourable events or good fortune”. Chance is not a scientific concept and cannot be defined. Its closest scientific equivalent is probability which can be estimated using past samples of similar circumstances and it is this probability that is used in aviation safety to predict accident and incident rates and types. However, usage of the term ‘luck’ is often as a catch all to explain the unexplained or even shrug responsibility by claiming an action to have been influenced by forces well beyond human control.

*Luck is the Domain of Bankrupt Gamblers; not Aviation Safety Professionals*
Asked to suggest factors that they believe had been responsible for the good safety record in Australia, the responses were as follows:

**What factors have contributed towards Australia’s safety record?**

<table>
<thead>
<tr>
<th>Factors</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weather</td>
<td>50%</td>
</tr>
<tr>
<td>Crew</td>
<td>40%</td>
</tr>
<tr>
<td>Low Traffic Density</td>
<td>30%</td>
</tr>
<tr>
<td>Maintenance</td>
<td>20%</td>
</tr>
<tr>
<td>Luck</td>
<td>10%</td>
</tr>
<tr>
<td>Terrain</td>
<td>10%</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>10%</td>
</tr>
<tr>
<td>Crew Interaction</td>
<td>5%</td>
</tr>
<tr>
<td>Good ATC</td>
<td>5%</td>
</tr>
<tr>
<td>S. O. P's</td>
<td>5%</td>
</tr>
</tbody>
</table>

**Figure 5.5.1 Answers from Large-Transport Aircraft Crews**

Luck was ranked in 5th place, having been cited by approximately 29% of crew members. However, the results from air traffic controllers were a little more concerning:

**What factors have contributed towards Australia’s safety record?**

<table>
<thead>
<tr>
<th>Factors</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luck</td>
<td>45%</td>
</tr>
<tr>
<td>Low Traffic Density</td>
<td>35%</td>
</tr>
<tr>
<td>Weather</td>
<td>20%</td>
</tr>
<tr>
<td>Maintenance</td>
<td>10%</td>
</tr>
<tr>
<td>Good ATC</td>
<td>5%</td>
</tr>
<tr>
<td>Crew</td>
<td>5%</td>
</tr>
<tr>
<td>Regulation</td>
<td>5%</td>
</tr>
<tr>
<td>Terrain</td>
<td>5%</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>5%</td>
</tr>
<tr>
<td>Professional Pride</td>
<td>5%</td>
</tr>
</tbody>
</table>

**Figure 5.5.2 Answers from Air Traffic Controllers**
The perception held by military and civilian air traffic controllers is that luck has been the number one factor in preventing a fatal air accident within Australia involving an RPT class aircraft. This may represent a worrying mindset or reveal an interesting cultural trait which is worth further examination.

Certainly a belief in luck is not something encouraged by anyone other than the likes of Casino owners or Bookmakers. Ashford (1993) observed that, "...a PhD thesis which attempts to prove the existence of luck would be scratching stony ground." Indeed, luck is often spoken of but is entirely unprovable as a concept and therefore inadmissible as a scientific notion. The euphemistic use of the term 'fortuitous' to describe the chance outcome of a particular set of circumstances may just be an excursion into semantics. The term may be used to evaluate an outcome, but it is not a valid explanation of the process. Nothing happens because of luck and as it represents a value judgment, one man’s good luck can easily be another man’s bad luck:

Suppose a concrete slab dislodged from a motorway bridge and fell onto a passing motor car, injuring the driver. The driver of the car in front may consider himself to be lucky to have been missed, whereas the casualty may feel that he was unlucky. Both of these statements, as value judgments stand as valid, but neither explain why the slab fell where it did. The circumstances behind the collision may be the result of a variety of factors including:

- erosion forces on the bridge slab e.g. precipitation, temperature change, salt
- wind strength and direction
- vibration from passing vehicles
- the speed and direction of the vehicles passing beneath the bridge
- maintenance program for the bridge

Admittedly, many of these factors are difficult to quantify and the drivers would not be expected to readily evaluate the relative contribution of each of them as they drive their cars. However, the example does illustrate that none of the forces fall under the description of luck. In other words, luck does not make things happen, it just describes an individual’s satisfaction of the outcome.

5.5.1 The Origin of Perceived Luck

The widespread use of the term luck raises two interesting questions for research, regardless of whether it is proven to exist or not. These questions are;

a) If so many people cite luck and it does not exist, what do they really mean?

b) What is the effect of luck belief?
a) If so many people cite luck and it does not exist, what do they really mean?

Explaining the ‘luck’ factor is not easy as being a generic, catch-all term, it may mean different things to different people. One possibility is that luck is a convenient way of explaining the unknown - which in turn may be the result of a number of factors including naivety, ignorance, misapprehension or mistake. In the aviation context this may be because many people have a very limited view of aviation safety and the factors that have an influence upon it. Simplistic attitudes which are formed on the basis of limited experience or exposure to selective information have created a number of myths about safety. For example, there is a sizeable populous within the industry which looks at accidents solely in terms of primary causes and therefore believe that pilot error is currently the most important variable in aviation safety. The natural progression seems to be that the failure of an airline safety system through pilot error is unlucky and not the result of the myriad of processes which systemic investigation reveals.

Luck may also be used as a way to describe the effect created by greater margins of safety. In turn, these margins may be shown to be either natural or intended - for example, clear visual conditions may afford a margin of safety which could prevent a mid-air collision following a breakdown of separation (natural) or undeclared runway pavement in excess of ICAO minima may prevent an overrun (intended). Aviation safety has always been based on safe-side failures and duplication which creates a margin of safety within which aircraft can still operate without incident. Of course, once a margin of safety is entered there is less room for error without an accident occurring so the bigger the margin of safety, the lower the probability of exceeding it.

While a number of ‘near-misses’ are heralded as examples of ‘Australian luck’, there are plenty of similar stories from around the world to balance them out. When an Ansett A320 had to make a go-around at Sydney Airport in 1991 to avoid colliding with a DC-10 at the intersection of the two main runways, there were critics who suggested the difference between a near miss and an accident was luck. The Ansett flight crew would dispute that, as would the regulator who had deemed that SIMOPS (simultaneous operation of runways) should only operate when aircraft were in clear visual range of each other.

Both aircraft were landing; the DC-10 on Runway 34 and the A320 on the crossing Runway 25 which was allowable under SIMOPS in visual conditions. The DC-10 was required to have the other aircraft in sight and stop short of the runway intersection whereas the A320 was just required to keep the DC-10 in sight throughout the landing. As the two aircraft neared the intersection, the Captain of the A320 (who was non-flying pilot) observed that the DC-10 did not appear to be slowing in time to stop and elected to go-around only a matter of a few feet above the runway. There was no collision but subsequent investigation suggested that the two aircraft may have impacted if the go-around had not been expedited.

Despite there being a number of complex issues surrounding the incident, including the difficulty of seeing the intersection from runway 34 after touch-down because of its hump and lack of markings, the factors which prevented a collision could not be put down to luck. Both
aircraft were aware of each other’s presence and meteorological conditions were required to be clear before the mode of operation could commence. The Captain of the A320 was observing the DC-10 at all times and was able to apply the go-around power as necessary. The possible accident was avoided, in spite of multiple failures because of the safety net provided by the regulator and airline operating systems and not because of luck.

Systematic investigation of any aircraft incident will conclusively prove that luck was not a factor, either in a positive or negative sense. The contribution of chance to the way that multiple factors came together on a particular day is not disputed, but where ‘chance’ is the correct term to use, there is no reason to believe its distribution to be anything other than random. For example, say an engine has a design failure rate of 1 in 50,000 hours then the likelihood of it occurring when a particular aircraft is flying on a weekday or a weekend may be reasonably classified as chance. In this example, there are no possible factors which would specifically dictate where that chance occurred. However, if such a failure occurred more frequently in a particular geographic area then deeper investigation may reveal it to be the result of a number of factors including:

- distribution of that aircraft or engine type
- level of flying completed in that area
- performance stressors e.g. temperature, precipitation
- maintenance integrity
- pilot airmanship
- use of derated take-off power

Again, none of these factors are explained by luck or chance. This enhances the argument that regional variations in performance are not down to unknown factors which can only easily be described as luck.

Several aviation accidents and incidents have been labelled as being the result of good or bad luck. They include the following two major accidents;

United Airlines Flight 232 experienced an uncontained failure of the number 2 (tail) engine on 19th July, 1989 en route from Denver to Chicago with a loss of all hydraulic power. Technically this was an unsurvivable accident, but the flight crew managed to successfully crash land the aircraft at Sioux City, Iowa with 185 survivors. The performance of the flight crew was exemplary and assisted by a ‘dead-heading’ Check Pilot who administered the crucial variable thrust (the only remaining control on the aircraft). Was the fact that the Captain of the flight had spent some of his own time practicing such a scenario in the flight simulator beforehand a stroke of luck? Was the presence of a Check Pilot another stroke of luck? In both
cases, it seems that there was some fortuity, but there are also a number of issues that were definitely not luck including the attitude of the crew members towards extra-curricular training, access to the simulator and the use of scheduled services to dead-head crew. To consider the outcome of this incident to be the result of luck detracts from the efforts of the crew and airline.

On 8th January 1989 a British Midland Boeing 737-400 aircraft suffered severe fan-blade damage to one of its engines whilst en route between Heathrow and Belfast. The flight crew shut down the wrong engine with the effect that the aircraft was unable to conduct a stable approach to East Midlands Airport and collided with terrain short of the runway with the loss of 47 lives. Although there were a great number of issues behind this accident, the question of luck is raised with regard to the procedure for shutting down a rough riding engine.

The first generation -200 series aircraft were known to have unreliable instrumentation for diagnosing vibration and rough running within the engines. They also received all the cabin bleed air from the No. 2 engine and both of these facts contributed to the crew’s decision to use a simple test to diagnose which was the errant engine. The procedure was to pull the throttle back on either engine and examine whether this made any difference. This was done for the No. 2 engine and the vibration stopped leading the crew to believe that they had correctly identified the failure. Unfortunately, the effect of their action was to disconnect the autothrottle which allowed more fuel to be supplied to the damaged No. 1 engine which was now running apparently smoothly. When the aircraft demanded more thrust on final approach, this engine sustained further damage and lost power which led to the ground collision. Had the crew throttled back on the No. 1 engine first then the accident would have been averted, but was their decision the result of bad luck?

Firstly the knowledge carried over from the -200 series regarding bleed air was incomplete for the -400 series which took air from both engines. Also the unreliable instrumentation which required the crew to use the ‘trial and error’ test was fixed on the -400 series, but was not used because the crew had not undergone complete conversion training and were therefore unaware of it. Finally, the procedure used was unsuitable for this series of B737 and should have been revoked. As all of these factors could have been corrected (and subsequently were), it is not possible to pass them off as being the result of luck.
b) What is the effect of luck belief?

There is no reason why Australian carriers should have been blessed with more luck than those from any other nation. However, this has not prevented the development of the widely held belief of the importance of luck in creating the safety record.

As mentioned earlier, there are a number of people who put Australia’s good safety primarily down to luck. There is no doubt that there have been a number of incidents where an accident was very narrowly avoided by circumstances which could easily be described as luck, but it is not responsible for the safety record of a nation. There are those who say that explaining factors which others may have put down to luck is an excursion into semantics, but this ignores another crucial issue: If the next generation of aviators are brought up to believe that luck has played a major role in the safety record, then there is a danger that they will believe this force to be beyond their control. In other words, the danger is either in taking the complacent approach of believing Australia to be the ‘lucky country’, or the fatalistic approach of assuming luck to be out of human control and therefore will inevitably run out at some point.

Trompenaars looked at indicators which would assist in the quest to determine whether luck believers existed because of cultural traits. Asked a question to test whether individuals believed themselves to be Captains of their own fate, the following table charts the percentage of respondents who believe that what happens to them is their own doing:

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Germany</td>
<td>35</td>
</tr>
<tr>
<td>China</td>
<td>35</td>
</tr>
<tr>
<td>Egypt</td>
<td>48</td>
</tr>
<tr>
<td>Japan</td>
<td>56</td>
</tr>
<tr>
<td>Turkey</td>
<td>57</td>
</tr>
<tr>
<td>Czechoslovakia</td>
<td>57</td>
</tr>
<tr>
<td>Singapore</td>
<td>58</td>
</tr>
<tr>
<td>UAE</td>
<td>58</td>
</tr>
<tr>
<td>Nigeria</td>
<td>59</td>
</tr>
<tr>
<td>Poland</td>
<td>62</td>
</tr>
<tr>
<td>Greece</td>
<td>63</td>
</tr>
<tr>
<td>Portugal</td>
<td>64</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>64</td>
</tr>
<tr>
<td>Italy</td>
<td>65</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>69</td>
</tr>
<tr>
<td>Romania</td>
<td>70</td>
</tr>
<tr>
<td>Sweden</td>
<td>70</td>
</tr>
<tr>
<td>Finland</td>
<td>70</td>
</tr>
<tr>
<td>Thailand</td>
<td>71</td>
</tr>
<tr>
<td>Brazil</td>
<td>71</td>
</tr>
<tr>
<td>Austria</td>
<td>71</td>
</tr>
<tr>
<td>India</td>
<td>72</td>
</tr>
<tr>
<td>Indonesia</td>
<td>73</td>
</tr>
<tr>
<td>UK</td>
<td>75</td>
</tr>
<tr>
<td>Belgium</td>
<td>76</td>
</tr>
<tr>
<td>Denmark</td>
<td>76</td>
</tr>
<tr>
<td>Netherlands</td>
<td>77</td>
</tr>
<tr>
<td>Ireland</td>
<td>78</td>
</tr>
<tr>
<td>Norway</td>
<td>80</td>
</tr>
<tr>
<td>France</td>
<td>81</td>
</tr>
<tr>
<td>Spain</td>
<td>81</td>
</tr>
<tr>
<td>Australia</td>
<td>81</td>
</tr>
<tr>
<td>Argentina</td>
<td>81</td>
</tr>
<tr>
<td>West Germany</td>
<td>82</td>
</tr>
<tr>
<td>Canada</td>
<td>83</td>
</tr>
<tr>
<td>Pakistan</td>
<td>84</td>
</tr>
<tr>
<td>Switzerland</td>
<td>84</td>
</tr>
<tr>
<td>USA</td>
<td>89</td>
</tr>
</tbody>
</table>

Figure 5.5.3 Captains of their Fate Redrawn from Trompenaars, 1993
A very high proportion of Australians (81%) believe they have significant control over their own destiny which in contrast to some of the more collectivist cultures. Whilst this phenomena is partly related to the position individuals believe they hold in society, it is also related to the number of controllable variables they perceive. Where these variables are not controllable, especially under collectivism, success may be perceived to be achieved through luck or other factors beyond the individual’s control. This includes the reaction to critical incidents as well as other less critical life experiences such as career path. In the former situation this can include religious beliefs which can affect what is often referred to as ‘fatalism’. That is whereby the outcome of certain situations are felt to be outside human control - for example, at the will of Allah. It is beyond the remit of this thesis to consider the implications of different religions on flight safety, but it is worth noting that several expert witness flight instructors that were interviewed during the course of this research recounted experiences whereby flight training students from Muslim countries abandoned the flying controls in a critical phase of flight declaring “it is Allah’s will”. Notable is the Australians’ reaction which was that of direct intervention to recover the situation.
Chapter Six

The Operational Environment

The operational environment represents the physical infrastructure of the aviation system which, although directly linked to the human environment, contains a number of elements which are unique. Elements considered include the flight vehicle, air traffic management and airports.
6.1 Equipment

As the aviation system is centred around the vehicle i.e. the aircraft, it seems reasonable that the specific types of aircraft used may have an effect on the safety of the operation. This may be at any or all of several levels which include:

- Design;
  * Aircraft Flying Characteristics and Performance Limitations
  * Buyer Furnished Equipment (BFE)
- Maintenance
- Regulatory Requirements

6.1.1 Aircraft Design and Selection

**Aircraft Flying Characteristics and Performance Limitations**

Every aircraft design has its own particular set of specifications which will distinguish it from other types. These differences of design will determine the performance level of each type and its ability to cope with certain operating excesses. The operation of aircraft close to their intended performance envelope reduces the margin of safety. Conversely, an operator that specifies extra equipment or capabilities for a particular aircraft model may also reap the benefits of a wider margin.

Structural failure of aircraft is a rare event and one that is usually associated with poor maintenance levels rather than airframe design. (Although the latter cause is significant and mentioned in greater detail below.) A number of accidents occurred during the first years of jet aircraft introduction when aircraft were flown beyond their capabilities. However, in the majority of such cases, the true cause was a flightcrew problem of training or overconfidence. For example, in 1965 an American Airlines B727 crashed short of Cincinnati Airport on final approach. During a rushed approach the crew had reduced operating power and lost track of an increasing descent rate. In older, propeller driven aircraft the excessive sink could be arrested relatively easily, but the newer jet engines required a much longer spool-up time.

Certain aircraft types are prone to airframe icing which has obvious flight safety implications. The low wing, rear engined DC9/MD-80 family and Fokker F28/70/100 aircraft are all prone to clear icing on their wings. When shaken loose, particularly by take off, ice becomes ingested in the engines with a danger of loss of thrust at the most critical point. Accidents occurred in 1991 (SAS, MD-81) and 1989 (Air Ontario F28) with this as a causal factor. The loss of an ATR 72 in 1993 led the NTSB to conclude that the aircraft had undergone an uncommanded asymmetric aileron excursion caused by a build up of ice on the wing.
As documented in the natural environment section, in 1992, an Ansett Australia BAe 146-200 aircraft lost power in all four engines while flying around a large storm cell near Meekatharra, WA. Flying into an area of unusually warm air at high altitude, the engines were unable to supply sufficient fuel and power was lost through ‘roll-back’. (BASI, 1994c) Although the manufacturer was aware of the possibility of roll-back and had issued an operational notice, there were a number of omissions such as the possibility of more than one engine being affected. Following the incident new operational ceilings were set for the aircraft type to prevent recurrence.

**Unforeseen Type Deficiencies**

New aircraft types are only certificated for use after extensive flight trials. However, in certain cases aircraft types have been certificated with latent design defects which later present themselves through incidents. Whether such oversights are a function of imperfect regulation or simply a limit to the level of knowledge or experience is of little consequence to the operator who suffers the unforeseen fault. By definition, such accidents are beyond the control of the operator, but nevertheless can significantly affect an airline’s safety record.

The accident record for jet transports reveals that such incidents are few and far between mainly due to the rigorous testing required by certification bodies around the world. The fact that the majority of the world’s aircraft are built either in USA or Europe where regulatory standards are very high make unforeseen deficiencies a rare event. However, the series of accidents involving DeHavilland Comet aircraft illustrated how advances in technology can still fall foul of the unknown. The Comet 1 was built with square windows which allowed fatigue cracks to develop under the stresses of pressurised operation and resulted in a number of catastrophic structural failures. The loss of three BOAC Comets led to the withdrawal of the aircraft’s certificate of airworthiness and significantly affected the airline’s safety record.

There is also debate as to the unpredictability of the DC-10’s design fault regarding the rear cargo door. In 1972, an American Airlines DC10 flying over Windsor, Ontario experienced a rear cargo door blow-out, sustaining damage to its control systems which were all directed through the cabin floor to the tail of the aircraft. (Stewart, 1987) The aircraft landed safely and modifications were recommended to the latch mechanism of the door. However, it seems that the manufacturer’s modifications to new aircraft were incomplete and in 1974 a Turkish (THY) DC10 was lost at Ermenonville, near Paris after a similar cargo door blow-out. Barnett et al. (1979) suggest that this loss was not to be classified as a design flaw as “...apparently it was at least somewhat related to questionable maintenance procedures by the airline involved”. The modification carried out by Douglas to the latch was defective and made the likelihood of a failure higher. It meant that a little amount of brute force applied by a ground handler could cause the pin to bend, appearing to be in position when the opposite was true. As ground handlers are generally recruited for ‘brawn over brains’, some of the responsibility must lie with Douglas. In other words, had another carrier been operating that particular
aircraft, there is a significant chance that the same accident would have happened and so it is a poor indicator of THY’s attitude towards safety.

**Existence of Hazard in Australia**

Significant design problems are reviewed below for the large transport type aircraft which may have or do operate within Australia. The analysis covers Western built aircraft only because of a lack of information regarding aircraft built in the Eastern Bloc.

a) DeHavilland Comet Series

The first version of this aircraft was not ordered by Qantas as they were already happily equipped with Lockheed Constellation aircraft for long distance routes. However, with the takeover of British Commonwealth Pacific Airlines (BCPA), Qantas took over an order for Comet 2s "...subject to the usual technical considerations" (Gunn, 1988), but as the Comet disasters saw the Airworthiness certificates revoked for Comet 1 and 2 aircraft, the order was never completed.

The Comet 4 was considered by Qantas in competition with the B707, L1649 Super Constellation and Bristol Britannia 310. One of the concerns for Qantas was the poor record of structural integrity experienced by DeHavilland aircraft. Dick Shaw, technical advisor to Qantas assessed the Comet 4 and although he commented that there was no trouble or expense spared in ensuring the aircraft was free from structural problems,

"The integrity of an aircraft design depends on the philosophies and objectives of the Chief Designer and his section leaders. It also depends on the integrity, ability and outlook of all the design staff, down to the most junior design draughtsmen. It is quite impossible for an outsider, no matter how technical, to assess a large firm for the integrity of its design detail on a new and unproven project. In this respect the common and prudent practice is to judge each manufacturer on its past record." (cited in Gunn, 1988)

Qantas chose to order the Boeing 707 and no Comets ever flew in Australian service. History reveals that the design related accidents were limited to the early series 1 aircraft. Although the second production batch (Comet 4) recorded a significantly higher accident rate than younger designs, in terms of total losses, it had a better record than the DC8, SE210 and B707/720. (See graph 6.1.1)
b) Douglas DC10 Series

None of this aircraft type have been purchased by Australian carriers. In 1971 Qantas considered the DC10 alongside a further order of B747 aircraft, but chose the latter option on grounds of price, operating costs and type commonality. Had the airline bought the DC10 then it is not inconceivable that a Windsor-style incident could have occurred. However, it is arguable as to whether a Ermenonville type accident may have befallen Qantas. Following the Windsor incident, certain airlines (e.g. Laker) took the initiative to fit addition fail-safe locking devices to their aircraft. It seems likely that Qantas would have fallen into this category.

c) Boeing 767 Series

Both Qantas and Ansett Australia operate this type of aircraft. If the findings of the accident investigation are to be believed, it would be possible that the in-flight deployment of reverse-thrust equipment suffered by Lauda Airways in 1991 could have occurred to an Australian aircraft with similar catastrophic results. The discriminating factor which caused the accident to happen to a Lauda aircraft is not known. All B767 aircraft were modified at the instruction of the manufacturer following this accident.
d) Boeing 737 Series

At the Australian House of Representatives inquiry into air safety, an ACAA airworthiness inspector revealed that an Australian Airways B737 was allowed to fly on domestic routes for four months after the similar fault which may have caused the loss of the Lauda Air B767 was discovered. (Herald Sun, 1995) The warning light had been disconnected and although the ACAA had been led to believe that the problem had been rectified after a few days, a subsequent inspection revealed this not be the case. The inspector blamed "...unqualified or incompetent people making judgements about the plane’s safety" for the occurrence. As this incident followed the Lauda Air crash, then responsibility must fall solely on the operator for ignoring a design defect that was now known of and could be fixed.

Recent discussion following the loss of two B737s in separate unsolved accidents is cause for some concern. In March 1991, a United Airlines B737 crashed on approach to Colorado Springs with a loss of 25 souls. This was followed by a similar accident in September 1994 involving a USAir B737 on final approach to Pittsburgh International Airport with a loss of 132 souls. Both accidents remain unsolved although the main theory centres around an uncommanded rudder excursion which pitched the aircraft's nose to the ground in an unrecoverable dive. Similar rudder deflections have occurred to British Airways and Qantas B737 aircraft, albeit without such catastrophic consequences. Research into the problem is ongoing, but with the B737 being the most common jet aircraft in the world, there is justifiable concern.

e) ATR 42/72 Series

None of this type of aircraft currently operate within Australia. Two accidents resulting from in-flight icing have occurred fairly recently so the influence of these concerns on potential operators within Australia are difficult to assess. However, as the problem is now recognised, operators can no longer blame these problems on 'unknown' design defects. A redesigned wing is now available and modifications have been made to existing aircraft.

f) BAe 146 Series

The engine roll-back incident at Meekatharra (BASI, 1994c) represented an all engine failure scenario that had not been anticipated by the manufacturer or operator. Although the aircraft involved lost significant altitude (21,000 ft) before engines restarted, the incident would not have occurred at a significantly lower altitude because of the presence of more dense air. It is therefore incorrect to speculate that had the aircraft been cruising at e.g. FL150 then it would have made a forced landing as the icing conditions would not have occurred at such an altitude. However, this did represent a very close call for the RPT industry and the reaction was suitably high level with operating restrictions being placed on all BAe 146 on the Australian register.
Whilst the above aircraft types have been highlighted as suffering from major problems, it should be noted that all aircraft designs will accumulate defects which will need attention through airworthiness directives or manufacturers’ recommendations. This may include modifications such as airframe strengthening, avionics upgrades or engine alterations. This is a standard process within the industry which reflects the considerable investment represented by RPT aircraft. Airworthiness directives must be complied with, but advisories are at the discretion of individual operators and this provides an indication of corporate attitude. All of the aircraft types operated by Australian carriers have had airworthiness directives issued. This does not necessarily suggest that the aircraft were unsafe, rather that modification improved their operational efficiency.

Another consideration is the fact that ‘unforeseen type deficiencies’ can strike at any time and there is no reason to believe that this will not continue to be the case in the future. Recent accidents which are still under investigation such as TWA 800 off Long Island in 1996 may point to serious problems with the centre wing fuel tanks of B747 Classics; an aircraft type operated by both Ansett and Qantas. Further, there is always the risk of problems associated with ageing airframes such as the catastrophic airframe failure suffered by an Aloha Air B737 in 1988. Ansett, for example currently operate some of the oldest B767s in the world.
6.1.2 Aircraft Maintenance

The maintenance of aircraft is fundamental to the safe operation of the aviation system, yet its impact on the accident record is often underestimated. Boeing (1996) report the proportion of 'Maintenance as Primary Cause' accidents to be comparatively low, especially when compared to 'Flightcrew as Primary Cause'.

![Figure 6.1.2.1 Redrawn from Boeing, 1996](image)

Figure 6.1.2.1 records an average of 3.4% Maintenance Primary Cause Accidents for the 'jet age' period 1959 and 1995 which rises to 4.9% in the ten year period 1986 to 1995. Ashford (1994) also records a low proportion of maintenance causal factors in his analysis of 219 accidents (see figure 2.6.2) with only 15 maintenance factors highlighted out of the total of 839. However, it is also possible that other factors listed, such as engine failure or structural corrosion may be classified as maintenance related.

Whilst this proportion of primary cause and causal factors may seem low, other research has highlighted the fact that “maintenance incidents contribute to a significant proportion of worldwide commercial jet accidents” (BASI, 1997). Hobbs and Williamson (1994b) examined human factors in airline maintenance and highlighted the fact that in terms of fatalities, 'maintenance accidents' accounted for the second highest number of fatalities after controlled flight into terrain.

The authors cite figures prepared by the Boeing Safety Engineering Department for the ten year period 1982 - 1991 which attribute 1481 fatalities to 'Maintenance and Inspection' issues (although what constitutes a 'safety issue' remains a little vague). Such statistics include accidents with loud statistical noise such as the loss of a JAL B747 at Mount Osutaka in 1985 which claimed 524 lives; the highest toll in a single aircraft accident.
BASI (1994b) also note that Marx and Graeber (1994) “...estimated that 12% of major accidents involved maintenance as a contributory factor.” Reason (1994) also notes a study by Weiner of Boeing which examined 200 fully documented accidents and found maintenance and inspection errors present in 34. Whilst maintenance deficiencies rarely cause accidents as primary cause, they are much more frequently found as causal factors. Accidents may occur as a result of improper handling of the aircraft in response to a ‘survivable failure’, but in these circumstances, it may be argued that the failure of the last line of defence would not have been catastrophic if it had not been needed in the first place.

In spite of the significance of maintenance failures on aviation safety, “...there is a lack of empirical research on the nature of maintenance incidents and the human factors which contribute to them” (BASI, 1997). “Yet maintenance errors continue to account for a small but conspicuous number of accidents” (Reason, 1994). One of the most important issues which has come to the fore in maintenance safety is the predominance of human error as the central issue. This is a fact that can often be lost when ‘pilot error’ and ‘human error’ become used interchangably and ‘maintenance error’ is left as a separate category, almost as if the maintenance side of aviation is not a human centred function. For example, Stone and Babcock (1988) ask how to address the issue of pilot error, stating: “The labels ‘pilot error’, ‘operator error’ and ‘human error’ all describe the same characteristic.” This is far from the truth as pilot error refers specifically to errors made by (or blamed on) the pilots whereas human error is the larger subset which includes errors made by pilots as well as others such as maintenance workers, designers, air traffic controllers and management. Some may perceive this to be little more than an excursion into semantics, but others will recognise the need to get the message...
right. To give the impression that, in aviation, human error is exclusively the domain of pilots is, at best, old fashioned and, at worst, dangerous (Braithwaite, 1997).

Using figures produced by the UK CAA (1992) which looked at 6672 occurrences to UK registered aircraft over 5700 kg Maximum Take Off Weight (MTOW), Hobbs and Williamson (1994b) observed a total of 537 maintenance discrepancies. Of these, the top eight factors were as follows:

<table>
<thead>
<tr>
<th>DISCREPANCY</th>
<th>PERCENTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>incorrect installation of components</td>
<td>50 +</td>
</tr>
<tr>
<td>wrong parts fitted</td>
<td>6.7</td>
</tr>
<tr>
<td>electrical wiring discrepancies</td>
<td>6.1</td>
</tr>
<tr>
<td>loose objects left in the aircraft</td>
<td>4.8</td>
</tr>
<tr>
<td>inadequate lubrication</td>
<td>4.8</td>
</tr>
<tr>
<td>cowlings / fairings not secured</td>
<td>4.1</td>
</tr>
<tr>
<td>fuel / oil caps not secured</td>
<td>3.9</td>
</tr>
<tr>
<td>landing ground lock pins not removed</td>
<td>1.7</td>
</tr>
</tbody>
</table>

![Figure 6.1.2.3](image) Top Eight Maintenance Discrepancies Redrawn from Hobbs and Williamson, 1994b

Although these statistics relate to incidents as well as accidents, they illustrate the prevalence of human error within the maintenance environment.

Having established the importance of maintenance at an industry level and the centrality of human error to the frequency of maintenance or inspection failures, it makes sense to examine the Australian system in the context two areas; firstly, whether maintenance error is prevalent but ameliorated through other lines of defence such as pilot performance and secondly, if maintenance error is less prevalent, how the human factors issues have been controlled.

6.1.2.1 How Common are Maintenance Failures in Australia?

Anecdotal evidence regarding the reasons behind Australia's good record for airline safety cited the quality of maintenance as a significant factor. Both expert witnesses and those involved in the survey suggested that the quality of maintenance was good. Using question 3.7 (open ended), the Australian Pilots ranked 'good maintenance' as fourth place (see Figure 6.1.2.4) behind weather, crew factors and low traffic density.

Good maintenance also ranked fourth for Air Traffic Controllers (see Figure 6.1.2.5) behind luck, low traffic density and weather.
Figure 6.1.2.4 Reasons Behind Australia's Good Safety Record (Pilots)

Figure 6.1.2.5 Reasons Behind Australia's Good Safety Record (ATC)
Question 3.8 tackled a similar issue by offering 17 answers of which respondents were able to flag any that they felt applied. The question requested them to highlight 'which of the following factors do you consider have been highly significant in Australia’s safety record for commercial RPT jets?' The top ten results for Australian pilots are shown in Figure 6.1.2.6 split by carrier;

![Question 3.8 Top Ten Responses (Pilots)](image)

Displaying a similar trend to the responses to question 3.7 with maintenance being ranked fourth overall, Figure 6.1.2.6 also demonstrates a difference in perception between the RAAF, Ansett and Qantas. In the case of the latter, good maintenance actually ranks the second most important factor behind crew training. In Ansett, the integrity of maintenance is only ranked sixth and in the RAAF it is ranked fifth. This fact is reflected in the increased fear of maintenance failure held by these two operators compared to Qantas.
A similar response came from both sets of air traffic controllers who also ranked maintenance in fourth place, although the top three factors changed somewhat from those listed in question 3.7. Most noticeable is that 'luck' has dropped to fifth place and 'good ATC' has risen to first.

These perceptions are very important, as pilots in particular represent the end users of the maintenance product. A significant number of expert witnesses also highlighted the quality of the maintenance culture within the Australian carriers. It is typified by the attitude towards minimum equipment list (MEL) failures. MEL's can be 'carried' on aircraft subject to approval in the aircraft manufacturer's and airline's master minimum equipment lists. The aircraft is still deemed to be airworthy, albeit with less duplicate safety systems available. The use of MEL failures is to allow aircraft to continue on service flights back to their maintenance base. Ansett, Australian and Qantas strictly believed that aircraft should not carry MEL deficiencies.
over between maintenance checks which is common practice elsewhere in the world. However, there is some concern that this situation is changing as a result of commercial pressures and may therefore become a safety issue in the future.

A strong emphasis on engineering reliability has existed within the Australian aviation industry from its early days. This was largely a function of the tyranny of distance and the characters involved in attempting to conquer it. The former concept meant that aircraft needed to be imported into and assembled in Australia and the latter demanded that aircraft were reliable enough to fly between disparate locations over inhospitable terrain.

Qantas is one of a very small number of airlines that actually assembled its own aircraft and as such developed an exceptional engineering knowledge. In 1926, under the direction of Arthur Baird, Qantas assembled six DeHavilland DH50s, something which “Hudson Fysh believed was the company’s most remarkable achievement” (Bunbury, 1993). Whilst this procedure ceased well before the jet age, it established a tradition of engineering excellence which is deep rooted in the culture of Australian aviation. Another factor which has remained important is the distance Australia finds itself from airframe and engine manufacturers. It is a country which has never built high capacity turboprop or jet aircraft and depends on manufacturers situated in Europe and North America. This is one of the reasons why the Australian industry has a high degree of self sufficiency when it comes to aircraft maintenance. Qantas “...has the largest aero-engineering organisation in the southern hemisphere, with a completeness of stocks and engineering skills which owes its qualities to Australia’s remoteness and need for independence” (Learmount, 1987).

The distance factor has had a dual effect, not just in terms of remoteness from manufacturers, but also in the need for reliability. Sparse population and poorly developed land transport systems meant that emergency landing sites were few and far between. Terrain and weather conditions which may be considered to be relatively benign by modern standards, were downright treacherous in the early days and aircraft reliability needed to be high. The high profile role played by engineers such as Arthur Baird in Qantas helped to develop an organisational culture which was not dominated by pilots as so often was the case in other carriers. Constantly pushing the endurance and range of aircraft was another priority which has stayed with the Australian carriers into the jet age with engineers like Ronald Yates who worked on long range versions of the B707 in collaboration with Boeing. (see Gunn, 1988)
6.1.2.2 How is Human Error in Maintenance Controlled?

Human error is inherent in any socio-technical system and aviation maintenance is no exception. Assuming that Australian carriers fly similar aircraft to their overseas colleagues in similar conditions, it is reasonable to also assume that their engineers are open to similar opportunities for error. The fact that there have been no fatal accidents involving Australian RPT jets points to a high level of maintenance integrity, and, as was the case with the absence of pilot error, this in turn points to control of human error in maintenance.

Many of the problems faced by maintenance engineers have parallels with the experience of flight crews. Errors fall into two categories; errors of commission and errors of omission, shifts are long and generally during unsociable hours. However, it is an area which has often been ignored in favour of the flight crew. Whilst the most frequently quoted statistics regarding human error tend to focus on pilot error (see Beaty, 1996; Hawkins, 1987; Hurst and Hurst, 1976; Stone and Babcock, 1988), a deeper examination of maintenance primary cause accidents would reveal that the vast majority, if not all, of those incidents involve human error.

In an attempt to minimise the effect of error (and acknowledging that it can never be totally removed from the system), several strategies exist within Australia at both the conscious and subconscious levels. Major carriers have always run intensive engineering apprenticeship schemes. In Qantas, this represents an annual cost of around $7.5 million which is supplemented by a further $1 million spent on engineering skills training for permanent staff. Whilst Licensed Aircraft Maintenance Engineers (LAMES) are licenced by the Regulator, they are also expected to pass exams within the airlines which are set at an even higher standard.

Quality Assurance Departments exist within both Qantas and Ansett which operate well in excess of the minimum requirements set by the Regulator. These formal structures are supported by other mechanisms which include the HEAR (Human Error and Accident Reduction) group and Engineering and Maintenance Incident Investigations within Qantas. The former group is made up of volunteers from the different divisions of Engineering and Maintenance who meet every two months with the support of management to produce reports and newsletters in an attempt to reduce the incidence of human error. The latter group meets following incidents (which may or may not also be investigated by BASI) in a no-blame atmosphere to better understand the causal factors behind even apparently minor incidents. Qantas has also had the post of 'Engineering and Safety Manager' for a number of years (a role now replicated in Ansett) who is a Safety Department employee with functional power in the Engineering and Maintenance Divisions.

However, in spite of formal quality assurance and training systems, it is still possible for dangerous errors to occur if the culture in which they try to operate is deficient. A slack attitude towards quality assurance systems will see them circumvented (for example, see Clapham Junction Railway Disaster, 1988). Two of the reasons that Australia's safety record is good are corporate attitude and an openness in communication, both of which have been discussed
earlier in the text. In the maintenance environment, this translates into an attitude that believes things must be fixed promptly and fixed first time. It also means that mistakes can be admitted and corrected without fear of reprisal or loss of face, and that errors can be highlighted without animosity. Young (1988) observes that "...there is no way in which Australian LAMEs will meekly do as they are told. They will do a task which is assigned to them, but will only do it if they are confident that the job can be accomplished safely, and the subsequent result is the correct one."
6.1.3 Buyer Furnished Equipment (BFE)

The provision of secondary safety equipment on board an aircraft to mitigate the consequences of an accident is controlled to a degree by the regulators of the countries it operates within and also the aircraft operator. Some equipment such as seatbelts and over-wing exits come fitted as standard by the manufacturer whilst others are termed 'buyer furnished equipment' (BFE). The latter category may include life-rafts, doctor's bags and defibrillators. The supply of buyer specified equipment can significantly improve survivability in incidents and accidents.

Due to the nature of buyer furnished equipment, the number of cases where accidents have been avoided because of their existence are poorly reported. Examples where equipment such as doctor’s bags and defibrillators have had a positive benefit exist at company levels, but are rarely recorded on any formal database. A few anecdotal examples do exist, the most famous being an emergency operation carried out on board a British Airways Boeing 747 aircraft en route from Hong Kong to London in 1995 using a coathanger, catheter and water bottle.

The continuing discussion surrounding the true value of some on-board equipment such as lifejackets and rafts over potential new equipment such as cabin water sprays may take a new turn in the light of the Ethiopian Airlines B767 accidents off the Comoros Islands. Ditchings at sea involving large jet aircraft are very rare (the only two other successful in-flight ditchings have involved a DC9 in 1970 and an RAF Nimrod in 1995) and the limited experience that is available seems to demonstrate that the majority of fatalities are the result of impact forces and would not be mitigated by the use of life-jackets. The important question is, of the survivors, how many would actually have done so regardless of the provision of life-jackets. This is a question for future research and one that can benefit from the Comoros accident investigation.

The long distance intercontinental operations conducted by Qantas required aircraft to be flown to the limits of their range capabilities. Therefore, any excess weight would have a significant effect on operating costs and should be eliminated. The advent of the Boeing 707 jet brought new possibilities in endurance flying, but required tight controls on weight to be economical. Evacuation slides had become mandatory for aircraft of that size (not least because the new breed of aircraft had sill heights 16 feet above the ground.) and cross water operations (i.e. all of Qantas' operations at that time) required the carrying of life-rafts for use in the event of ditching.

With the Qantas B707-138 series aircraft flying some of the longest range routes in the world, any weight penalty would have hit the airline hard and seriously affected operational profitability. One of the Qantas Engineers came up with an idea that was destined to become industry standard. This was the design of a combined ‘slide raft’ which was as useful for evacuation as it was for ditching and saved the weight of duplication. The invention was perhaps more significant than simply being a good idea. Qantas was an airline - an operator of manufactured products and not in the business of design, and yet they came up with a revolutionary design that was given to the industry for nothing (and there is real significance in the latter fact). It may seem obvious that any airline would be focussing its attention on
maximising the available payload, but Lewis (1995) believes that this is a good example of innovative 'Pioneering Spirit' which exists with the Australian aviation industry.

**Security Equipment**

It is a legal requirement that all RPT aircraft entering Australian airspace must carry handcuffs or similar restraints for the control of unruly passenger. Although problems of this nature are a relatively recent phenomena, the mandatory carriage of such equipment has not yet reached Europe. British charter carrier, Britannia who operate to a number of worldwide destinations, only carry restraints on the B767 aircraft operating to Australia. Interviews with training staff reveal that the restraints have only been used 'once or twice' during the three seasons of operation and would be of much greater value on European operations such as to Ibiza and Tenerife. The feeling was that most of the trouble came from '...a type of passenger that would not generally be flying to Australia on holiday'.

Ansett and Qantas flights carry restraints by law and have been used on a number of occasions. In particular they seem to be need on the long night flights from Perth to Sydney or Melbourne and on ‘footie specials’ - In Australia, distance forces football fans to travel by aircraft to certain games and any hooligan element, albeit diminished by the expense, are shifted from trains (see UK) to aircraft. It is further anecdotally speculated by flight attendants that the higher than average proportion of male flight attendants to be found at the Australian carriers leads to a greater willingness to intervene with boisterous passengers

**Defibrillators**

Defibrillators are carried on all Qantas flights and all Flight Service Directors are trained in their use. There are few airlines around the world that carry such equipment, due to cost and legal matters. In the USA, the ‘litigation culture’ has developed to the stage where the carriage of such equipment only increases the airline’s liability and is therefore avoided.

**Heavy Crewing**

The Boeing 747-400 series aircraft brought not only added capacity to the jumbo jet market, but also a new extended range capability. Routes such as Los Angeles - Sydney (14h 20m) and Singapore - London (13h 40m) could be accomplished in a single sector with an added operational bonus that Boeing had designed the aircraft for two-man operation (the previous classic series 747-1/2/300 series had all required three flight crew). Although not all 744 customers wished to use the full potential of the aircraft’s extended range, long distance operators were faced with the problem of crew duty time over flying time. Qantas has always maintained a policy of ‘heavy crewing’ (Green, 1993) whereby additional crew members are carried on flights which might legally be able to be crewed with less crew albeit at the extremes of their operating capabilities. Rest bunks are fitted for use by the additional technical crew members as BFE.
On condition monitoring - QARs

The QAR or Quick Access Recorder is a form of flight data recorder (DFDR) which allows the operator to remove a tape or disk following a flight to monitor the performance of both the aircraft and the crew. Used correctly and with the co-operation of pilot unions, the QAR information can help:

- Monitor the operating standards of the airline directly to identify any undesirable trends that may develop on a daily basis
- Make sure that training and route check procedures are achieving their objectives on the line and adjust them if the Flight Data Analysis program shows any problems or trends.
- Provide continuous monitoring of aircraft systems and performance.
- Monitor any engineering problems that may be affecting the operation of the fleet.
- Monitor operation requirements and/or constraints imposed by outside agencies, e.g. air traffic control.

Qantas decided to look at operations monitoring systems in 1987 under the direction of a steering committee appointed by the directors of flight operations and of engineering and maintenance. A decision was made to implement a continuous monitoring system on all of the company’s aircraft (which at the time consisted of B747 Classic, B747-400 and B767). The two types of system which were available were continuous monitoring or exceedance monitoring. The former requires all of the flight to be recorded for analysis at a later date by the ground station computer. The latter method requires additional on board equipment and records only exceedances to pre-programmed operational limitations.

The benefits of such a system are numerous. From an operational engineering point of view, the use of QAR data allowed Qantas and Rolls Royce to more actively monitor the use of derated or reduced-thrust operations. Such operations can lead to a significant increase in the time between large component changes and the closer monitoring afforded by QARs has led to up to a fifty percent increase in cycles between component change. Cost savings associated with this procedure alone are enough to cover the costs associated with running the program (Faulkner, 1991).
From a safety point of view, one of the early success stories of the programme came from monitoring the take-off performance of the B747-400 fleet. Qantas became aware that aircraft speed was bleeding back to V2 and below shortly after take off, especially when aircraft were close to their MTOW. Trend analysis conformed that this was something that was occurring with different crews at different airports and further investigation was made. It seems that in the change from the ‘gauge and dial’ B747 Classic aircraft to the glass cockpit -400 series, crews were tending to over-pitch the aircraft and lose air speed. Aircraft were coming close to suffering tail-strikes or stalling and amendments to the conversion training were made. A sharp decrease in such exceedances confirmed (and quantified) the success of the program.

Perhaps the most important aspect of the scheme is the way it was set up and run. This gives some insight into the attitude of the company and its crews and ultimately makes a significant difference to the long term viability of the scheme.

The Qantas flight data analysis office is based adjacent to the safety department and operates as a clean-room environment with strict security clearance required for access. All data is handled by a small, dedicated staff who will not entertain visits from active crews to the facility, to protect the integrity of the scheme. Should a pilot make a significant mistake or deviation which is flagged by the monitoring computer then they will be approached in a subtle and non-punitive way. This is usually in the form of an informal telephone conversation with the AIPA (Australian International Pilots Association) representative who will make inquiries into whether performance exceedances were the result of a ‘bad day’ (e.g. family problems) or a training deficiency. The union may be able to provide support in the case of the former or the pilot may chose to address the latter deficiency during recurrent training. Support for the scheme by the AIPA and its confidential, non-punitive nature are fundamental to its success.

In contrast, a similar scheme of on-condition monitoring was introduced into a Japanese airline. The Chief Pilot of that airline explained how the system worked at a conference (details withheld for anonymity) and was questioned about how the company responded to recurrent exceedances by particular individuals. The dialogue is printed below;

Q. What do you do if one pilot keeps making the same mistake?
A. We will phone him and tell him so.

Q. Do you offer any sort of retraining?
A. No, there is no demotion, punishment or retraining.

Q. But if the pilot keeps making the same mistake, do you not offer retraining to them?
A. No, there is no demotion, punishment or retraining.

Q. But what if he keeps on making that mistake?
A. He will not do so.
In other words, this was a scheme operating in a culture where retraining was seen as being similar to punishment or demotion. Crew were told of their mistakes and it was entirely up to them to correct their mistakes. The concept of recurrent mistake making was embarrassing to the culture and to save face was not considered in the formal response structure.

If this is the way that the QAR monitoring system works then it is likely to have deficiencies in the area of highlighting individuals' problems. However, this is not to say that the other aspects of the programme such as the engineering uses are any less effective than the Qantas system.

**Collision Avoidance Systems - TCAS**

TCAS or Traffic Alert and Collision Avoidance System is a radar system which detects other aircraft which may be on a collision course, using transponders which are carried on other aircraft. The TCAS system issues alerts and will suggest remedial action such as 'Climb' or 'Descend'. They are also intelligent systems such that should two aircraft fitted with TCAS equipment be flying on a collision course, they will be issued with opposing instructions i.e. one aircraft will be advised to climb and the other will be advised to descend.

The US FAA have mandated the fitment of TCAS equipment to all large RPT aircraft entering the country. However, this regulation is not mandatory elsewhere around the world. All of Qantas' and Ansett Australia's International fleets are fitted with TCAS and both domestic fleets are currently being fitted with TCAS radar to supplement the transponders which they have carried for some years. Interviews with expert witnesses suggest that the TCAS equipment is most needed for services which overfly the Far East and Eastern Europe where ATC provision leaves something to be desired.

Mid air collisions are comparatively rare although there have been a number of significant accidents where aircraft have collided even in clear skies. (Zagreb, Cerritos, San Diego, Saudia) As a result of the awesome inertia involved in the collision of two aircraft, these events are usually total fatalities and are therefore particularly feared by air crew. This is backed up in the survey responses to the question; "Please rank the top three factors you consider pose the greatest threat to your flying safety?"
What are the top three greatest threats to your flying safety?

- Engine Failure
- Snow / Ice Accumulation
- Windshear / Microburst
- Weather
- Judgment Error (Self)
- Judge Error (Others)
- Mid-air collision
- Maintenance Failure
- CFIT
- Security Breach
- Runway Incursion
- Management Error
- Inappropriate Regulations
- Acts of Aggression

Figure 6.1.3.2 What are the Top 3 Greatest Threats to your Safety (Qantas)

What are the top three greatest threats to your flying safety?

- Engine Failure
- Snow / Ice Accumulation
- Windshear / Microburst
- Weather
- Judgment Error (Self)
- Judge Error (Others)
- Mid-air collision
- Maintenance Failure
- CFIT
- Security Breach
- Runway Incursion
- Management Error
- Inappropriate Regulations
- Acts of Aggression

Figure 6.1.3.3 What are the Top 3 Greatest Threats to your Safety (Ansett)
The greatest fear of Qantas pilots (international and domestic) is that of mid-air collision, accounting for 18% of the response. This fear seems to have been heightened by an incident which occurred during the Gulf War where a Qantas B747 came within 50 feet of a USAF C5 Galaxy near Phuket. As such, neither aircraft had a TCAS unit and both aircraft came extremely close; only altimeter error prevented a mid-air collision. This story remains high in the consciousness of Qantas crews and was added to by an incident which occurred near to Darwin in 1995 when a Qantas Domestic B737 was involved in a serious breakdown in separation with a British Airways B747. (Note that Breakdowns in Separation are covered elsewhere). It was immediately following this incident that the decision was taken to fit the Qantas domestic fleet with TCAS equipment.

Ansett Australia (domestic only) crews rated the threat of mid-air collision in second place at just under 13%. The difference between that and the Qantas result may be the result of the airspace that Qantas International operates in (as mentioned above). However, it is interesting that a (at the time) non TCAS fitted fleet like Ansett have a lesser perception of the threat than the Qantas crews who have had TCAS equipment on their international fleet for a number of years. It is possible that the heightened awareness of other traffic - even non conflicting traffic - afforded by the TCAS displays has led to a greater perception of this danger.

However, this appears to be in contrast to the returns from the British Airline used as comparison. Asked the same question, the response was as follows;
Mid-air collisions ranked in sixth place attracting just over 6% of the response. This is of real interest as this carrier operates a fully TCAS fitted fleet of aircraft in many of the areas described by Qantas expert witnesses as having deficient air traffic control. This includes over Thailand on trips to Australia and over Greece, Turkey and Spain in Europe. This also includes a significant amount of flying on charter work into small airports which serve European holiday resorts, where ATC provision is often of a lower quality. Most of this carrier’s fleet operates in Europe where traffic densities are much higher and problems such as the use of different languages in communications are more prevalent.
6.1.4 Regulatory Requirements

It is the responsibility of the Regulator to ensure compliance with minimum standards in an attempt to ensure the safety and efficiency of air transport. In Australia, this is the responsibility of the Civil Aviation Safety Authority (CASA), an autonomous body created from the now defunct Civil Aviation Authority (CAA). The basis of national standards are the recommendations set out by the International Civil Aviation Organisation (ICAO) through the Annexes of the Chicago Convention. These recommendations are then accepted with little or no modification at member state level to become law. In Australia, standards have tended to be based upon "...US Federal Aviation Regulations (FARs) and the British Civil Aviation Requirements (BCARs) and the differences from them are quite minimal." (Dunn, 1988). Known as Australian Civil Aviation Requirements (ACARs) they cover a range of areas which can directly impact upon the quality of an airline's operation. These include licencing of:

- air transport
- provision of accommodation in aircraft
- registration and certification of aircraft
- safety of aircraft (including airworthiness)
- certification of operators of aircraft
- licencing of flight crew and maintenance engineers

In terms of the operational suitability of aircraft, it is the issue of airworthiness that seems to be of paramount importance. Although some definitions refer to airworthiness as the condition of an aircraft as being 'fit to fly', Dunn (1988) contends that in Australia it represents more of a process which is put into practice through the following:

- The establishment of appropriate design and maintenance standards for the particular operation and aircraft type
- The certification of the aircraft type to the relevant design standard; including navigation systems and other operational equipment for the designed operational role
- The maintenance of particular aircraft to the relevant maintenance standards; in organisation approved for the purpose and / or by individuals appropriately licenced
- The ensurance of continued fitness to fly of individual aircraft and aircraft types through in-service safety performance monitoring, the outcome of which can and does feed back into revised design and maintenance standards.
There are a number of reasons behind Australia demanding its own certification rather than accepting those granted by the FAA or UK CAA as is the case in many countries with equivalent and larger aviation industries. These include issues such as 'grandfather rights' which are accepted in the US, but not in Australia in certificating derivatives of existing aircraft series. Far from implying that other airworthiness authorities are deficient in their certification processes, the rationale behind Australia's independent certification is one of insurance or 'playing safe'. Dunn (1988) summarises the reasons as:

- A legal requirement for the Authority (CASA) to be satisfied as to the airworthiness of an aircraft before a certificate is issued.

- To give freedom to manufacturers and operators to develop design, construction and operation of aircraft in the most efficient manner, airworthiness requirements, with few exceptions, are expressed in terms of basic safety objectives, rather than black and white limits. This inevitably involves interpretations, equivalent safety considerations and such. It is an essential element of conformity certification considerations to understand the basis for these decisions.

- The most important reason is that the certification process itself provides the cornerstone for the continuing airworthiness function of the Authority. It establishes the required airworthiness function it aims to maintain.

This attitude has changed somewhat in recent years as CASA has looked at harmonising regulations with those of the US FAA and European JAA (Joint Airworthiness Authorities). This followed a resolution adopted by the 29th Assembly of ICAO encouraging global harmonisation and a general attitude change within the Australian industry throughout the relatively tempestuous 1990s.

In asking whether there are examples of accidents which had been prevented as a result of Australian certification, Dunn (1988) argues that there is no satisfactory answer; "There is no guarantee that had deficiencies discovered by the Australian teams not been corrected, an aircraft would have been lost." However, the author does concede that "The consequence is a lower probability of an accident occurring" (Dunn, 1988).

Nevertheless, there is a widely held belief that the style of regulation in Australia has been an important factor behind its good airline safety record. Brogden (1968) suggests "...the strict system of safety and operational controls" to be a significant factor and Ramsden (1976) also refers to "...Australia as a 'police state' in its air safety regulation." The reasons for this
approach reach beyond the way that ICAO recommendations were interpreted. The HORSCOTCI report (1995) observed that; “Other influences on regulatory development include requests from industry, community groups, and the public, government directives, international Airworthiness Directives from manufacturers or government agencies; major defect reporting systems, and the results of surveillance activities.”

Regulation of aviation safety is not a simple process in that there is not one single level of acceptable safety for all classes of operation. To set such a level would be all but impossible, not least because of the prohibitive costs that would be involved at the lower capacity end of aviation. Smith (1992) notes that “A large aircraft could be built with the speed, comfort and safety characteristics of a Cessna 172 which would be cheaper per seat to construct and operate. Conversely, an aircraft with only four seats could be built with the same level of safety and other features as a Boeing 747, but it would cost tens of millions of dollars and nobody could afford to travel in it.”

In line with ICAO standards, regulations within Australia prescribe air safety standards according to a hierarchy of classes of operation. (HORSCOTCI, 1995) The highest standard is for high capacity RPT aircraft; scheduled services for fare paying passengers using aircraft with more than 38 seats. All aircraft directly owned and operated by Qantas, (Australian Airlines) and Ansett fall into this category and are therefore operated at or above the minima for the highest level of safety regulation. The levels of safety regulation beneath this category are low capacity RPT (commuter - including Qantas and Ansett subsidiaries and partners), GA charter, aerial work, private operations and down to sports aviation. Variations in minimum standards cover both operations and airworthiness. The latter includes variations in maintenance standards where there are also two levels depending on aircraft size and style of operations.

Concerns raised during the Inquiry into Aviation Safety: Commuter and General Aviation Sectors (HORSCOTCI, 1995) included the operation of aircraft with lower regulatory standards under code-sharing or partner agreements without public knowledge. Qantas liveried partners include aircraft as small as the BAe Jetstream 31 and Cessna Titan. The latter aircraft needs either one or two pilots depending upon whether it is operating charter or low capacity RPT and there was genuine concern as to whether passengers were fully aware of the difference. A ticket bought on Qantas between London and Bourke may end up with the last leg being completed aboard a charter aircraft. Former Qantas, Director of Operations, Alan Terrell considered that to be misleading. (HORSCOTCI, 1995) Following the Inquiry, both Ansett and Qantas took a more active role in ensuring standards within its partner and subsidiary operations were in line with those of the parent airline.

The differing levels of regulation and the different accident rates is no coincidence although that is not to suggest that accident rates are directly a function of regulation. Smith (1992) noted accident rates for five levels of air operations based on US and Australian accident statistics (see figure 6.1.4.3) to be vastly different.
At the level of the major RPT carriers, the role of the regulator has always been important, not least because the level of regulated safety was that much higher than for other classes of operation. However, the importance of ‘self regulation’ should not be forgotten in terms of airlines complying with standards not just in case of surveillance by the regulator but because they believed them to be proper. The relationship between the major airlines and regulator has always been close, but not at the stage of being corrupt. Even in spite of this, there have been many times where the airlines have not been under close scrutiny, sometimes because they are behind the regulator. In some instances, carriers have taken their lead from the UK CAA or US FAA where regulations do not exist within Australia, only for the Australian regulator to eventually follow suit and make it law. Whilst such a process is satisfactory when the airlines are acting responsibly, it is open to some abuse and suggests that the regulator has not been able to execute its function adequately.

While safety regulation is designed to act as a framework on which the safety of a national aviation system is based, it is primarily concerned with setting minimum standards. Whilst higher minimum standards in one state compared to another may see a generally higher level of safety, it is more likely that major airlines see regulations as only the bare minimum. As such, differences between ICAO member states which accept recommendations in a near unadulterated form are likely to be quite small. The significant difference will be in the interpretation of those regulations by airlines, airfields, ATC providers and the surveillance arm of the regulator. In Australia, conservative regulation is indicative of a wider industry attitude towards safety rather than the powerhouse behind it.
6.2 Airport Integrity

Airports vary considerably in the quality of service they provide. This is not simply in terms of facilities for the passenger or cargo customer, but also in terms of the service they provide to aircraft. There are a number of influencing factors that include:

- The size, surface and condition of runway and taxiway pavements
- The availability of approach aids
- Obstacle clearance (both natural and man-made)
- Prevailing weather conditions
- Surrounding terrain and approach procedures
- Level of traffic versus ATS provision

Variations in which types of aircraft use a particular airport (and the loadings they carry) as well as issues of crew familiarity combine to make assessing the operational quality and safety of particular airports quite difficult.

IFALPA (The International Federation of Airline Pilots' Association) have a black list of airports and airspace around the world (known as Annex 19) which do not satisfy the standards of the association to one degree or another. They were approached in the course of this research to provide a copy of the aforementioned document, but were unable to supply any details of the list as their circulation policy restricts access to the "...central federation and its member associations." (Myers, 1995) IFALPA explained that they "...have found through unfortunate experience that relaxation of these controls and the subsequent availability of information to non-experts, or to individuals who might for one reason or another misinterpret or misuse it, can have regrettable consequences". Although they accepted the objectives of this research to be worthwhile, it was not worth making the entire thesis confidential and of limited access for the sake of this source of data.

Barlay (1991) lists sixty airports or countries where airports are renowned for being particularly poor and are included in IFALPA's list. It is not a list of third world or secondary airports as may be expected, but contains big international airports including fourteen in the USA. Even large airports such as New York JFK and La Guardia are included for their lack of safe overrun areas. None of the sixty are in Australia and Qantas only fly to six of them. (including Jakarta which was boycotted for a time by Australian pilots because of its inadequate facilities.).

6.2.1 Size, Surface and Condition of Runway and Taxiway Pavements

Aviation folklore suggests that the two most useless things in aviation are fuel left in the bowser and runway behind the aircraft. The length of runway becomes an issue for aircraft at both take-off and landing particularly when emergencies arise such as aborted take-offs or
misjudged touchdowns. However, it is not as simple as saying that the longer the runway, the greater the safety margin it provides. To investigate whether an extra margin of safety is assured at Australian airports by aircraft using runways in excess of their operating requirements seemed to be a worthy aim.

However, the performance of aircraft at take-off is affected by a variety of factors including weight, outside air temperature (OAT) and pressure, wind and the need, or otherwise for derated or noise-abated take-offs. This makes direct comparison quite difficult. Crews derive the required take-off runs from charts provided by the aircraft manufacturer and kept on the flight deck. This guide also specifies minimum required distances for take-off based on the extremes of all the controlling factors, but this does not provide a useful guide for answering the above question.

The original method to test the question was to compare the mix of aircraft types and their minimum requirements to runway lengths. That is to say that for a sample airport such as Melbourne Tullamarine built for long range ‘runway hungry’ aircraft such as the B707 or B747, what is the mix of short haul, short take-off and landing requirement types such as the later series B737, BAe 146 and propeller aircraft (e.g. Saab 340) and the long take-off and landing types. This method proved rather more difficult than originally anticipated and unable to be used reliably.

Interviews with airline pilots operating large aircraft types pointed out several problems:

a) Firstly, aircraft that required shorter distance take-offs than the runway provides often take the opportunity to execute derated take-offs. This is not only to preserve engine components and use less fuel, but also for noise abatement reasons (the latter being especially important at city-locked airports such as Sydney). Departure records do not show whether take-offs were derated or not.

b) Flights using the same aircraft types fly different route lengths, have different passenger and freight loadings and will vary in equipment configuration between airlines. For example, a B737-400 flown by Qantas Domestic carries about 20 less seats than, say, an Air UK Leisure B737-400. Added to this the weight differences of the varying luggage allowances between classes and the varying construction weights of business, first and economy class seats.

c) Pilots claim that their flying technique will be adjusted to the length of runway available. Aircraft needing short runways landing at airports with long runways will tend to take advantage of slower braking for the sake of passenger comfort and aircraft wear. Also excessive runway length can affect visual perception and make landings more difficult and are more likely to include variations in slope (e.g. Runway 34L at Sydney).
6.2.2 The Availability of Approach Aids

Accidents which occur on final approach account for the greatest proportion according to Boeing (1996) who estimate 23.6% of accidents to occur in this phase, which in turn represents an average exposure of 3% of the flight time. Hazards include undershoot, overshoot, veeroff and both stalled and heavy landings.

Precision approaches are those which utilise instrument or microwave landing systems (ILS / MLS) whereas non-precision approaches are those which use either no aids or NDB, VOR/DME equipment. Whilst larger airports such as Sydney and Melbourne are fitted with ILS equipment, many of the smaller airports which are served by jet traffic are not. Airports within Australia with ILS available on at least one approach are as follows:

- Sydney (Kingsford Smith)
- Melbourne (Tullamarine and Essendon)
- Perth
- Adelaide
- Canberra (also fitted with MLS)
- Cairns
- Darwin
- Hobart
- Launceston
- Alice Springs
- Townsville

Other airports use non-precision VOR/DME or NDB approaches. This does not necessarily mean that safety margins are lower at these airports, rather that their operations are more limited by meteorological conditions. In conditions of poor visibility, aircraft will be forced to divert to the nearest alternate airfield, an eventuality which is factored into carried fuel loading. On overseas routes, just about all of Qantas' destinations have at least one ILS approach available and 60-70% of designated alternates also do.

The Flight Safety Foundation CFIT Checklist (FSF, 1994) provides a tool for assessing the risk of a controlled flight into terrain accident at any chosen airport assigns a value to the presence of various hazards and countermeasures. It is based on the findings of the FSF CFIT Taskforce and provides an indication of the relative value of approach aids. For example, the presence of a procedure whereby the pilot (nonflying) independently verifies minimum altitude versus DME for a VOR/DME (non precision) approach is worth +20 points. The presence of second generation GPWS or better in the aircraft is worth +30.

In contrast, the presence of an ILS approach scores zero, a VOR/DME (non-precision) approach scores -15 and “if this is a non-precision approach with the approach slope shallower than 2.75°” scores -20. An approach using solely an NDB (also non-precision) scores -30 which is equal to the score of an airport with no ATC radar capability. The fact that non
precision approaches only deduct a limited number of points in comparison to relatively simple aircraft avionics (GPWS) or training solutions is an important consideration. In other words, the ability of approach aids to prevent accidents is significantly less than human centred training solutions. This view is supported by the data contained within Boeing's Accident Prevention Strategies (Boeing, 1993). In an analysis of 138 hull loss accidents where 606 prevention strategies were highlighted (an average of 4.39 per accident), the top three ranked strategies were 'flying pilot adherence to procedure' (49%), 'other operational procedural considerations' (45%) and 'nonflying pilot adherence to procedure' (29.5%). Maintaining 'approach path stability' is ranked eighth (15%) as an 'aircrew' factor, but the 'availability of approach aids' is 30th (2.5%) suggesting that other factors are more important such as adherence to procedure (e.g. on the subject of decision height) or response to GPWS.

On this evidence, it seems to be the case that the presence (or lack of) of approach aids is not the major factor in preventing (or causing) approach accidents. Other aspects of the natural environment (such as weather) and crew performance (at what is possibly the peak of their workload) play a more significant role. A separate investigation by the Flight Safety Foundation for the Netherlands Director General of Civil Aviation examined the influence of precision approach systems on accident risk. (FSF, 1996) Using a sample of 557 airports and 132 accidents, the team concluded that "On a worldwide basis, there appears to be a five-fold increase in accident risk among commercial aircraft flying non-precision approaches compared with those flying precision approaches." Whilst such a finding would seem to support the presence of ILS / MLS as a critical safety aid, it cannot be taken entirely on face value. FSF note that when stratified by ICAO region, the risk of non-precision approaches varies from three-fold to almost eight-fold. There are also other associated factors such as the absence of charted approach procedures, absence of terminal area radar coverage and "...many factors that influence overall approach-and-landing risk are outside the direct control of the airport or authorities". There are obvious benefits of non-precision approaches, but the absence of them does not necessarily equate with a poor level of safety. Whether an airfield is equipped with ILS and at whatever category is a function of both its need (prevailing weather conditions) and the level of traffic (cost). The approach minima associated with each category (for precision and non-precision approaches) are designed to facilitate a uniform level of operating safety for each mode.

In terms of visual guidance systems such as VASIS (Visual Approach Slope Indicator System), T-VASIS or PAPI (Precision Approach Path Indicator), main airports in Australia tend to be fitted with T-VASIS, a more accurate and flexible version of the original VASIS, pioneered in Australia. However, the significance of such equipment on the safety record is taken to be minimal. The Flight Safety Foundation in a study of approach and landing accidents observed that "Though visual approach guidance (VAG) is deemed an important landing aid, no association was demonstrated between the presence or absence of VAG and accident risk for the sample considered." (FSF, 1996)
6.2.3 Obstacle Clearance

The presence of obstacles at the critical climb-out and approach phases of flight can form a latent defect in the aviation system which may later combine with active failures such as engine failures, out of configuration aircraft or unstabilised approaches. ICAO Annex 14 (Aerodromes) details the minimum requirements for clearance surfaces around airports and these have in turn been accepted by member states including Australia. In considering differences in safety margins, consideration may be given not just to adherence to the ICAO recommended minima, but also to how far these are exceeded.

In accidents where aircraft have under-, over-shot or veered off runways, the severity of the outcome has often been dictated by exceedances of the required minima for obstruction clearance. As 80% of aircraft accidents are known to occur within 500ft of the active runway centreline and 3000ft of the runway thresholds (Hewes and Wright, 1992), the secondary safety effect of clear surfaces, whether intentional or not, is not insignificant.

Had the M1 motorway passing East Midlands Airport not run through a steeply sided cutting, the consequences of the 1989 Kegworth air disaster may have been less serious. The effect of other accidents such as the overrun of a USAir B737 at La Guardia Airport in 1989 and 1996 aborted take-off overrun accident in Kinshasa which killed 300 may have been different if surfaces around the airport had been different. However, such statements are based upon speculation and proving them would be difficult. It is possible that in areas with relatively poor obstacle clearance, such as the approach to Hong Kong’s Kai Tak airport, performance on the part of the crew would be modified in anticipation. Awareness of a hazard which is perceived to be extreme (such as a complex approach or departure) is enough to heighten alertness to a point where performance is improved and the hazard adequately counter-balanced.

The lack of accidents involving jet aircraft in Australia makes it difficult to speculate on the subject of obstacle clearance in excess of ICAO minima. Suppose an aircraft is making an approach to Sydney to land on the shorter, third runway 14L which juts out into Botany Bay. The crew is likely to be well aware of the fact that landing distance is more critical and would therefore aim to touch down close to the threshold or initiate a go-around early if required. Similarly, if an aircraft was to approach the longer 14R runway at Sydney, the crew would recognise that they had a longer area to decelerate which in turn would impact upon their go-around decision making.

6.2.4 Prevailing Weather Conditions

As discussed earlier, meteorological factors can have a significant effect upon aircraft operations, particularly around airports where aircraft are flying at slower speeds and are more susceptible to phenomena such as microburst / windshear. Differences in climate mean that each airport will experience a unique set of weather conditions and therefore some airports lend themselves to easier use than others. Airports such as Sydney and Melbourne experience good ‘CAVOK’ conditions for a large proportion of the time; a fact which is reflected in the
level of instrument landing systems. Sydney Airport, for example, is equipped with category one instrument landing (ILS) capability whereas airports such as London Heathrow are equipped to Category Three. The primary reason is the prevalent weather conditions, but it is all but impossible to speculate as to which operation is more safe. The five categories of ILS equipment (Cat I, II, IIIa, IIIb and IIIc) require different minima in terms of runway visual range and decision height which should all equate to similar levels of operational safety.

The importance of weather conditions is related not just to the provision of instrument landing systems at airports, it may also be linked to other factors such as runway pavement surfaces (including rubber contamination), commercial and other operational pressures. Runways which suffer from excessive rubber contamination can become prone to aquaplaning in wet conditions, commercial pressure not to miss an arrival or departure slot may encourage crews to fly in marginal conditions and the threat of concepts such as 'get-home-itis' at the end of long trips can also affect judgement.

Whilst it is possible to say that the prevalent conditions at most major Australian airports are favourable, it must be balanced against extreme weather conditions and the level of available precision navigational aids.

6.2.5 Surrounding Terrain and Approach Procedures

The Flight Safety Foundation study of accidents during approach-and-landing (FSF, 1996) concluded that “Worldwide, the presence of high terrain around an airport did not appear to significantly increase accident risk compared to airports without terrain.” However, there is a heightened perception of risk associated with operating into airports with surrounding high terrain or complex approach procedures. Accidents such as the 1997 loss of a Korean B747 at Guam and of a Pakistan International A300 on approach to Kathmandu, Nepal in 1991 occurred in areas of high terrain, but the principle causal factors were not the height of the ground. Whilst the investigation of the former accident appears to be centred around the use of a non-precision approach, the latter turned out to be primarily the result of a deflected VOR/DME beam.

Hong Kong is probably the most famous ‘hazardous approach’ where aircraft navigate between skyscrapers and high terrain to an airport protruding into the sea. However, the mere fact that the approach is so critical is probably one of the reasons that it has operated safely. The more obvious the hazard; the better human operators are at dealing with them. The concept of relief and collision risk is discussed in more detail in section 4.2.2

The loss of a Piper Chieftain at Young, NSW in 1993 (BASI, 1994) highlighted to the Australian industry the potential for disaster from unstabilised approaches to airports with non-precision approaches even in areas of relatively flat terrain. The aircraft descended below minimum safe circling altitude after crossing the airport NDB and collided with terrain only
275 feet about the airfield elevation with the loss of 7 souls. This was one of the major incidents which precipitated the HORSCOTCI inquiry into aviation safety in the Commuter and General Aviation sectors (HORSCOTCI, 1995). There are a number of reasons which would suggest that a similar accident would not happen to a jet aircraft in Australia such as the mandatory provision of two or more flight crew and the fitment of GPWS equipment. However, the many organisational issues that were highlighted by the BASI investigation (BASI, 1994) demonstrate that issues such as the height of surrounding terrain and meteorological conditions on the day were co- incidental to the numerous latent defects that were present within the carriers operation. The important message is that terrain and approach procedures, as relatively fixed variables in the operating system, are of less significance that the more variable aspects of the human environment.

Changes in approach procedures or those which are difficult to understand, especially by foreign crews who may lack local knowledge or familiarity are a different hazard and are discussed in section 6.3. Accidents such as the loss of an American Airlines B757 near Cali highlight the danger of collision risk following the loss of situational awareness. This is also a potential problem for Australian aircraft, especially at some overseas ports where there is high surrounding terrain or indeed cityscapes.

6.2.6 Level of traffic versus ATS provision

Air traffic control in the terminal area is where traffic density tends to be at its highest. Air traffic provision is at a commensurately higher level with approach controllers and ground controllers to manage operations. Air traffic control, particularly in regard to traffic density is discussed in more detail in section 6.3.
6.2.7 Rescue and Fire Fighting Provision

Under the recommendations of ICAO Annex 14, chapter 9, aerodromes are assigned a category for rescue and fire fighting service (RFFS) cover based on the dimensions of the aircraft using them, as adjusted for their frequency of operation. RFFS cover may be provided by public or private organisations located in such a way as to be able to meet the following response criteria: The operational objective is for the first RFFS tender to get from the initial call to a position where it is able to apply foam at a rate of at least 50% of the ICAO specified discharge rate within 2 minutes. The response should not exceed 3 minutes to any part of the movement area in optimum conditions of visibility and surface conditions. (ICAO, 1990)

The ICAO aerodrome category scheme is summarised in the following table;

<table>
<thead>
<tr>
<th>Aerodrome category</th>
<th>Aircraft over-all length</th>
<th>Maximum fuselage width</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 up to but not including 9 m</td>
<td>2 m</td>
</tr>
<tr>
<td>2</td>
<td>9 m up to but not including 12 m</td>
<td>2 m</td>
</tr>
<tr>
<td>3</td>
<td>12 m up to but not including 18 m</td>
<td>3 m</td>
</tr>
<tr>
<td>4</td>
<td>18 m up to but not including 24 m</td>
<td>4 m</td>
</tr>
<tr>
<td>5</td>
<td>24 m up to but not including 28 m</td>
<td>4 m</td>
</tr>
<tr>
<td>6</td>
<td>28 m up to but not including 39 m</td>
<td>5 m</td>
</tr>
<tr>
<td>7</td>
<td>39 m up to but not including 49 m</td>
<td>5 m</td>
</tr>
<tr>
<td>8</td>
<td>49 m up to but not including 61 m</td>
<td>7 m</td>
</tr>
<tr>
<td>9</td>
<td>61 m up to but not including 76 m</td>
<td>7 m</td>
</tr>
</tbody>
</table>

This table then determines the minimum amount of extinguishing agents and the minimum number of RFFS vehicles to be provided;

<table>
<thead>
<tr>
<th>Aerodrome category</th>
<th>Foam performance level A</th>
<th>Foam performance level B</th>
<th>Complementary Agents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water (l)</td>
<td>Discharge rate foam soln / min (l)</td>
<td>Water (l)</td>
</tr>
<tr>
<td>1</td>
<td>350</td>
<td>350</td>
<td>230</td>
</tr>
<tr>
<td>2</td>
<td>1000</td>
<td>800</td>
<td>670</td>
</tr>
<tr>
<td>3</td>
<td>1800</td>
<td>1300</td>
<td>1200</td>
</tr>
<tr>
<td>4</td>
<td>3600</td>
<td>2600</td>
<td>2400</td>
</tr>
<tr>
<td>5</td>
<td>8100</td>
<td>4500</td>
<td>5400</td>
</tr>
<tr>
<td>6</td>
<td>11800</td>
<td>6000</td>
<td>7900</td>
</tr>
<tr>
<td>7</td>
<td>18200</td>
<td>7900</td>
<td>12100</td>
</tr>
<tr>
<td>8</td>
<td>27300</td>
<td>10800</td>
<td>18200</td>
</tr>
<tr>
<td>9</td>
<td>36400</td>
<td>13500</td>
<td>24300</td>
</tr>
</tbody>
</table>

Figure 6.2.7.1 ICAO RFFS Categories ICAO, 1988

Figure 6.2.7.2 ICAO RFFS Cover ICAO, 1988
However, the above formula allows the use of a remission factor to be applied when the number of movements of the largest aircraft is fewer than 700 in the busiest three consecutive months of operations. In this instance, the category may drop by one level. It is therefore conceivable that a large aircraft, operating infrequently into an airport may not have adequate extinguishing agent available in the event of a fire. (Taylor, 1988)

The ICAO recommendations for RFFS (which apply to international airports) only become legislation through the actions of the member states and there are a large number of airports around the world that do not have the cover which is recommended for that level of traffic.

6.2.7.1 Rescue and Fire Fighting Cover Reduction

Lamble (Fire International, 1993) reported that, in Australia, there was “...no specialised Civil Aviation Authority fire and rescue services at many of the country’s 400 regional airports”. This means that aircraft as large as B737, F28 and BAe 146 are operating into airfields where the rescue and fire fighting function is covered solely by the CFA (Country Fire Authority) and often on a retained only (volunteer) basis.

George Macionis, then general manager, CAA fire and rescue services commented that CAA policy was to cover around 90% of air passengers to or above those recommended by the ICAO Annex 14 tables. This meant that airports such as Mount Isa (QLD), Tamworth (NSW) and Avalon (VIC) which are regularly used by aircraft up to 737-300 size (106 seats) are covered only by the local fire brigades. Even a rapid response by off airport fire tenders is very much less effective at knocking back aircraft fires as foam application rates are, at best, one third of those achieved by airport tenders. In Queensland, a State Fire Service spokesman suggested that it would take 20 minutes for three appliances to reach Maroochydore / Sunshine Coast Airport where B737-300 aircraft land. When the British Airtours B737-200 G-BGJL caught fire on take-off from Manchester Airport in 1985, the first rapid intervention vehicle (RIV) was firefighting within 25 seconds of the aircraft coming to a stop. Nevertheless, 55 of the 137 on board were killed.

The fact that operations of this nature are within the rules of the regulator does not guarantee an absence of risk. The balance of cost and benefit - in this case the balance between the cost of RFFS cover against the likelihood of a fire occurring at one of the uncovered regional airports is one that has been judged to be acceptable. Yet this situation has not always been the case in Australia. Before the Civil Aviation Authority became a Government Business Enterprise (GBE) and was required to cover its own costs through ‘user-pays charges’, major airports were provided with cover in excess of ICAO minimum guidelines. The current situation is within the legal guidelines set by regulation and is therefore ‘legally safe’. This may, however, be less safe than the previous set up.

Another indicator of the attitude of the Australian aviation industry to the importance of rescue and fire fighting is in the use of labour. Active fire fighters within Australia do only the duties
directly related to rescue and fire fighting. This is different to many countries including the USA (where firefighters will do other airport tasks such as snow-clearing and grass-cutting) and Canada (where fire fighters do only that and are not responsible for rescue). The Australian Bureau of Industry Economics (BIE, 1994) published a comparison of labour productivity for RFFS personnel as part of an attempt to establish performance indicators for airports. Although the CAA’s RFFS management objected to the suggestion that Australian productivity lags behind their European and North American, the graph also demonstrates a more generous attitude towards RFFS provision. The notion of RFFS ‘productivity’ is difficult to rationalise as true operational efficiency could only ever be measured by performance in dealing with an incident. No two incidents are ever the same and are rare enough to be almost impossible to compare.

6.2.7.2 Performance of RFFS within Australia

It is difficult to reasonably assess how effective RFFS provision has been within Australia by virtue of how infrequently it has ever been needed. As a secondary safety measure, a sparseness of primary safety failures has meant that the safety of the system has been assured before this last line of defence.

In 1992, an Ansett B727 was forced to land at Brisbane Airport with an uncontained engine fire within the No.2 (centre) engine. The RFFS responded to this declared emergency and successfully knocked down the fire with no injuries to passengers or flight crew. However, rather ironically, the only injuries that were sustained were by RFFS personnel who drove rapid intervention vehicle into a drainage ditch on the way to the aircraft.

Bruce Pitcher, Deputy Chief of the CAA’s RFFS team points out that full scale emergency exercises are conducted once a year. The ICAO requirements, set out in Annex 14 call for such full scale exercises to be conducted every two years so Australian practice is currently in excess of these recommendations.
6.2.8 Security and Terrorism

In the widest spectrum of air safety, one of the most visible threats is from air pirates and saboteurs. Most travellers are very conscious of a number of such incidents: The terrorist bomb that downed Pam Am flight 103 over Lockerbie, Scotland in 1988 and the blowing up of three aircraft at Dawsons Field are just two examples. The distribution of such attacks is far from random as motives are often influenced by politics.

Most studies of air safety remove sabotage, hijack and acts of aggression from their statistical database as it is widely felt that these causes of aircraft loss are beyond the control of the airline and therefore would not represent a fair assessment of an airline’s efforts to be safe. Pan Am and TWA were considered to be ‘flag carriers’ for the USA and were therefore recurrently targets for terrorist aggression both upon their aircraft and airline offices. This is doubtless because their presence in a foreign nation appeared to be as ambassadors to a nation often disliked, especially by many Middle Eastern countries. The extra risk that such airlines are exposed to is not a result of the way they are run or equipped, it is an unfortunate by-product of their country of origin.

Aircraft Hijack

Clyne (1988) suggested the ‘anatomy of skyjacking’ to have evolved as follows over the last 30 years. Each category is considered in turn relative to Australian carriers:

2 For purpose of Transportation 1961-1988
3 The Mentally Unbalanced 1961-1988
4 Political Terrorists 1968-1988
5 Escaping Criminals 1971-1973
7 Religious Fundamentalists 1983-1988
8 Bomb Saboteurs 1984-1988

Figure 6.2.8.1 Eight Categories of Hijack From Clyne, 1988

1 Escaping refugees - Largely a function of geography and politics and hence out of the control of an airline.

Australia is a free country; its citizens are able to leave the country as they wish providing they have a valid passport. Escaping refugees may only be expected to attempt to board at locations outside Australia where neither Ansett nor Qantas have fifth freedom rights to fly domestic
sectors. This means that only passengers with international documentation will be aboard their aircraft. This type of hijacker is therefore of minimal threat within Australia.

2 For the purpose of transportation - This generally occurred between Cuba, Columbia, Venezuela and the United States in the absence of direct flights or affordable alternatives. Lower fares have reduced the frequency of this crime. It is a function of geography and politics and therefore out of an airline's control. Once again this type of hijacker is unlikely to be found within Australia.

3 The mentally unbalanced - This is obviously a random occurrence. There is no reason for this not to have occurred in Australia. Indeed, the only two incidents recorded involving Australia jet passenger aircraft both fell into this category.

4 Radical groups use air piracy for protest, propaganda purposes and political blackmail. Traditional offenders include the Palestinian Front for the Liberation of Palestine, the Black Panthers, the Japanese Red Army, the Baader-Meinhof Gang, the Eritrean Liberation Front, the Armenians and the Sikhs. Once again this is a function of geography and politics and not a function within an airline's control. Such radicals groups are not generally found in Australia and arguably have negligible political gain to be made from attempting to attack an Australian aircraft at an International location.

5 Escaping criminals - This is generally a random occurrence. There is no reason for this not to occur in Australia although there are obviously some countries such as in the Middle and Far East that favour corporal and capital punishments and are therefore more likely to attract this type of problem. It is a factor beyond an airline's influence. If they are flying on an internal flight where security is less rigorous, then the aircraft would not have previously had the range to fly anywhere where they could seek asylum. However, since Qantas and Australian Airlines merged, long-haul aircraft types (up to the B747-400) now operate domestic sectors such as Sydney to Melbourne before continuing to International destinations such as Singapore. While this remains a potential threat, it seems rather unlikely.

6 Extortionists - This is also a random occurrence that seemed to peak following the cult status that D. B. Cooper attained following his hijack of a Boeing 727. (Cooper forced the aircraft to land and demanded $200,000 and two parachutes which were delivered to the aircraft.) Stricter security screening and harsh jail sentences have made this category all but disappear, although there is no reason for this not to be any less of a problem in Australia than anywhere else in the World.

7 Religious fundamentalists - This concept has mainly been the responsibility of Islamic fundamentalists and Sikh extremists. Once again, it is a function of geography and politics and therefore out of an airline's control. Although Australia is predominately Christian by virtue of the original white Anglo settlers, it is now home to a broad spectrum of religious groups. So far, this multi-denominational
mix has not caused any major problems which may be a feature of the relaxed culture that seems to exist within Australia.

8 Bomb saboteurs - Aircraft provide bombers with an opportunity to create a very visible statement with maximum loss of life with a relatively small device. For example, the bomb that destroyed Pan Am Flight 103 was a small semtex based device hidden within a radio-cassette player. Its explosive charge was enough to cause the complete in-flight break up of the largest passenger aircraft type flying. Targets are selected by religious fundamentalists and political terrorists and therefore are a function of the airline’s country of origin and not the airline. Australia currently represents a moderate style of government as is therefore far less likely to be a target than carriers from countries such as USA, the former Soviet republic or the Middle East. It should be noted however, that Qantas has placed particular emphasis on passenger bag matching which further minimises the threat. If such matching had taken place on Pan Am 103, the explosive device would not have been loaded onto the aircraft.

This brief summary illustrates the rationale behind removing criminal activity from studies of airline safety. Terrorism is, by it very nature, a difficult subject to study as much evidence is based on hearsay and insinuation or is classified and inaccessible. Hijacking involves a deep understanding of criminal psychology and is therefore felt to be well outside the remit of this research project. In line with airline safety study convention, the frequency and distribution of skyjacking and terrorism is not to be considered as a contributory factor in creating Australia’s air safety record. It is, however, worthy of inclusion in this report as a point of discussion:

Bill Chapman of the Police & Criminal Studies Department of Exeter University (1993) confirms that terrorism and hijacking in Australia is very small scale and limited to Aboriginal and Croatian groups, neither of which are extreme enough to carry out acts of major sabotage or murder.

While most terrorist and hijacking incidents are well out of the control of individual airlines they do affect the safety record of airlines and leave great impressions upon the customers’ perceptions of safety. Bearing in mind that the decision to travel by a particular mode or with a particular company is based upon perception and not empirical evidence, such events take on an important significance.

In the case of Australian airlines, the lack of incidents only compounds the image of good safety. The lack of negative publicity is such as to play a part in the overall positive image the customer and those in the industry have.
6.2.9 Aircraft Loading

In the busy apron area, aircraft are susceptible to damage from ground handling which is frequently not reported, either through omission or to avoid punishment. The large number of people moving around an aircraft during turnaround makes such events a concern for all aircraft operators. "The cost of ramp accidents to the aviation industry Worldwide was US$2 billion annually, of which some US$750 million was in respect of repairs to aircraft damaged on the ground." (Kilbride, 1996)

The loading of cargo can also cause problems for flight crew if stowed incorrectly. An unbalanced centre of gravity (Cg) will affect an aircraft's flying characteristics, as can cargo which shifts during flight. The carriage of dangerous goods when incorrectly packaged, labelled or mixed can also cause in-flight problems.

There are relatively few large aircraft accidents caused by deficient aircraft loading. Crashes due to Cg imbalance tend to more prevalent in the general aviation sector where a small movement can significantly effect the trim and stability of the aircraft.

The most common problems for large aircraft come from hazardous cargo or ground damage. Hazardous cargo may include oxidising agents, poisons, flammables, corrosives and even livestock. Although many passenger aircraft types include halon fire extinguishing equipment in belly hold areas, this is not the case with deck hold cargo on freight-only and 'Combi' type aircraft. The total loss of a Valujet DC9 in 1996 in the Florida Everglades was primarily the result of an uncontrolled hold fire caused by the carriage of defective oxygen tanks as belly hold freight. The intense fire burned through control lines and entered the cabin and resulted in the loss of control by the crew.

Ground damage has, thus far, caused few accidents. Standard Operational Procedures require flight crew to conduct a visual walk-round inspection of the aircraft prior to departure. However, in practice, such an inspection is rarely at the point where no more ground handling equipment is to be moved around the aircraft. The majority of incidents are in the form of scrapes, indentations and perforations of the aircraft skin. (Ashford, Ndoh and Brooke, 1995)

It is when such damage weakens or punctures the aircraft's pressure skin that problems can occur with the flying aircraft.

It is damage to the pressure skin that does not cause an immediate breach that is the greatest threat to an aircraft. An aircraft that fails to pressurise will not climb above normal cabin pressure height (8000 ft). However an in-flight failure of the skin at altitude can result in the explosive decompression of the aircraft and possibly either the loss of structural integrity or physical damage to persons on board the aircraft through frostbite and hypoxia. Although the loss of a JAL B747 in 1985 was proven to be the result of a structural failure caused by faulty repair, it highlighted the potentially catastrophic consequences of an explosive decompression.
Whilst the level of ground damage in Australia is significant, it was not flagged a particular danger by any of the expert witnesses until pressed. This may reflect one of two things; either that the problem is indeed minimal, or that it is underestimated. Various experts pointed to the relatively quiet aprons at Australian airports and the fact that ground handling was currently the responsibility of Ansett or Qantas and not third-party contractors. As traffic increases then the threat may be expected also to increase. However, in anticipation of this, Ansett and Qantas have invested in innovative ramp teambuilding and technical training programs. There is also a move towards implementing overseas training solutions such as the SCARF (Safety Courses for Airport Ramp Functions) program operating under the European Commission. (See McDonald and Fuller, 1994 and McDonald, White, Fuller, Walsh and Ryan, 1993.)

Returning to the subject of inflight incidents related to loading, a review of BASI’s OASIS database (Friend, 1995) for incidents involving cargo revealed only five recorded incidents between 1993 and 1995. They are summarised as follows:

<table>
<thead>
<tr>
<th>Aircraft:</th>
<th>Registration:</th>
<th>Date:</th>
<th>Category:</th>
<th>Location:</th>
<th>Damage:</th>
</tr>
</thead>
<tbody>
<tr>
<td>B767-277</td>
<td>VH-RMG</td>
<td>25/01/94</td>
<td>5</td>
<td>Perth</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
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</tbody>
</table>

No cargo restraints between cargo bays 4 and 6 had allowed 1.3 m of movement and loud thump.

<table>
<thead>
<tr>
<th>Aircraft:</th>
<th>Registration:</th>
<th>Date:</th>
<th>Category:</th>
<th>Location:</th>
<th>Damage:</th>
</tr>
</thead>
<tbody>
<tr>
<td>B747-238</td>
<td>VH-ECC</td>
<td>09/10/94</td>
<td>5</td>
<td>Cairns</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</table>

Preflight inspection revealed shifted cargo in two pallets and a missing fire protection cover.

<table>
<thead>
<tr>
<th>Aircraft:</th>
<th>Registration:</th>
<th>Date:</th>
<th>Category:</th>
<th>Location:</th>
<th>Damage:</th>
</tr>
</thead>
<tbody>
<tr>
<td>B747-438</td>
<td>VH-OJM</td>
<td>12/01/95</td>
<td>5</td>
<td>Los Angeles</td>
<td>Nil</td>
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Aircraft was recalled to the apron as a container had been loaded in the wrong compartment.

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<th>Date:</th>
<th>Category:</th>
<th>Location:</th>
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<tbody>
<tr>
<td>B767-277</td>
<td>VH-RME</td>
<td>28/01/95</td>
<td>5</td>
<td>Melbourne</td>
<td>Nil</td>
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No cargo restraints between cargo bays 4 and 6 had allowed 1.3 m of movement and loud thump.

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<th>Aircraft:</th>
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<tr>
<td>B747-238B</td>
<td>VH-ECB</td>
<td>04/03/95</td>
<td>5</td>
<td>Papeete</td>
<td>Nil</td>
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During cruise, inspection revealed a cargo pallet was unsecured and beginning to move. It was secured by its pallet locks.

The geographical layout of Australia dictates that a relatively high volume of freight is carried by aircraft. In 1991, international freight to and from Australia had risen to 360,000 tonnes. (BTCE, 1993) This is in the form of dedicated freighter aircraft and as belly hold cargo, with Qantas also using ‘Combi’ aircraft until 1995. Ansett Australia operates two B727 and two BAe 146 freighters and Qantas operate a DC10 freighter aircraft. Both airlines offer belly hold freight capacity for domestic and international flights. International flights tend to carry high load factors and fly close to aircraft range limitations.

BASI figures for 1990 (BTC, 1991) indicate that of 3830 recorded incidents, fourteen involved dangerous cargo which is less than 0.4% of the total. These incidents cover all types of aircraft...
including general aviation. Between 1992 and 1994, of 95 dangerous goods incidents in Australia, only five involved declared dangerous good shipments (Huggins, 1995). The remaining 90 involved hidden or undeclared dangerous goods including those carried on board by passengers. In one case, a passenger’s matchbook collection caught fire in baggage aboard a Brisbane to Darwin flight.

In 1983, the Australian Dangerous Goods Air Transport Council (ADGATC) was formed from airlines, freight forwarders, travel agents, education and training institutions, airport and regulatory authorities. (Huggins, 1995) The council is one of only a handful of similar bodies around the world and lobbies ICAO and IATA on behalf of the Australian industry. For example, approved packaging for dangerous goods was competing with similarly looking, less effective alternatives. Although the United Nations operated a marking system to identify approved packaging, it was not a requirement for aircraft use until the ADGATC persuaded ICAO and IATA to amend the rules.

Whilst dangerous goods or shifting cargo accidents have been relatively few in number, there is considerable potential for catastrophe. This was highlighted by the loss of the Valujet DC9 and the crash involving an An-32 at Kinshasa, Zaire which was overloaded and failed to climb causing over 300 deaths and 253 serious injuries in 1996. Australia seems to have experienced good quality aircraft loading and ramp handling which is not a function of any specific innovation, rather the expectations and operating culture of the organisations involved. Aided by a relatively low level of traffic and a lack of adverse weather conditions on the airport apron, this has helped to maintain a good level of ramp safety. However, there is significant potential for future incidents as traffic density increases and other third-party handling agencies enter the market.
6.3.1 Air Traffic Control

As soon as more than one aircraft occupies the same area of airspace, there is a need for some sort of control strategy to avoid collision. In the early days of aviation, in the absence of radio communications, the only available strategy was the 'see and avoid' principle. This type of control is reliant upon the vigilance of pilots to spot other aircraft, their ability to take evasive action, and upon weather conditions which allow clear sight. Should an aircraft enter cloud, the see and avoid principle becomes a useless form of control.

Loss of visual reference was also a problem for navigation, in the early days especially as aviators used physical features such as roads, railway lines and rivers for routes. Indeed, in the relatively featureless terrain of Australia, navigation was particularly difficult. The use of radios for positional-vectoring and communicating with the ground brought numerous benefits after their introduction in the 1920's. However, such facilities were limited primarily to the USA and Europe and it was 1934 before the first air radio stations were built in Australia.

"Five major aircraft accidents in Australia ...had an important effect on the development of the air traffic control system." (Bigsworth, 1988) These are discussed in greater detail earlier in the thesis with particular respect to the introduction of radio and navigation aids.

The development of air traffic control around the world was somewhat ad-hoc in the early days as demands were led by geographical and industry constraints. In Europe, flights tended to be over many small countries and consequently involved the crossing of a number of borders, whilst in USA, the home of mass production, congestion became a problem. In Australia, aircraft flew over vast areas of unpopulated country and could easily become lost.

In the 1920's and 1930's, European and American airlines were in contact with the ground via radio communication stations. In bad weather, two or more ground stations could take bearings on radio transmissions and tell the aircraft where it was. However, in Australia, a country of only 6 million people, where airlines were small and held limited political power, there was no such facility. Economic strife, unemployment and hunger overshadowed ATC provision. In 1934, three ground communication stations were set up at Melbourne, Darwin and Launceston (aeradio stations). Direction-finding units were introduced in 1935. (Charlwood, 1981)

Following the loss of Stinson VH-UHH en route from Brisbane to Sydney in 1937, an aircraft which was not fitted with a radio, the Amalgamated Wireless company were called upon to set up and run an expanded network of aeradio stations. Whilst the inquiry into the accident claimed that radio would not have prevented the accident, the political impact was so great that it provided the impetus needed to set up the aeradio system. Communications Officers who manned the new system were forced to work in relatively poor conditions with the help of pilots operating in the outback, creating a spirit of co-operation that "...has continued to the present day" (Charlwood, 1981). These officers did not control traffic; all decisions were left with the pilot.
A second, major fatal accident occurred in October 1938 when DC2 *Kyeema* flown by ANA struck Mount Dandenong 20 miles beyond Melbourne airport in broken cloud. Evidently the pilot had been mistaken in his visual pinpointing of the ground by 20 miles and had declined the offer of a directional fix from the ground communications officer. The subsequent investigation was fiercely critical of government delays in providing pilots with direction finding equipment and considered what may be done to make civil flying safer. A system whereby movements of aircraft could be checked by a competent person on the ground was recommended. Essentially, this was the birth of air traffic control in Australia. It was followed by the recommendation that experienced airline pilots be appointed by the Department of Civil Aviation as flight check officers.

Australia’s size meant relatively few aircraft were operating over vast areas where nav aids were few and far between. The pilot therefore needed protection against his own mistakes to avoid being forced down without a clear idea of his whereabouts. The Flight Checking Officer’s (FCO) role was to assist a pilot in his preflight planning and check his position during flight. This was similar to ‘flight dispatchers’ elsewhere in the world, except in Australia, they also had the power to refuse approval of a flight plan if they felt it did not match the regulator’s requirements. Pilots were required to estimate the length of flight and carry enough fuel to reach an alternate airfield with one hour’s fuel left in reserve. Minimum cloud base and visibility were laid down for safe landing at each airport and if conditions fell below these minima, the FCO was obliged to close the airfield and demand a diversion. Position had to be passed from pilot to aeradio officer, although the FCO also had to check if it was reasonable for the pilot to be in that position. Finally, it was the FCO’s task to keep the pilot informed of changing weather conditions and nearby aircraft.

The FCO was a function only provided in Australia and although they sometimes made unpopular decisions such as diverting aircraft, the whole aviation community realised the system was protected by these highly experienced officers. Most were senior airline captains with 10,000+ hours, familiar with aeronautical decision making and not to be disobeyed. Whilst this was a development well before the jet age, its significance to this thesis is in terms of the mantle of safety which became expected from the air traffic system.

The advent of the Second World War brought the need for major advances in air traffic control in Britain and Europe. More was learnt about the control of aircraft in the five and a half years of war than in the previous twenty years of peacetime operation.

The post-war era saw a general realisation of the potential of air transport. Servicemen had come to accept air travel as something natural and there were thousands of now spare aircraft and skilled airmen who were keen to continue their aviation career. The 1944 Chicago Convention which established the International Civil Aviation Organisation (ICAO) acknowledged the need to standardise services to aviation although the time between the end of the war and the publishing of ICAO’s recommended practices and standards was a difficult period. Flight control officers returned, but to a very different system. The USAF had left runways, hangars and control towers and introduced radio telephones, allowing controllers to
speak to aircraft for the first time in Australian skies. By the end of 1945, the Department of Civil Aviation, aware of the risk of mid-air collision, decided aircraft flying the same route at the same altitude should be separated by ten minutes flying time. How this was to be done was a problem eventually solved by a Sydney FCO. A simple computer made of a glass disc and clock face allowed the positions of aircraft to be calculated from its airspeed and departure time.

In 1946, the first Superintendent of Air Traffic Control was given the task of organising Australia’s system of control. With help from the 1937 ICAO conference in Melbourne, the final plans were decided and a system was created which has continued to evolve up to the present day. Australia was separated into a number of Flight Information Regions (FIRs) each named after its main centre. An air traffic control unit was set up in each FIR generally augmenting an existing aeradio station. Control areas were created along major air routes and permission to enter could only be granted by ATC. All aircraft wishing to operate in controlled airspace therefore needed two way radio.

Australia also decided to treat all aircraft as if they were unable to see each other, as if they were flying in cloud. In most other countries this is not the case (e.g. US VFR) where pilots flying in clear weather can rely on their ability to ‘see and avoid’. Whilst traffic densities were very much lower than those in the US, Australia decided that the potential problem of delays caused by ATC separation was outweighed by the risk of having controlled and non controlled traffic in the same airspace. Therefore, strict minimum separation distances were enforced across the whole system from the beginning.

At International conferences, Australia supported its decision by emphasising the risk of deteriorating weather and the lack of decision and action time for two aircraft approaching at closing speeds up to 1000 knots. Recognising the heightened risk where aircraft converged around aerodromes, control zones were established. Within these zones, the restricted airspace extended to the ground unlike in control areas which allow uncontrolled traffic to operate below certain altitudes. For aircraft operating outside control areas and therefore not separated by ATC, they were required to report their whereabouts to Aeradio / Flight Service who then passed this information to other pilots. Each pilot was then responsible for maintaining adequate separation.

On 2nd September 1948, DC3 Lutana struck terrain near Nundle, NSW with the loss of 13 souls. The aircraft was about 100 miles off course but still in radio contact. Whilst the inquiry failed to determine the cause, ATC was highly criticised. Following the 1947 ICAO conference, the Lutana disaster and international investigations by aviation experts, a new ATC system was shaped.

Air traffic control was split into three sections: Traffic separation became the responsibility of airport control (in the tower) and a new area control section was formed. The third area retained the FCO’s task of providing individual pilots with a safety service and became Operational Control. This was the start of modern air traffic control, which although
supplemented with new technology, has remained largely the same since.

The function of Operations Control, as provided by the then Civil Aviation Authority, ceased in 1992 with responsibility passing to the pilot in command or airline. Whilst this was intended to reduce the use resources, especially as the CAA had become focused on 'user pays', the by-product was to remove a safety margin from the operating system. For example, up to 1992, Operations Controllers were able to close a runway because of inclement weather. After that date, flight crew were given full responsibility for making a decision to land in poor weather; a decision made with one less expert in the loop. Arguments from pilots that Operations Controllers were closing runways at times when the weather was still ok because of a lack of operating experience or information may be counterbalanced by other occasions where pilot decision making is marginal for similar reasons. As the Operations Controller was only able to make a 'fail-safe' decision (i.e. he could not command a pilot to land, only not to land), the removal of his input from the process may be seen to be a reduction of the safety net although to what effect is not immediately apparent.

The role of Flight Briefing Officers (FBO) was also removed in the early 1990's under the controversial Review of Resources within the Civil Aviation Authority. The Briefing Officer was responsible for collating flight planning information from flight crew for entry into the air traffic system. Whilst it was the responsibility of the flight crew to prepare the information, the FBO also acted as a safety net to make sure all of the necessary details were correctly formatted and forwarded. Technology has made it easier for such information to be submitted, although once again, how much the removal of the FBO as a safety margin has had an effect is not readily obvious.
6.3.2 Collision Risk and Traffic Density

Ashford (1994) observed that for 219 large aircraft (over 5700kg MTOW) accidents, only 3.7% were considered mid-air collisions. Unfortunately even though the review was of causal factors, it does not discuss what other factors (such as lack of situational awareness or failure to look out) were involved in each accident. It is also possible that as mid-air collisions, by definition, involve two aircraft, that the number of accidents is effectively doubled for incidents involving two (over 5700kg MTOW) aircraft. A review of the Boeing accident database (Boeing, 1993) reveals a total of 22 mid-air collisions from a total of 962 accidents (2.3%). Of these, ten accidents were fatal (two involved two passenger aircraft). Air Traffic Control deficiency was deemed primary cause in six (three fatal), crew error in eight (four fatal) and undetermined/other accounted for the remaining eight (three fatal).

Although there are a number of recorded cases of mid-air collisions, few are deemed to be the direct result of high traffic density.

However, in September 1976, a BEA Trident 3B and Inex-Adria DC9 collided over Yugoslavia with the loss of 176 souls. Both aircraft were under the control of Zagreb Air Traffic Control Centre which was the second busiest centre in Europe (Stewart, 1994). Controllers were working at overload using procedures that could allow just such a system failure to occur. The active controller, who had worked three consecutive 12 hours shifts and was covering the late arrival of another member of staff, became task saturated and lost track of the spatial orientation of the two aircraft. The accident was not simply a function of the traffic density, but more the ability of the ATC to cope with a particular level of traffic.

Other factors which increase collision risk include the presence of aircraft in the wrong position. In 1978, a PSA B727 collided with a Cessna 172 over San Diego after the flight crew lost sight of the Cessna and assumed they must have flown past it. The light aircraft had turned onto an unauthorised heading which was a collision course with the B727. A third aircraft is speculated to have been in the area also without clearance and this may have confused the B727 crew as to the real position of the C172. Once again, the systemic cause of the crash was the inadequacy of the control strategy to separate aircraft (particularly when one or more aircraft is flying contrary to clearances) rather than the traffic density.

These two examples had tragic outcomes, but represent only the tip of the iceberg as far as breakdowns in separation go. In terms of system safety, a breakdown in separation may be considered to be every bit as serious as an accident. Studying statistics for near misses reveals that such occurrences are not just a function of traffic density. There are, for example, instances when particularly low traffic density can lead to low arousal and therefore poor vigilance. In May 1995, a Qantas B737 and BA B747 were directed onto a collision course 160 NM north of Broken Hill, Australia. A collision was narrowly avoided as a result of a TCAS (Traffic Alert and Collision Avoidance System) resolution advisory on board the B747 which allowed an evasive manoeuvre to be carried out. BASI estimated that a collision was very narrowly avoided.
Although the formal BASI investigation into the incident was still ongoing at the time of writing, initial reports suggest that there were only three aircraft under the direction of the controller at that time. However, the controller was interrupted by "nine separate items involving 25 interchanges" (BASI, 1995) whilst attempting to perform a time of passing (ToP) calculation. The high mental workload caused by the interruptions is suspected to be a reason behind the erroneous calculation that created a collision pair. Traffic density was not a factor, but controller workload was.

Ratner (1987) observes that, "Many of the reported incidents worldwide have occurred in very low workload conditions, where inattention associated with well-known human performance difficulties in maintaining vigilance in low-stimulus environments was involved." He also adds that such a phenomenon has also been the most difficult to correct.

When two aircraft, say A and B, enter the same airspace, a single collision pair is produced i.e. aircraft A and B may collide. When a third aircraft is added (C), so the number of collision pairs is increased:

\[
\begin{align*}
A & \text{ may collide with } B \\
A & \text{ may collide with } C \\
B & \text{ may collide with } C
\end{align*}
\]

As the number of aircraft increases, so the number of collision pairs increases at an exponential rate. Hence, the inclusion of aircraft D means 6 possibilities of a collision:

\[
\begin{align*}
A & \text{ may collide with } B \\
A & \text{ may collide with } C \\
A & \text{ may collide with } D \\
B & \text{ may collide with } C \\
B & \text{ may collide with } D \\
C & \text{ may collide with } D
\end{align*}
\]

BASI (1991) observed that the number of collision pairs could be calculated using the following formula:

\[
P = N \times (N-1) / 2
\]

Where N is the number of aircraft operating in the specified area of airspace.
The critical issue in considering the effect of increasing traffic density is that although the collision risk also increases, this is only the case in the operation of ‘see and avoid’ airspace.

**See and Avoid**

This most basic form of air traffic control is based upon a maritime principle for slow moving shipping (Marthinsen, 1989). It requires the vigilance and ability of flight crew to recognise and avoid possible collisions. The more aircraft in one piece of airspace, the more to spot and avoid, and therefore an increase in collision risk. (Although there is some evidence that collision risk diminishes for a while as the increase in aircraft and therefore perceived risk leads to an increased awareness and vigilance on the part of flight crew.)

See and Avoid is a method of ATC that is only suited to very low traffic areas and is generally unsuitable for fast aircraft due to the closing speeds involved. Although Graham and Orr (1970) estimate that at closing speeds of between 101 and 199 knots (for example, two Cessna 150’s flying head-on), 97% of collisions are prevented; above 400 knots closing speed only 47% of collisions are avoided. Two fast jet aircraft may reasonably reach head-on closing speeds of 1200 knots where it is unlikely that either flight crew would see each other’s aircraft should they be on collision course, let alone attempt any evasive manoeuvre.

**Controlled Airspace**

Controlled airspace describes various levels of ATC which involve an air traffic controller. These may range from procedural (non radar) control to primary and secondary radar coverage. Approaches to large airport such as Melbourne and Sydney will be controlled by a
mix of primary and secondary radar whereas small airports (where controlled) and cross
country air routes (outside radar coverage) will depend upon procedural control. Radar
coverage within Australia is limited as shown in figure 6.3.3 below;

![Radar Coverage in Australia](image)

Figure 6.3.3 Radar Coverage in Australia CAA, 1995

Whilst this covers the vast majority of high capacity arrivals and departures, it does leave a
huge area outside of radar coverage in procedural control or outside controlled airspace. By
itself, this does not equate to a degradation of safety, providing that the systems operate
effectively. Procedural control, for example, demands greater separation distances than radar
control to attain a similar level of efficiency. Operations outside of controlled airspace under
MBZ (Mandatory Broadcast Zones) or CTAF (Common Traffic Advisory Frequency) attain an
acceptable level of safety, providing that aircraft adhere to procedure.

The absence of radar coverage, does however, remove a safety net from the ATC system.
Where aircraft are involved in a breakdown in separation (whether as a result of
misinterpretation of control instructions or because of incorrect instructions), the controller is
unable to see a possible collision pair or receive an automated warning. As mentioned
previously, in 1995, a British Airways B747 and Qantas B737 narrowly avoided each other
North of Broken Hill whilst flying in opposite directions along a two-way air route.
Miscalculation of the relative position of each aircraft by the air traffic controller lead to a
climb clearance which brought the Qantas B737 within one second of colliding with the B747.
The collision was avoided solely by the British Airways crew’s reaction to a TCAS resolution
advisory. At that time, both Qantas and Ansett domestic fleets carried only TCAS transponders
and not full systems. Had the BA B747 not been equipped with full TCAS, then a fatal
collision would have most likely occurred. Had the aircraft been flying in radar coverage then
the controller would have been able to see the relative position of the two aircraft.

Even in areas of radar coverage, equipment failures can lead to incidents. In 1995, an Ansett
B737 suffered a failure to its SSR transponder and in effect became invisible to primary radar.
This went unnoticed by the controller who therefore failed to hand over the aircraft to its next
sector. This situation continued for over an hour until the arrivals controller at Melbourne
questioned why an Ansett aircraft was not five minutes behind the Qantas arrival as was usual. At this point, radio contact was re-established with the 'ghost' aircraft and it landed safely. The silent failure by the single SSR transponder on the B737 represented a poor level of redundancy (European aircraft carry two transponders) and was not self reporting. The failure of the controller to detect that the aircraft had disappeared from the screen also represented a grave error whereby another aircraft could have easily been assigned that altitude.

This incident and the near miss North of Broken Hill represent failures of the ATC system which are neither unique to Australia, nor directly a function of traffic density. Lack of radar coverage in the first example removed a potential line of defence, but such provision could not be justified at that level of traffic. Indeed, if traffic density were a factor, it was that underload led to controller inattention and a lack of justification for technological defences such as radar or full TCAS.

Traffic density in Australia is generally relatively low. Former ACAA Chairman, Dick Smith (1993) suggested that at any one time, there is approximately 3% of the traffic flying over Australia as there is over the similarly sized continental USA. Indeed, there are over 200,000 aircraft registered in the US compared with less than 10,000 registered in Australia. (ACAA, 1994c). However, Australia's 1100 air traffic controllers are responsible for one-ninth of the world's airspace (ACAA, 1994b) and therefore the existence of a hazard cannot simply be related to the level of traffic. The possible hazards include:

1. Air Traffic Control error;
   a. incorrect or inadequate instruction / advice
   b. failure to provide separation
   c. failure of interface with other controllers

2. Flight crew error;
   a. omission of action / inappropriate action
   b. loss of situational awareness
   c. slow / delayed action
   d. failure in look-out (particularly in see-and-avoid)

3. Uncontrolled events;
   a. unauthorised entry to controlled airspace / change of flight level
   b. covert military aircraft operations

One of the crucial factors which should be considered is the fact that traffic is not equally spread across the Australian system. This fact is not made clear in Smith's (1993) analogy and yet is of major significance. Traffic is centred around a relatively small number of cities on the
Eastern Seaboard, and Perth where traffic is often a mixture of low level private and GA operations, military and commercial RPT traffic. Figure 6.3.4 was prepared by Airservices Australia (1997) to demonstrate the level of IFR (Instrument Flight Rules) traffic in Australia.

This diagram gives an indication of the concentration of traffic around the Eastern Seaboard, particularly round Sydney, Brisbane, and Perth. It does not include international operations which would significantly increase traffic levels at the large ports and across the centre toward Derby. The significance of this diagram is twofold; namely in demonstrating that in certain areas, traffic density is high and brings with it the sort of pressures that may be expected, and secondly, these areas are also prone to high storm severity (see figure 6.3.5).
The presence of severe storms, especially around Sydney, Brisbane and Perth Airports adds another dimension to the issue of traffic density. This is not least because the greatest effect of weather on aircraft is at low altitudes on departure or arrival and these are the areas where traffic density is highest. Comments from the pilots' questionnaires regarding arrivals at Sydney included concerns about the level of traffic, complexity of arrival or departure procedures and weather conditions (such as crosswinds) being at the limits of safe operation in the name of noise sharing. Once again, it is not a single causal factor that risks causing an accident, rather a combination of several.

6.3.2.1 Review of the Air Traffic Services System of Australia

In November, 1986, Ratner Associates Inc. (RAI) was commissioned to review the Australian ATS system with regard to its adequacy for meeting the requirements of Air Navigation regulations. This represents one of the most thorough reviews undertaken of any ATS system and is therefore worth special consideration. The review (Ratner, 1987) concluded that, "...the Australian ATS (Air Traffic Services) system is basically sound. The number of reported BoS (Breakdown of Separation) incidents is less than 1 in every 50,000 aircraft movements, and the character of the incidents is similar to overseas occurrences."

They also concluded more specifically that "Although traffic conditions in Australian airspace often saturate the traffic-handling capacity of a sector or larger area during the busiest periods, system overload per se, that is, traffic levels beyond the inherent capacity of the present system, has not been a significant contributor to the occurrence of BoS incidents". They also highlighted the fact that Australia is apparently "...relatively free of many of the problems with which other ATS systems are grappling": mixed controlled / uncontrolled airspace, airspace intrusions, persistent occurrence of non-English phraseology and joint military / civil use of airspace with separate ATC units.

Notwithstanding these generally positive comments, RAI made a large number of observations about problems within the air traffic system. In respect of BoS, they found complacent attitudes, inadequate foresight and planning, reliance on individual technique (which may be deficient) and a lower degree of standard operational procedures (than in other similar systems). These factors were compounded by insufficient understanding of technical information regarding aircraft operation, poor supervision, a lack of standardisation and a comparatively low level of experience amongst ATC officers. This translated into a lack of motivation at all levels which has affected on-the-job training and the press for constructive change. (Ratner, 1987)

Whilst such remarks may seem damning of the system, it should be borne in mind that the review was designed to look for areas of weakness in anticipation of the reorganisation of the Department of Civil Aviation. It had already been stated in the overview that the Australian ATS system has a safety record "...amongst the world's highest", but that such "...past performance is no guarantee of future performance." (Ratner, 1987) RAI also recognised the
fact that the air traffic system had grown in complexity meaning that it was becoming increasingly stressed in certain areas. They note that “it is necessary to rely increasingly on the backup and support capabilities of the system to ensure continued safety and efficiency. The backup and support mechanisms currently in place in the ATS system have not advanced at rates commensurate with the system’s traffic loads and complexity.” Assuming that the situation was not corrected then it seems logical that increased traffic would stress the system to a point where its defences were breached and an accident occurred.

RAI revisited the Australian ATC system in 1992 at the request of the Bureau of Air Safety Investigation in response to an increasing number of incidents. “Comparison of incident data from the 1982-1986 period with the data from the period 1 July 1988 through 30 June 1991 indicates a higher average number of incidents in the more recent period, both on an absolute basis, and when adjusted for changes in the average traffic volume” (Ratner, 1992). The number of incidents involving large aircraft had also doubled during this period, a time which also included the restructure of Air Traffic Services from the Department of Civil Aviation to the Civil Aviation Authority Government Business Enterprise.

RAI had numerous concerns regarding the integrity of the system which varied from issues of technology deficits and airspace configuration to training issues and high level safety management. The apparent decline in standards, particularly in respect of BoS incidents involving large aircraft, was attributed to “...increased system complexity in response to industry pressures and traffic growth”. (Ratner, 1992) This situation was much as RAI had predicted in the 1987 review and this was observed to be partly as a result of “...lagged implementation of operational changes” by the new CAA management.

Recommendations for remedial action were numerous and have been addressed at various speeds over the last few years. These have included structural changes within the organisation (in addition to the CAA’s devolution ) such as the enhancement of the Quality Assurance role, attempts to increase human factors expertise, the foundation of a Board Safety Committee and the development of a formal safety management strategy.

The situation remains in a state of comparative flux as major changes such as the introduction of TAAATS (The Australian Advanced Air Traffic System) and deferral of Airspace 2000 continue. Crew fears regarding the risk of mid-air collision are high and issues of airspace management remain highly political at both industry and federal levels. The future integrity of the air traffic management system is far from clear, but the efforts towards improvement are continuing and have the potential for either significant improvement or catastrophe.
6.3.3 Concerns Regarding ATC Integrity

Both pilots and air traffic controllers were asked about their concerns for the integrity of the Australian system in a number of different ways.

Question 3.1 asked respondents to rank the top three greatest threats to their flying safety from a list of fourteen categories (which included an 'other - please specify' response):

3.1 Please rank the TOP THREE factors you consider pose the greatest threat to your flying safety? (With "1" representing the factor that concerns you most.)

The results were of significance, particularly in terms of the perceived threats from airspace management and the risk of collision.

The single greatest fear amongst Qantas pilots is the threat of mid-air collision. Whilst the element of dread is heightened by the almost guaranteed fatal outcome of mid-air collisions, the answer is significant from an airline where all of the International fleet has TCAS.
Australian Aviation Safety: A Systemic Investigation and Case Study Approach

What are the top three greatest threats to your flying safety?

- Engine Failure
- Snow / Ice Accumulation
- Windshear / Microburst
- Weather
- Judgment Error (Self)
- Judge Error (Others)
- Mid-air collision
- Maintenance Failure
- CFIT
- Security Breach
- Runway Incursion
- Management Error
- Inappropriate Regulations
- Acts of Aggression

Figure 6.3.3.2 Answers from Qantas Crews (International - B747)

What are the top three greatest threats to your flying safety?

- Engine Failure
- Snow / Ice Accumulation
- Windshear / Microburst
- Weather
- Judgment Error (Self)
- Judge Error (Others)
- Mid-air collision
- Maintenance Failure
- CFIT
- Security Breach
- Runway Incursion
- Management Error
- Inappropriate Regulations
- Acts of Aggression

Figure 6.3.3.3 Answers from Qantas Crews (Domestic - B737 & A300)
International and Domestic operations were split into B747 (international) and B737 / A300 (Domestic). The answers from the B767 fleet were removed as these aircraft operate both domestically and internationally. The result was that the fear of mid-air collision was high for both fleets although slightly higher for the Domestic fleet. Whilst International crews voiced fears about the integrity of overseas ATC (supported by Qantas policy that no aircraft will operate north of Darwin with an unserviceable TCAS), Domestic crew were operating in aircraft which did not carry full TCAS (The aircraft had only TCAS transponders). There is no regulation within Australia that mandates the use of TCAS on RPT aircraft although it is required on aircraft entering the USA.

Since the date of the survey, the Qantas Board approved the fitment of full TCAS to the entire Domestic jet fleet. This was immediately prior to the near-miss involving a Qantas B737. Expenditure on TCAS equipment within Qantas now equates to some $1.1 million per annum.

What are the top three greatest threats to your flying safety?

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<tr>
<th>What are the top three greatest threats to your flying safety?</th>
<th>percentage who chose category</th>
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<tbody>
<tr>
<td>Engine Failure</td>
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<tr>
<td>Snow / Ice Accumulation</td>
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<td>Weather</td>
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<td>Judgment Error (Self)</td>
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<td>Acts of Aggression</td>
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In Ansett, the response was similar to Qantas, with mid-air collision rated as second. Although the response (13%) is lower than Qantas (Domestic: 18%). At the time of the survey, none of the Domestic Ansett fleet had operational full TCAS, but a decision has been taken subsequently to introduce it to the entire fleet. All Ansett International aircraft have full TCAS although no International crews were involved in this survey.
Air traffic controllers appear to have a far less pessimistic approach to the threat of mid-air collision than their pilot colleagues. This may be for one of two reasons; firstly it may be based on a confidence in their own ability to maintain adequate separation between aircraft at a consistently high level of reliability, or secondly it may be a function of a lower level of risk perception which is a function of being a passive participant in the system and not an active participant such as the pilots of passengers. Risk perception theory would back up the latter disparity, although this does not easily explain why maintenance and engine failures are ranked so highly by air traffic controllers. It seems likely that the opinions of controllers are based upon limited experience in all areas of aviation other than their own.

In addition to this question was an open ended question regarding the perception of the greatest threat to the future safety of aviation in Australia;

3.9 In your own words, what do you consider will pose the greatest threat to the safety of RPT carriers in Australia in the future?
What Do you consider to be the Greatest Future Threat?

![Bar chart showing the percentage of people who chose each category as the greatest future threat. The categories include Commercial Pressure, Economic Rationalisation, Fatigue, Misdirected Regulation, Political Interference, ATC Inadequacies, Increased Traffic, Poor Training, Sydney Airport, Complacency, Low Maintenance Standards, Low Experience, Poor Management, Deregulation, Mid Air Collision, QF Privatisation, Security Deficiencies, Poor Aids, Crew Dissatisfaction, Foreign Crews, Speed of Change, Ergonomic Mismatch, Post Dispute Effects, MEL Carry Overs, Airspace Management, No TCAS A/C, No Consultation, Overseas ATC Inadequacies, Weather, Runway Incursion, Extended Retirement Age, Bogus Parts, Older Aircraft.]

Figure 6.3.3.6  Qantas - Greatest Future Threat to Australian RPT Safety

The categories used on the above graph were developed from the range of answers. Issues relevant to ATC integrity include ‘ATC Inadequacies’ (17.1%), ‘Increased Traffic’ (15.8%) and more specifically, operations at Sydney Airport (9.8%). Whilst increased traffic has been shown not to be directly linked to collision risk, there is genuine concern amongst Qantas crews that the current or proposed ATC system will be unable to cope with the level of traffic.
This is in spite (or possible because) of the proposed introduction of TAAATS in 1998 and the anticipated introduction of the much delayed Airspace 2000.

Specific comments regarding Sydney Airport point to the confusion caused by politically motivated decisions regarding runway use and departure / arrival routes, and the non-standard introduction and use of SIDs (Standard Instrument Departures) and STARs (Standard Arrival Routes). This is in addition to the highest traffic levels in Australia, the risk of severe weather conditions and surrounding traffic from General Aviation airports such as Hoxton Park and Bankstown. Pilots also wrote of extended delays at peak times being regular occurrences with high speed, high capacity aircraft being asked to hold in area of intense traffic.

Other issues included a fear of ‘Mid-air collision’ (5.6%) (see earlier in this section) which was not explained to be in a specific location or due to a specific primary cause. Although only a low percentage recorded this factor for question 3.9 compared to question 3.1, it is probably because this represents an outcome, whereas ‘ATC inadequacies’ and ‘Sydney Airport’ represent systemic issues which may lead to the same outcome. It is also a function of the high level of dread attached to mid-air collision rather than a widespread belief that it is likely to be the ‘greatest’ threat to Australian RPT safety in the future.

Finally, a number of comments referred specifically to ‘Airspace Management’ (1.7%) problems and ‘Overseas ATC Inadequacies’ (1.3%), these may be assumed to be similar problems to the other categories. It is difficult to discriminate between poor airspace management and the problems of increased traffic, Sydney Airport and general ATC inadequacies. In the latter case, it is also difficult to determine what proportion of inadequacies are represented by overseas ATC.

The situation from within Ansett was rather different (see figure 6.3.3.6) where 23.2% of pilots cited ATC inadequacies as a major threat with 17.4% referring specifically to Airspace Management deficiencies and 14.7% citing Sydney Airport as a particular danger area. Increased traffic represented a similar proportion to Qantas at 14.7%. The differences between the two carriers may be the result of different experience. For example, Qantas International crews may have significant experience of overseas ATC systems which make Australia look relatively good. Airspace Management is obviously an issue within Ansett that had been much talked about, which would explain the huge disparity between the two carriers’ responses. However, the ‘ATC’ threats within Ansett are still seen to be more of a problem than in Qantas which may be a function of the nature of Ansett operations.

Ansett operate more of their services to low traffic areas which may include a high proportion of CTAF / MTAF operations outside of radar coverage and in areas where General Aviation is operating in ‘See and Avoid’ conditions. This also explains why they also cited a category which was unmentioned by Qantas, namely the presence of aircraft without TCAS transponders.
Note that within the Ansett responses, even answers categorised as ‘political interference’ included a number of comments regarding complex ATC procedures which appear to be based on political motivations in respect to ‘noise sharing’. 
The RAAF Transport crews seem less pessimistic about ATC inadequacies than their civilian counterparts, but similarly wary of airspace management deficiencies. The former probably reflects expectations of operating older equipment and training for combat situations where ground based ATC is not assured. The attitude towards airspace management suggests concern about the ability of the system to operate effectively regardless of the technical equipment and may suggest lack of faith in the ATC organisations.
Perhaps unsurprisingly, CAA controllers ranked ATC inadequacies much lower down their list than pilots, although overall, they cited more perceived threats. What is perhaps of greater concern is the high ranking of 'poor training,' which, although is not aimed specifically at their organisation, does rank higher than the responses from pilots. Training within the ATC environment has suffered from lack of recruitment numbers and an ill-fated attempted at tertiary level training with the University of Tasmania.
For RAAF ATC, Airspace management ranked very highly, as did the threat of ATC inadequacies. Military ATC spoke of using old equipment and low levels of experience, which are a function of high staff turnover due to a result of the promise of higher salaries elsewhere, especially in locations such as Singapore and Hong Kong. Concern about the effect of increased traffic seemed to be related to the perceived ability of the military ATC infrastructure to cope, and observations regarding the state of civilian air traffic control.
Many of the constraints of the current air traffic system have been recognised, not least in response to the two Ratner Associates reviews. The prime strategy to manage increased traffic and assure the integrity of air traffic services is the introduction of TAAATS. This represents probably the most technologically advanced air traffic system in the world and will operate from two major control centres in Melbourne and Brisbane from 1998. Advances include the graphic display of aircraft under procedural control (i.e. outside radar coverage) based on reporting, aircraft speed, wind and heading, proximity warning and terrain warning which will all add an additional margin of safety to prevent incidents such as the near mid air collision North of Broken Hill discussed earlier.

Whilst this system is not yet on line, it seems to address one of the concerns relating to the integrity of the ATC system. How smooth the implementation of such a system will be depends on a series of factors beyond the scope of this thesis. However, the fact that such an advanced system is to be introduced in anticipation of severe difficulties, rather than in response to a particular incident or accident, suggests a responsible and forward thinking attitude.
6.3.4 Communications and Language

Air traffic management is no different from aircraft operation, in the respect that communication is both its strongest defence and its weakest link. FAA research conducted in 1985 (ACAA, 1994) examined operational errors and deviations in the US air traffic system and listed 98% as having human error as primary cause. In turn an ACAA ATS forum held in 1994 found that “...inadequate communication is a major human factor in most failures of the system” (ACAA, 1994). A workshop conducted at the 1992 Australian Aviation Psychology Association Symposium (Hayward and Lowe, 1993) to examine ATC issues concluded that “Effective communications between differing parts of the system in the ATS environment is essential. Indications are that in some instances the quality of this interaction may lead to a reduction in safety standards.” In many ways, such a statement underestimates the potentially catastrophic consequences of inadequate communication, especially in areas of procedural (non radar) control where voice communications are often the sole means of separation (other than TCAS and see-and-avoid).

Cushing (1994) suggests that there are two distinct areas of communication problem which are pertinent to the ATS environment; namely those which are language based and those which are not. Consideration of both in the context of the Australian environment is worthwhile.

**Language Based Communication Problems**

Although English is the recognised international language for communication in aviation, there are a number of factors which can affect the integrity of communications. When International flights enter control zones where the local language is either Spanish, Russian, Chinese or French, they may find that local aircraft talk to controllers in their native tongue. Whilst such a procedure is not inherently dangerous and controllers will be able to communicate in English as required, it reduces the margin of safety afforded by crew listening into the communications between ATC and other aircraft, and building their own picture of spatial awareness. Communications within Australian control are in English, which makes it easier for other crews to monitor communications.

In instances where English is being used as a second language (ESL), either by ATC or aircraft there are a number of problems associated with translation and interpretation. English is a somewhat ambiguous language and literal translation can be confusing. What may seem like subtleties to English speakers (for example, punctuation, intonation and inference) can cause considerable confusion amongst ESL speakers. Whilst the use of standard phraseology is designed to combat these problems, it is an ideal that often fails in times of extreme stress or when used with heavy accents.

Major disasters such as the 1977 Tenerife air disaster where a Pan Am and KLM B747 collided, and the 1976 mid air collision involving a BEA Trident 3B and Inex-Adria DC9 illustrated the consequences of a single word communication error by an ESL speaker and the tendency for controllers under intense stress to revert to their native tongue. Cushing (1994)
notes an example involving a wide-body aircraft which was taxying to the terminal and had to
cross an active runway. Asking the ground controller, ‘May we cross?’, the reply came as
‘Hold short’. The aircraft crossed the runway, narrowly missing a landing aircraft only for the
subsequent investigation to find that the crew had heard ‘Oh sure’ and not ‘Hold short’.

Strong accents are not the exclusive domain of ESL speakers and can apply just as much to
regional dialects. It may be that errors made in communication between two English speakers
are more likely to go unchecked than when one speaker is more obviously struggling with
language than the other. In the near miss incident involving a BA B747 and QF B737 North of
Broken Hill in 1995, the British Captain became quite deadpan in the way he notified the
controller of the TCAS resolution advisory and near miss, to the point that the controller
seemed not to register the seriousness of the incident from the communication. Reaching a
‘controlled rage’ which may be interpreted as ‘typically British’, the Captain communicated in
a way that the controller interpreted to be ‘calm and non-plussed’. An Australian or American
Captain may have been more animated in the way they reported the incident.

Australian ATS and operators may be seen to have an advantage in communications by virtue
of speaking English as their native tongue. It provides an additional margin of safety although
to what degree is difficult to evaluate. The temptation may be to use non standard phraseology
with other English speakers which can then cause confusion or misinterpretation when used
with ESL speakers. Conversely, a reliance solely on standard phrases does not aid
understanding of abnormal situations. In an incident in 1997, an International crew landed at
Sydney using standard phraseology, but could not then understand instructions for taxying to
the terminal. They were left blocking the taxiway for nearly two hours until an interpreter
could be located. An ability to understand non-standard phraseology, especially in abnormal
or emergency situations can only add to the flexibility of the safety system. Whilst Australian
operators may operate in areas where a second aviation language is allowed, it is not to be used
for International operators. Therefore, although there is a potential problem, it is limited to the
presence of other aircraft in the sky.

Non-Language Based Communication Problems

Communications problems with the ATC interface are not limited to those of language, other
problems are related to anything from technology to compliance. Communications technology
has advanced considerably during the jet age and with the assistance of satellites, but is still
susceptible to interference and failure. Loss of critical information due to poor transmission or
overlapping messages has the potential for error although standard operating procedures
require such information to be verified through read-back confirmation.

Problems of compliance are potentially the greatest source of communication errors. As was
demonstrated earlier, the single greatest category of crew error is a deviation from
standard operating procedure (33%). Whilst these are not specifically judged to
be ATC deficiencies, they give an indication of a problem that affects both flight
crew and air traffic controllers. Sears' (1986) analysis of 93 accidents found deficient ATC / crew communications to be present in 9% of accidents (see diagram 2.6.3), yet this is not necessarily a fair indication of the prevalence of deviation from standard operating procedure in ATC / crew communication. RAI (Ratner, 1987) observed "...a marked tendency for ATCOs (air traffic control officers) and FSOs (flight service officers) to develop their own personal styles of operation, practices and techniques...our comparison of the Australian ATS system with others showed that this tendency is far more pronounced than in other modern ATS systems."

In contrast, within the major carriers, the culture of strict compliance with standard operating procedures, especially within Qantas, provides a defence against the use of non standard phraseology in ATS communications. Nevertheless, non standard phraseology is still used, but is being addressed through additional human factors training.

Problems of compliance are not limited to the consequences of using non-standard phraseology. They also exist as a result of misinterpreted instructions or procedures which may in turn be the result of change. As detailed in section 6.3.3, a number of concerns were voiced by both pilots and controllers alike regarding the speed of change and what were seen as politically motivated revisions in approach and departure paths, especially around Sydney airport. A culture appeared to have evolved in the mid 1990s whereby STARs were cancelled early (where traffic permitted), to facilitate a faster arrival, and were then recommenced because of slower than expected preceding traffic. Such a practice was totally alien to the concept of standardisation which STARs were designed to embrace, and was ended swiftly in 1997 following the inaugural Airservices Safety Forum.

The relatively small network operated by Australian carriers and diversity of aircraft types mean that aircraft, and therefore flight crews, will operate to a limited number of ports. This can only enhance the level of familiarity associated with ATC procedures. However, long haul operations, especially for Qantas, will mean that a large number of overseas air traffic control authorities are involved and destinations may be operated to relatively infrequently by individual crewmembers. The risk is a lack of familiarity which is addressed through an efficient, fail-safe system of chart updates and communications systems within flight operations which may include NOTAMs for information regarding approach aids.

Communications remain as important to the integrity of air traffic services as they do to pilots and there is every reason to believe that cultural strengths of open and direct communication with minimal loss of face are strengths behind the Australian air traffic control system. However, International destinations have always, and still do, involve flying through areas of questionable communications ability, a fact reflected in Qantas' standard operating procedure that no aircraft will fly north of Darwin with an unserviceable TCAS unit.
Chapter Seven

Conclusions

The conclusions draw upon the evidence collected and analysed within the three environments of operation. They answer the aims and objectives set out in chapter one and lead into ideas for future research borne out of this thesis.
7.0 Conclusions

A safe system is one where hazards and countermeasures are effectively balanced in a stable equilibrium. Achieving such a balance in a complex socio-technical system such as aviation is not easy, not least because, as a transportation mode, it is a system that is in a state of constant evolution. Advances in technology or training in one area of such a system will have to interact with a myriad of changes elsewhere which may include attitude, organisational size or external influences in the form of economic or regulatory pressures. Largely opaque technical systems such as aviation make the full understanding of all influences an unrealistic aim. Risk management techniques generally acknowledge this constraint and attempt to achieve system safety through multiple defences or filters designed to break the ‘accident chain’.

In considering the safety of Australian commercial aviation, it has been necessary to try and understand how a multiplicity of factors have interacted in a system of considerable complexity. This has included examining time-series data collected through a series of primary and secondary techniques, and covering a period where technological and human system changes have been, at times, dramatic. Aviation is still an industry in its infancy. This is illustrated by the fact that Qantas co-founder and eventual Chairman, Hudson Fysh, saw the airline’s equipment go from the first ‘rag, stick and wire’ Avro 504K to the introduction of the turbojet Boeing 707 all whilst he was still an employee. The changes that have occurred even within the ‘jet-age’ since the introduction of the Comet and B707 have been spectacular and not without considerable impact on aviation safety. Yet in spite of the ongoing change, aircraft accident rates have remained relatively static since the early 1970s. In Australia this has meant no lives have ever been lost in a commercial jet aircraft accident.

Attempting to learn from the successful aspects of the Australia aviation system requires focus at both the micro and macro levels. Different safety issues achieve disproportionate levels of attention; either in response to accidents or indeed because of an apparent lack of accidents. It is easy to be misled as to the individual influence of different factors, and case studies have to be wary of uneven coverage. Notwithstanding this, the relative importance of different elements of a safety system can change over time to reflect advances in technology or training. For example, whilst weather remains an important influence on aviation, technological advances such as instrument landing systems (ILS), jet engines and weather radar have altered the significance of the threat.

As such, it is all but impossible to develop a calibrated universal model to describe a safe aviation system based solely upon this case study of Australia. It is nevertheless possible to highlight the relative merit of each of the areas examined within this case study based upon their effect on the accident record, perception and future potential. Analysts wishing to draw maximum benefit from this case study can do so by examining the individual effect of each component as well as its effect on an active operating system. To aid this process, conclusions are separated into both hazards and countermeasures, and into the three environments of analysis.
7.1 The risk exposure of the system

Hazards to the safety of the Australian commercial aviation are summarised as follows;

**Natural Environment**

In the natural environment, anecdotal focus tended to be predominantly aimed at the positive aspects of the ‘relatively benign climate’ and ‘good aviation weather’. However, there are a number of significant threats which deserve highlighting.

Australian aircraft are likely to encounter strong microburst and windshear conditions, especially in the tropical and subtropical regions of the country. Whilst such a threat may be seen to be obvious in the far north ports such as Darwin, it also affects the other large ports including Perth and, in particular, Sydney. Weather conditions at the latter are known to deteriorate quickly, a fact which is related to the airport’s location at Botany Bay. Fear of microburst / windshear encounters was significant amongst Australian crews, largely because when it is encountered at low level, it is very difficult to recover. It is also a phenomenon which is poorly predicted and lasts for only a short time. An approach or take-off in such conditions is also prone to additional risk due to aircraft operating at maximum take-off weights or at the end of long sectors, or lack of familiarity from overseas carriers. This can be further exacerbated by commercial pressure to ‘get-in’ to this busy airport, approach and departure procedures which are confusing and frequently changed, and the expectation that ‘...it doesn’t happen here’. While the number of windshear / microburst related accidents recorded in Australia is low, this does not mean that the incidence of the phenomena is insignificant. This is a threat that will grow with complacency or increases in traffic unless due consideration is given either to the magnitude of the threat or the prevention strategies currently available such as predictive windshear radar.

Other meteorological threats that exist in Australia include severe rain, turbulence, in-flight icing and dust storms. Their frequency may be lower than in other countries which may minimise the hazard, but once again, a lack of incidence can also lead to either a complacency that there is no significant threat, or problems that stem from a lack of operational experience.

Both Qantas and Ansett are involved in International operations which means that by definition, half of their landings and take-offs are at overseas ports. These include aerodromes in all climates. Once again, long distance flights may mean that conditions are experienced at take-off in a fully laden aircraft or at the end of an long sector where the performance of the aircraft or aircrew respectively may be degraded. Heavy crewing and flight time limitations may mean that pilots are only manually landing aircraft once or twice in a month. The potential is for extreme weather conditions, an unfamiliar crew with relatively low currency on handling an aircraft and a heavy aircraft. Whilst such a threat may be counteracted to a degree by the extra alertness level afforded by unfamiliarity, it should be recognised as a threat which can be counteracted through training.
Although flat terrain is repeatedly cited as a positive attribute of the Australian environment, it does not mean that relief around airports is insignificant. Controlled Flight into Terrain (CFIT) accidents often occur around airports and not necessarily because of high relief. Terrain around Australian airports is also responsible for weather conditions such as low level rotary shear and is supplemented by microclimatic phenomena at airports such as Sydney.

The so called ‘tyranny of distance’ experienced both in terms of interstate and international operations has, historically, been a prime motivator for demanding reliability. Alternate landing sites in remote areas are rare and early pioneers often fell foul of a lack of ground support. Had the potential for aviation during the early 20th Century not been realised then Australia would have been left behind by its traditional trading partners because of the huge distances involved and lack of alternative transportation networks. Even now the importance of air travel for international trade to and from Australia is huge. Add to this the practical issues of aircraft operating long sectors at high load factors and it is clear that modern aircraft are pushed to the limits of their operating envelopes.

**Human Environment**

The more recent trend in aviation safety seems to have been in highlighting the fallibility of the human environment. Indeed, there is human error to be found in every accident, even though many texts seem to cite a figure of around 70%. Human error is inherent in aviation as it is in any system involving human input. Whilst understanding of human frailties at both physiological and psychological levels has advanced significantly, it remains a relatively soft and often controversial area of science. For many, it represents the final frontier in conquering safety issues, yet it remains poorly understood and the source of many heated arguments.

The traditional approach to human fallibility has been one of removing the ‘problem’ or blameworthy individual; a fact which is reflected in countless accident investigations. Yet, the same mistakes are then repeated around the world, often with catastrophic consequences. This situation seems to have been allowed to continue because of the relatively good safety record enjoyed by aviation. In the event of a fatal crash, it is usually the flight crew that are killed first which has made ‘pilot error’ a convenient way of closing cases of human error. The more recent trend towards understanding multiple causal factors in terms of latent defects and active failures (which may go right back to management decision making, recruitment or systems design) have begun to challenge the traditional approach. No longer can the vagaries of human performance be placed in the ‘too hard basket’ or blamed on errant personalities.

At a conceptual level, the essence of human error is the process of risk perception and risk taking. Decision making, which is at the heart of human behaviour is based upon assessing hazards and countermeasures to achieve an outcome which is deemed to be of acceptable risk. Individuals rarely make risk taking decisions that they believe will have an outcome with an unacceptable cost (whether it be financial or physical). Instead they perceive an outcome where benefits outweigh costs. However, the process is often affected by incomplete
knowledge of the nature of the risks or the effectiveness of countermeasures. Risk taking decisions are not always obvious as being such; one of the reasons why some risks are underestimated. For example, even hesitating over a decision is a risk taking decision process in itself.

Decision making occurs not just at the level of individuals, but right through to organisational levels where corporate culture can strongly impact upon risk taking decisions. Deficient organisational cultures will negatively influence the decision making skills of its employees. Similarly, leadership which focuses on short term objectives will send signals to the line workers. Organisational behaviour becomes self perpetuating and entire safety cultures can be damaged to the point of an accident. Examples from within the Australian aviation system of poor safety cultures, especially in the GA and Charter sectors are plentiful and provide an early warning of a potential attitude shift within the entire industry culture if not checked.

Another, more specific corporate hazard is the process of change; something which is particularly prevalent in a dynamic, high technology industry such as aviation. The Australian aviation industry has undergone significant structural change, especially during the last ten years. The regulator has changed both its identity and the way its operating income is funded, the ‘two airline policy’ of domestic regulation ended, Qantas absorbed Australian Airlines before being publicly floated and Ansett became an international carrier. Whilst change in itself is not inherently dangerous, it does have the potential to result in operator unfamiliarity and unforeseen hazards.

A significant aspect of change within the Australian aviation industry has been the role of the Government. Whilst the ending of Domestic ‘two airline policy’ regulation was aimed at opening the system to free market forces, the playing field for new carriers was far from even. Both Ansett and Australian Airlines had massive infrastructure bases, owning not only the equipment directly associated with airline operations, but also a network of support services including travel agents, airport terminals and holiday resorts. The attempts of new carriers (Compass MKI and MKII) failed, but at the same time serious denting the profitability of the existing carriers. The merger of Qantas and Australian airlines created a very different operation, forcing Ansett to establish international partnerships and start overseas operations. Meanwhile, changes within the CAA were precipitated by a high level of political intervention, especially following the apparent decline in commuterline safety. The creation of a Government Business Enterprise that was responsible for making its own revenue and maintaining safety surveillance was fundamentally flawed and led to the creation of Airservices Australia and CASA. Even following this restructuring, the former has been placed under considerable political pressure on the subjects of Noise Pollution and ‘Airspace 2000’ and the latter on the subject of Board membership. Turbulent times within the industry, further hampered by party political agendas have created the risk of both individuals and corporations missing the most important safety issues.
An unusual hazard which seems indicative of current attitude is that of 'luck belief'. Frequently cited as anecdotal evidence from expert witnesses and the perceptions survey, the explanation of good safety being a function of luck raises two concerns. Firstly, such a belief indicates a lack of understanding of the complex safety system that has worked well so far; secondly a genuine belief in a mystic force beyond human control. A poor understanding of systemic safety can lead to ill advised changes whilst belief in a force beyond human control may lead either to complacency (belief in good luck) or a form of fatalism (belief in bad luck).

**Operational Environment**

Within the operational environment, there are numerous technological hazards. Whilst in the strict sense, these may all ultimately be the result of human deficiencies, they are highlighted as failure sources which are specific to certain types of operation within the aviation environment. In terms of the aircraft which are operated, there is always a threat of unforeseen problems which may be overlooked because of system complexity or opacity. These include deficiencies associated with certain types of aircraft such as the DC10 rear cargo door or more general problems associated with major leaps in technology such as the introduction of jet and fly-by-wire aircraft. The Australian environment is not immune to such problems although their effects have been minimised by actions such as conservatism in type selection, as was the case with the DH Comet.

Some of the other technological problems, which may not be specific to particular aircraft types, stem from the condition of the aircraft. The continued airworthiness of any design is highly dependent on maintenance and the quality control which regulates it. Whilst many maintenance failures are not catastrophic, they can induce subsequent errors by flight crew. The lower the number of failures, the less the need to rely upon the last line of defence (flight crew). The quality of maintenance is controlled both internally, through quality assurance, and externally, through the regulator. Poor surveillance by either party can combine with a lack of vigilance by the other with potentially disastrous consequences.

The quality of aerodrome facilities can also be critical, especially when aircraft are operating near the limits of their performance envelope. In Australia, an example may be RPT aircraft operating at regional airports with meagre facilities. Overseas, an example may be Australian aircraft operating at airports in marginal conditions, when heavy or at the end of long sectors. Other hazards around the aerodrome include ramp accidents and those involving incorrect loading of aircraft. This may be a function of ground staff not directly employed by the airlines or involved in the servicing of a particular aircraft.

Another external agency which is part of ensuring the safety of the aviation system is the air traffic control provider. In the course of an international flight, an aircraft may pass through numerous control providers of varying standards. The risk of mid-air collision or impact with high terrain is especially significant as the results are generally severe (i.e. 100% fatalities). Complicated or poorly understood approach procedures, especially at airports without
precision approaches (which is most of the domestic aerodromes other than capital cities) are a particular threat when combined with other human factors considerations. For example, communication problems, especially associated with different cultures and native tongues are a major threat to any international operation.

Security threats to aircraft, particularly in terms of terrorism, hijack or military action have accounted for a significant loss of life, although it is a fact which is generally excluded from safety statistics. Nevertheless, security incidents are generally high profile and significantly affect the perceived safety record of the carriers involved. Whilst operators are often targeted because of their nationality, they can also be selected at random which therefore makes security threats a universal hazard.

7.2 The risk countermeasures of the system

Risk countermeasures which exist to maintain a good record for airline safety occur both by design and by virtue of the systems that aviation operates within. In other words, countermeasures may be a function of the natural environment; where Australian aviation operates or the human designed operating environment or the wider human environment in which that works.

Natural Environment

The natural environment represents a relatively stable variable which allows safety systems to be constructed around it. Weather is mostly predictable within climatic zones and physical geography is generally unchanging except within the built environment. Anecdotal evidence points to ‘good aviation weather’ in terms of generally stable flying conditions and lack of ground icing. Certainly operations do not experience some of the extremes of North America and Europe, affording an extra risk countermeasure in normal operations. Even when weather is good in Australia, the large RPT carriers use weather radar and extra facilities of the Bureau of Meteorology through subsidy. Additional factors include a high collective level of experience which is afforded by the major airlines and the relatively small route network. Also, a lower level of commercial pressure may reasonably be expected to assert less pressure upon flight crews to operate in marginal conditions.

The relatively flat terrain reduces the need for ‘hot and high’ performance critical operations and those involving complex approaches or departures over inhospitable terrain. It also reduces the need to fly through icing levels and has an impact upon general weather conditions.

The ‘tyranny of distance’ also had a significant positive impact upon the early history of aviation. Hazards associated with the distances and lack of settlement demanded solutions which led to the establishment of an industry level culture of reliability and innovation. Whilst
advances in technology have changed the operating environment there are many aspects of the original culture that have remained as expectations and common practice. For example, cross-checking by Second Officers even when not specifically instructed by SOPs.

**Human Environment**

Whilst the role of human designers, decision makers and operators are most often mentioned with regard to error and the fallibility of socio-technical systems, the human factor also represents the strongest element. Any successful defence against system failure (incidents or accidents) has a human component associated with it. This is primarily a function of the unique ability of humans to evaluate consequences and rationalise in decision making, exceeding any computational power currently available. Although human strengths and weaknesses can be seen to vary between individual, common elements may be highlighted as cultural traits. Ranging from workgroup and organisational levels to professional, industry and national levels, culture is the biggest single influence on human behaviour and therefore one of the most powerful influences on risk taking decisions.

Cultural strengths highlighted at national level in Australia include a high degree of individualism and a shallow authority gradient. In turn this has engendered a frank and open style of communication at both micro and macro levels. This makes cross-checking easier and facilitates the more efficient exchange of safety information. At an industry level, this is complemented by a culture of strict adherence to standard operational procedures, a fact which has often been overlooked in previous studies of the Australian culture. There is a great historical pride in the Australian aviation industry, supported by a ‘Pioneer spirit’ which has been forced by the geographically disparate location.

The culture of the aviation industry is also sustained through the expectations of the general public and Government. Safe operations have become an expectation in a country that is highly dependent upon aviation for intrastate and international travel. Such expectations have a secondary effect on the allocation of resources and the priority of safety on the political agenda. Recent problems at commuterline level attracted a disproportionate level of attention which have assured a high level reaction to regain a level of acceptable risk by Australian standards.

At a corporate and industry level, one of the frontline strategies in ensuring that decision making is enhanced is training; something which exists at both a structured academic level and a less formal ‘lead by example’ level. Airlines have long since placed strong emphasis on the integrity of training for all disciplines. Formal education is supplemented by a generally high level of experience and the strength of corporate culture in setting, communicating and enforcing standards. Communications systems and styles which facilitate this process have also allowed easier introduction of industry-standard safety strategies such as Crew Resource Management (CRM), Flight Data Analysis and Ground Proximity Warning Systems (GPWS).
The structure of Australia's aviation industry is very different to that of other nations of a similar size. In an area of land approximately the same as continental USA resides a small fraction of the equivalent population. There were two major domestic carriers and one international carrier with Qantas now being a combination of both. This situation was largely because of Government policy which limited competition on the domestic network to two airlines and made Qantas an entirely international carrier. As such, competition was severely limited which arguably led to a high level of economic stability. This allowed safety minded operators to exist without the pressures of lower quality predatory competitors, a situation quite different from the deregulated US industry. The deregulation of the Australian domestic market has not seen any long-term competitors appear on the scene. However, the absorption of Australian Airlines into Qantas and subsequent public floatation has seen pressures both overseas and especially on Ansett Australia. A lack of experience with international operations was one of the latent defects in Ansett behind the B747 VH-INH incident at Sydney in 1994.

However, the ability of the industry to learn from mistakes, particularly those made by others is another important facet of industry culture. Historically, Australia is used to looking towards its 'mother country' for a lead and then improving upon those ideas. There is no loss of face experienced within Australian carriers looking at what others do in an attempt to assure best practice. Expertise is drawn from throughout the world to supplement home grown skills.

**Operational Environment**

On more specific issues relating to the Operational Environment, strengths are numerous and centre around the medium of the aviation system; the aircraft. Whilst the number of large commercial jet aircraft manufacturers around the world is small and therefore companies such as Boeing or Airbus supply aircraft to most large airlines, there are some important differences in design. A long standing demand for reliability meant that aircraft selection and specification was extremely cautious. Aircraft with checkered histories such as the DH Comet were rejected for more conservative strategies, and successful designs often required significant modification to be accepted by both the regulator and operators.

Maintenance has always been a high profile area within the Australian system, not least because of the background of its pioneers and, again, the critical need for reliability. The quality of maintenance within Australia is recognised globally. It is supported by the cultural factors mentioned above and comprehensive training. Buyer Furnished Equipment on aircraft supplements the margins of safety afforded by the basic design and includes such things as GPWS, TCAS, QARs and defibrillators.

Regulation within the Australian aviation system has traditionally been strong yet conservative, although recent crises of confidence appear to have rocked the CAA and then CASA to their collective cores. Historically, the regulator was an organisation with a great deal of operational expertise which was therefore better able to work with the industry. A more recent shift towards employing career civil servants and making politically motivated
appointments has raised many questions about the ability of the regulator to effectively do its job. However, whilst this is of grave concern in the lower levels of the industry such as General Aviation and Commuterline operations, it appears not to have damaged the airlines which have evolved into largely self-regulating bodies by following JAA and FAA best practice and assisting CASA in setting standards.

Aerodrome quality was a difficult variable to assess as the effect of variables such as runway length, approach aid provision and ground facilities are directly related to other factors such as prevailing weather conditions and aircraft equipment. Further, differences in regulatory requirements are designed to ensure equal levels of safety in operation, regardless of, for example, category of ILS. Australian airports are maintained to ICAO standards and while many airports do not have precision approach aids, this is generally balanced by other factors such as weather and crew training.

The Australian aviation system remains generally less busy than its European or US counterparts. Airports have only two ground handling organisations, both owned by the two major airlines. As a result, the ramp remains less chaotic and, thus far, a controllable hazard. However, this is a situation that may change with increased traffic and if third party ground handling agencies are introduced.

Rescue and Fire Fighting cover represents a secondary safety measure which is rarely called upon because of a lack of incidents. However, at major airports in Australia cover is above ICAO minima and benefits from being tasked solely with its core function, unlike many such organisations overseas. This provision is indicative of a culture that is not complacent about secondary safety in the light of good primary safety. This provides an additional margin of safety which may one day make a critical difference to the outcome of an incident.

Security threats in Australia were of relatively low concern because of the moderate political climate. However, airlines are always at risk of criminal activity such as hijack or bomb threats, mentally unstable individuals and other newly developing threats. Security for International operations out of Australia is at the same levels as the more highly threatened US, providing an added margin of safety which is reflected in the general lack of incidents.

The level of ATC cover at major ports is good and Australia plans to introduce the most advanced ATC system in the world (TAAATS) in 1998. Concerns that the ability to deliver a safe air traffic management system which were raised in the late 1980s and early 1990s are being addressed through initiatives such as TAAATS and a Boardroom led commitment to improving system safety.

System reliability in general has been very high with the operational and human environments not taking the hazards of the natural environment for granted. Positive cultural factors associated with natural culture and historical challenges has helped to build a strong safety system with numerous safety margins. Open and frank communications have acted as the
conduit by which a sound level of system safety health has developed and herein lies the key to a successful future.

The industry needs to recognise its strengths and build on them whilst other industries or countries try to emulate them, within their own system constraints. Open and frank observations contained within this research aim to be part of the ongoing process and not evidence to be used in a reckless or critical manner. Australia's safety record has not been the result of luck, rather the outcome of a complex, but well designed operating system.

7.3 Future threats to the system's safety health

Although the aim of this thesis has been to concentrate on what Australia does right, it is not intended to give the impression that all is perfect. Safety is not a state which can be reached, it is a continuing battle against an ever changing multiplicity of threats. Those who believe they have achieved a state of 'being safe' risk falling foul of complacency.

There are a number of threats to the future of aviation safety which have become apparent during the course of this work. The threats perceived by flight crew and air traffic controllers are detailed in Appendix 7 and summarised below;

Economic pressure on the aviation industry is always high because of its intense capital utilisation and dependence on blue chip and service industries. In Australia's case, this has been heightened by significant structural changes undergone by the aviation industry within the last decade. These have included the ending of the two-airline policy, merger of Australian Airlines and Qantas, public flotation of Qantas, and Ansett's expansion into International operations. Cost cutting within both airlines has been significant and placed pressure on all aspects of the operation. Whilst many fear that this will directly impact upon safety, some signs point to a more integrated approach towards both safety and efficiency. Ansett's current business recovery strategy puts safety visibly first and includes human factors training as a core methodology to achieving efficiency and safety by working smarter, not harder.

An increase in traffic, which is predicted at approximately 7% will bring additional pressures to the industry, not least in its attempts to compete with in the Asia Pacific region where growth is predicted to reach up to 11%. One of the challenges will be increasing pressures on infrastructure, especially air traffic services, airports, training and maintenance. Growing pains do not have to mean a degradation of safety, but the industry must adopt sound risk assessment methodologies if it is to adequately manage the change process. Problems which may have been underestimated because of a lack of incidents may become tomorrow's accidents if not catered for. For example, aircraft making approaches or taking off in marginal weather conditions where in less busy conditions this may have been avoidable.
Culture has been shown to have played an important role in the safety health of aviation and changes at any level can have an indirect effect on the future. Changes at national level may be quite slow, but in a fast developing, underpopulated country such as Australia the effect of change should not be underestimated. Political motivations and public expectations have a significant effect on resource allocation and priorities. Issues such as noise pollution, particularly with reference to Sydney airport will put major pressure on operating efficiency.

Industry and corporate culture can usually change more quickly than national culture as events within the CAA / CASA during the 1990's have shown. Individuals, when placed in key positions, can have a significant effect on the way organisations operate. Positive examples include charismatic leaders like Herb Kelleher (Southwest) and Richard Branson (Virgin Atlantic) who have managed to assert their individual style on their organisation’s operations. Negative examples are plentiful and all industries need to be aware that although accident investigation has moved on from apportioning blame to individuals, it has also shown the root of many accidents to be high level decision making at CEO or Board level.

The mid 1990's have also brought changes to the way the Australian industry is regulated. A widescale regulatory review commenced in 1997 aiming to review the entire Australian regulations and to step towards harmonisation with the FAA or JAA. The process is currently suspended in the light of another CASA Board level reorganisation. The temptation to harmonise or follow the lead, particularly of the FAA, should, at least, pay respect to the need for cultural suitability. Regulations which may appear excessive by US or European standards may be responsible for additional safety margins and any changes should be thoroughly examined for their systemic ramifications.

Finally, there is the constant and chronic threat of complacency which is associated with any operating system that appears to be working. A lack of accidents is only a very rough guide of system safety health and in aviation, where the consequences are potentially catastrophic, not a sensible measure of current performance. The determining factors as to whether Australia manages to keep its clear record for fatal aircraft accidents do not include the past accident record. Constant evolution of the aviation environment will require adaptation of the many risk countermeasures if safety is to be maintained.

Complacency is a significant threat, not least because it can strike at the core of the strongest aspect of the Australian system, namely the human environment and in particular, the various levels of culture which have held it together successfully so far. Whilst complacency represents a mood that ‘nothing needs to be done’, a further threat is from a belief that ‘nothing can be done’; a sort of fatalism towards factors beyond human control. The latter has been expressed by a number of witnesses as a feeling that ‘Australia is due for a crash’ or that the good record ‘has to come to an end’. Accidents do not occur because statistics say they should and whilst a good accident record is no guarantee of future success, neither is it a bad omen.
7.4 Final Remarks

It is hoped that this thesis has revealed the hitherto underestimated human contribution to system safety and placed the more recognised environmental factors in context. In understanding how a safety system has evolved and operates, it has set out to reduce the opacity of the Australian aviation safety system. In doing so this provides opportunity for Australians to recognise their strengths and weaknesses and continue to develop a safety system which is responsive to change. The case study approach also provides an opportunity for those outside of the system to draw from its strengths and heed the warnings of the Australian experience.

Approaching this task as a systemic case study is innovative in its own right and lends itself to other case studies of 'good practice' in other countries and in other industries. It is an approach that demands considerable effort and draws from a multiplicity of skills, yet its ultimate benefit in a world of increasingly complex systems is undeniable. There are no new accidents, only variations on a theme and therefore past experience, viewed through a structured case study methodology, holds the key to future risk management.
7.5 Future Research

A good research project ends up asking almost as many questions as it answers and it has always been the intention of this thesis to provoke thought on the subject of aviation safety and the many facets of it which have been approached during this work. One of the most important objectives of case study research such as this, which look at the entire system rather than a single focussed issue, is to gain a broad perspective of how several issues interrelate. This is necessary, not only to promote a wider understanding of how the system operates, but also to guard against focusing too much on one particular factor.

For example, the emphasis upon Crew Resource Management which has come especially from the USA and other Anglo cultures runs the risk of being treated as the key factor behind future accident prevention at the expense of other prevention strategies. The wide acceptance of CRM appears to be a good thing and yet there are still neither standard metrics available to assess the quality of different CRM courses or particular course components, nor indeed any universally accepted tools to assess the effectiveness of the training on individuals. Although the training was brought in as a non-jeopardy situation where individuals could not fail the course, there will come a point where 'if CRM is that crucial to a pilot's airmanship, then it must also be assessed as something they could fail at'. At the moment, its development is driven primarily by anecdotal evidence and a 'gut feeling' that because the accident record demonstrates that in many cases crew co-ordination is poor immediately prior to accidents, a training strategy that aids effective communication for problem solving must be a good thing. The aviation community is still not confident enough to reply to the charge that the individuals who sit at the back of CRM sessions and disregard the training content are perhaps the ones that are going to have accidents anyway.

The CRM movement has risked losing focus - as mentioned earlier in the text, certain countries or cultures that seem resistant to the principles of CRM may already be safer by virtue of stricter adherence to standard operational procedures. Although both skills cover different areas - strict SOP adherence works well for normal operations and CRM comes to the fore in abnormal situations, they may both have a similar effect on the overall safety picture. This may also mean that prudent application of both skills may have an increased or even doubled effect. Only a view of the 'big picture', afforded by such case study research allows these observations to be made.

Some of the areas for future research which have come to light from this thesis are discussed below:
7.5.1 Culture at its many levels

Although this was never the intention at the inception of this research, the subject of culture has emerged as an important theme throughout. The multi-level influences of various cultures from the work-place, professional cultures, through organisational and industry cultures to the effect of national culture have all been important and worth deeper examination, particular from the point of view that aviation is a very multicultural industry which is becoming ever more so. The birth of global carriers such as British Airways which sees a number of different operators flying the same corporate flag through various franchising and ownership deals has already led to a mixing of both organisational and national cultures.

A number of challenges have become apparent during this research. For example;

7.5.1.1 The effect of nationality on safety

As suggested in the text, the mere mention of attempting to link nationality to safety records, particularly in aviation, is enough to cause political consternation, especially when done in a way that implies, ‘we are better than you!’ This has been one of the reasons why previous safety studies have been so controversial, especially as they have often originated from the USA - a not particularly modest culture. (Beaty, 1995 notes that the motto of the US F111 squadron based in the UK was ‘We Are The Greatest!’ which was in contrast to the RAF’s “Piece of Cake” attitude. He suggests that this is some sort of “...Freudian defence mechanism” whereby the “...USAF elevate the man and the RAF denigrate the dangerous operation.”)

Nevertheless, close examination of the accident record reveals the unquestionable fact that some airlines are safer than others and some countries are safer to fly in than others. A deep investigation into the reasons behind this fact is long overdue and will ideally require the efforts of an international collaboration. This is not just to avoid the natural bias of looking at any cultural difference from the researcher’s own host culture, but also to attain the integrity required for data collection to be valid and for the results to be trusted. If existing knowledge of cultural factors is correct then cultures where saving face is important will be likely to be selective in terms of the safety information they are likely to present. Even in the course of this research, the answers from a certain large British Airline were very much ‘the company line’ and not particularly honest. The argument may be that safety information should not be presented too freely to outsiders and if this is the case then safety differences become more about the ability to market (or even lie) convincingly. This does not help develop a real understanding of the big picture.
7.5.1.2 Identifying corporate culture traits and their effect on safety / communications

To date, studies of organisational culture tend to be particularly from the point of view of efficiency and, while safety may be judged to be inherently linked to efficiency, deep investigations into the effect of organisational culture on safety have been few and far between. What studies do exist have tended to be undertaken into the 'unsafety' of an organisation. This may be in the form of an official accident report (such as BASI accident reports) or a public inquiry such as the New Zealand Royal Commission into the 1979 Mount Erebus Disaster. As a result of these studies being retrospective and usually after significant loss of life, the facts are often changed so as to minimise blame or liability for those who are left behind. People are naturally less inclined to speak about what they did wrong compared to what they did right. In the case of the Erebus Royal Commission, Justice Peter Mahon (presiding) observed that he considered that the evidence produced before him by the Air New Zealand management was "...nothing short of an orchestrated litany of lies" (Mahon).

As was stated earlier in this thesis, it was University of Manchester's Professor of Psychology, James Reason who stated "Should we not be studying what makes organisations relatively safe rather than focussing upon their moments of unsafety? Would it not be a good idea to identify the safest carrier, the most reliable maintainer and the best ATC system and then try to find out what makes them good and whether or not these ingredients could be bottled and handed on?" (Reason, 1993). To this end there has been a move of sorts towards examining system safety health as a proactive safety tool although it is not well established so far. The Australian BASI have made progress in this area with its INDICATE program (BASI, 1997) but remains unique in this area. A project of the Civil Aviation Safety Authority's Regulatory Reviewal Project has been set up to examine the 'Risk Assessment of Aviation Organisation' using a panel of industry representatives as its expertise. However, the project is still in its infancy and not expected to deliver findings until mid 1998. It does not include any formal academic research element, but may provide the basis for a study in this area.

7.5.1.3 Effect of multiculturalism on safety / communication

Although, by their very definition, international carriers have been operating in multicultural environments since their inception (whether this be the air traffic control, ground handling or engineering staff), aviation is becoming an ever more mixed industry. Already, airlines such as Singapore, Emirates and Malaysian have between 30 and 40 different nationalities within their respective flight crew divisions. Work such as the NASA/UT crew research project has helped develop an understanding of the need to 'translate' training across national boundaries, particularly in the context of crew resource management training. However, the challenge that has generally remained in the 'too hard' basket has been that of multicultural training i.e. training e.g. CRM with a number of different cultures together. This is a subject that has been mentioned by several expert witnesses throughout this research project.
A maintenance supervisor within Qantas explained that although the majority of his staff were second (plus) generation Australian, spoke with English as a first language and were brought up with Australian attitudes and values, there was a minority of foreign staff too. Recent recruitment of Vietnamese staff revealed that they were incredibly hard workers although there was a tendency for them to close ranks and keep quiet to cover up any mistakes. Some problems arose when they spoke in their native language to each other as the Australians sometimes thought they were talking about them. It was quite obvious that the training needs of the majority group were different from the rest. If they were both put through separate CRM courses (as is the way in Japan Airlines) then there was a risk that one or other of the groups would feel alienated and the full integration which was one of the aims of the CRM training would not be achieved. What was needed was a single training programme that was sympathetic to both sets of needs without appearing condescending to either party. The answer does not appear to be out there, either in academia or industry and this is why future work is proposed.

Captain Surrendra Ratwatte (1997) of Emirates suggests that although their airline flys with 32 different nationalities of crew member, there is no major cultural problem. He purports that because there is no one dominant culture, and because individuals are aware of the fact that there are many different cultures working together, their behaviour is modified to take account of this. In fact, this process also works at the recruitment stage where applicants who do not wish to mix with other cultures will either not apply or be rejected on application. It seems more likely that problems will arise when there are only one or two cultures in minority to a main culture. For example, within Qantas, flight attendants have traditionally been recruited from within Australia. This often means first generation Australians with a second, foreign language, but all with English as their first. The recent recruitment of Korean flight attendants to operate on the route to Seoul has been because of a shortfall in Australian recruits that can speak the language. Some problems have started to arise when two Korean flight attendants are having a conversation in their native tongue and the Australians have felt left out or that things were being said behind their back. This presents new problems in crew cohesion that have not been present in this airline in the past which may impinge upon safety issues.

Another challenge within this area is related to communications between flight deck and ATC and the effect of cultural variation on this process. Although most of the work in cross-cultural communication in aviation has been slanted towards flight deck, aircraft or maintenance cell communications, they all represent areas where crews are together for a period of time and are able to use body language (which can account for between 55 and 70% of communication). The virtual crew that is formed when an aircraft passes into a particular control zone may only last a matter of minutes before a new ‘crew’ is formed. In the case of the aircraft this may be as they pass over different control sectors in one country, from military to civil control or different countries. In the case of the ATC section, this may be a changing mix of domestic and overseas nationalities, different airlines, military and civil traffic. Although all communications are expected to be completed using standard English phraseology, it is becoming increasingly obvious that there are a significant number of occasions when this
protocol is not enough. Operational requirements can further complicate this process - one airline which flies B747SP aircraft to Australia uses a Captain, First Officer, Flight Engineer, Navigator and Interpreter where only the latter has a working knowledge of English and is also the only non-aviator on the crew. The communication loop is slow and non-standard instructions (such as the cancellation of a standard arrival (STAR) procedure) can be misinterpreted or filtered by the interpreter so that the message never reaches the Captain (e.g. for fear of loss of face).

7.5.1.4 The contribution of economic change to organisational culture change

Aviation is a high capital business that is particularly prone to economic cycles. Major airlines such as Pan Am, Braniff and TWA have all been through bankruptcy protection, with only the latter surviving the economic fallout of US deregulation and the stock market crash of the late 1980’s. Deregulation of the US and Australian aviation industries along with liberalisation in Europe have created new pressures not just for the airlines but also the regulators, ATC systems and service providers such as maintenance facilities. Airlines have also tended to change from state to private ownership for example, British Airways, Qantas and Australian Airlines with a new urgency to make a profit for shareholders rather than that being simply a desirable aim. Although none of these changes per se could ever be proven to have a direct negative effect on safety standards, there is always a risk that organisational change will allow this to happen. As this thesis has shown, some of these changes in management style or operating priorities have led to a degradation of safety margins either as a result of naivete or in the name of rationalisation where a lower level of acceptable safety is allowed.

What is relatively unknown is how these organisational changes are affected by the role of economics. As accidents are extremely expensive (both in human and financial terms), theory would suggest that safety could be achieved through economic forces. Yet safety is often priced as a cost rather than a saving by virtue of it being negatively reported. (It is all but impossible to price an accident prevented by a safety initiative.) The process of culture change can be relatively invisible and confused with other changes which naturally occur over time for example, as a result of technological change. Its time-series nature also makes it relatively difficult to observe. The development of a conceptual tool for assessing the organisational culture of a particular firm at a particular point in time would provide a useful ‘snapshot’ which could be compared with another assessment at a later date. The understanding of the importance and mechanism of organisational culture will need to be enhanced before the effect of external forces such as economic change can be properly understood.

7.5.1.5 The contribution of technological advances to corporate culture change

As mentioned above, technological change is a time series feature which makes the influence of other factors on organisational culture relatively difficult to isolate for analysis. Advances at the ‘sharp end’ of aviation have brought safety benefits through systems such as GPWS and TCAS albeit with the threat of other problems such as the ‘deskilling’ of crews. These have
occurred alongside ‘blunt end’ technological advances such as the dawn of the paperless office and improved communications mediums.

An important question that such advances raises relates to the relative improvement of accident rate. Although aircraft have become more advanced to minimise human error, the accident rate has remained static since the early 1970’s.

7.5.2 Risk

7.5.2.1 The contribution of culture to risk perception and acceptability

The historical emphasis on risk has tended to be directed from the more tangibles of engineering probabilistic risk assessment or financial planning. Both of these areas rely on stable mathematical principles to predict ‘failure’ rates in performance and as such have tended to steer away from the vagaries of human performance inputs. In other words, the dependence on probabilities for quantifying and assessing risk does not lend itself to including the risk profile of humans.

This is partly due to the subjectivity of individuals’ risk perceptions and acceptabilities and the inherent capability of all humans to both over- and underestimate risks. (This was discussed in greater detail within the body of this thesis.) Nevertheless, it is the case that groups of people do display similar traits on risk taking and closer study of the influence of these groups (or indeed the influence of people on these groups) appears to be warranted.

The “collective programming of the mind” (Hofstede, 1980) which is culture is in many ways a self perpetuating phenomenon. Those who group together tend to do so because they have something in common with the other members in the group (which may be accepting a certain level of risk such as in a caving society) and it is also true that the behaviour of members within a group is heavily influenced by culture of the group.

7.5.2.2 The relationship between risk perception and complacency

The underestimation of risk can lead to a reduced level of risk countermeasures which in turn may lead to conditions of unsafety. Whether this process is the same as the onset of complacency is a question worth deeper investigation. Complacency in safety issues may the result of a number of factors, but what is definite is that a complacent attitude can be highlighted as a latent failure within a number of organisational accidents. This may be at any level from the ‘accident face’ operators to those at management and board level who are making fallible decisions. Whether the process of being complacent is as a result of personality traits i.e. can individuals be ‘complacency prone’? or whether it is the result of incomplete information is an important discovery to make. Even if the latter were found to be predominant, it may be that this process works in two directions. In other words, whereas a full appreciation of the risks of a particular activity may minimise the level of fallible decisions
taken through naivety or ignorance, it may also mean that excessive risk countermeasures or safety margins are reduced. However, the latter situation is difficult to accurately predict, especially in the case of complex high technology systems such as aviation.

7.5.2.3 The concept of luck in aviation

Related to the subject of complacency is a belief in luck. This subject was mentioned earlier in the text, but is worth revisiting for several reasons. Firstly, the high proportion of survey respondents who suggested luck to be a factor in the good safety record for Australian aviation is an area that deserves further investigation. The higher proportion of Air Traffic Controllers who stated 'luck' (than pilots) may be indicative of a the different culture that exists within these two groups. It may also indicate a range of other things which could include an indication of how opaque the operating system may seem or the number of 'close calls' that controllers see, but pilots are not aware of. In the case of the former, the fact that pilots have been exposed to human factors and CRM type training for almost ten years in Australia, whereas controllers are only just getting a feel for the subject may be the cause of misunderstanding. Incidents where a mid-air collision has been avoided “...only through the luck of the controller spotting the offending aircraft” may appear to be ‘lucky escapes’ whereas the safety net held fast. A deeper understanding of systemic safety issues may be all that is required to reduce the proportion of luck believers.

However, the solution may not be that simple. There are plenty of people who are great believers in luck as the profits of the gambling industry will show. If these people work in the aviation industry (and there is no reason to believe otherwise) they experience either of two emotions; firstly a belief that sooner or later, luck will run out, or a belief that the system is blessed with a certain amount of luck.

Whether the concept of luck in aviation is as simple as a lack of systems knowledge, or a genuine belief in some mystical, random (or indeed non-random) force, it is recommended that research attempts to explore this area. Luck is very much a human concept and as human error is found in 100% of accidents, it deserves a more complete understanding.

7.5.3 Performance Indicators

7.5.3.1 The development of indicators of system health

The move towards more systemic investigation of accidents and incidents has helped to develop a greater understanding of system safety and the multiple factors which need to be in place to cause an accident, or indeed prevent one. As such the investigative emphasis has shifted from 'post-mortem' or punitive towards that of investigation incidents as a means of prevention and now to the stage of attempting to highlight latent defects well before they compromise the efficiency of safety of a system.
However, such a task is easier said than done. Although models such as those produced by Reason (1990, 1991) allow organisational failures to be more fully understood in terms of multiple causal factors, it stops short of being a proactive tool for actively monitoring system safety health. The challenge is to develop a simple, inexpensive methodology to accomplish this task which can is attractive to all levels of operator, not just those with an active safety culture.

In Australia, the need to make inroads into the area of safety performance indicators was highlighted by the findings of the House of Representatives Standing Committee on Transport and Communications Infrastructure’s Investigation in Aviation Safety (HORSCOTCI, 1996). An initial attempt by BASI, CASA and the Department of Transport fell short of producing active indicators plotting as they did, general trends over a ten year time period. (BASI etc.) A longer term and fresher strategy appeared in the shape of the INDICATE program (Identifying Needed Defences in the Civil Aviation Transport Environment) which has been trialled with Kendell Airlines in 1996/7.

In addition to this program, which has been mainly aimed at the Regional airline sector, a working group of the CASA Regulatory Role Review Program was set up in 1997 to examine the area of risk assessment within aviation organisations. The group consisted of member of CASA, aircraft operators, Airservices Australia, BASI and other interested parties. Progress has thus far been slow, not least because of a genuine lack of available assessment tools or methodologies. A format was suggested to follow that used by the Flight Safety Foundation (FSF) for their ‘CFIT Checklist’ which is a three page document whereby any operator can score their general risk of suffering a controlled flight into terrain type accident by answering simple questions, each of which have a predetermined weighting. Whilst this concept has great merit in that, once it is developed, it would be an inexpensive and convenient tool for any operator to use, it is still far from completion.

A valuable area of research would be the development of a comprehensive set of system safety indicators which could be assessed using a simple checklist which would be weighted similarly to the FSF CFIT Checklist. Using the experience of complex high technology industries outside aviation, such as petrochemical and nuclear, a ‘self-diagnosis’ package could be useful made available to the aviation industry. The design must be simple, easy to use and need minimal training before implementation if it is to catch the full spectrum of operators and not just those with particularly safety conscious attitudes.
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Appendices
Glossary of Terms

Anemograph - An item of meteorological measuring equipment to record wind speed and gustiness.

Boeing 747 Classic - This term refers to the -100, -200 and -300 series aircraft which retained three crew (captain, first-officer and flight engineer) to operate in a non-glass cockpit environment.

Circadian Disrhythmia - A physiological condition caused by operating contrary to the body’s natural daily wake-sleep rhythms.

Flight Attendants - Flight attendants are also known as cabin crew and cabin attendants.

Flight Crew - This somewhat ambiguous term can refer to solely the flight deck crew or the collective of aircraft crew. Also known as “aircrew” in some airlines. Must be used with some caution.

Go-Around - A go-around is the term given when an aircraft is commanded to abandon approach, apply power to climb and then return to try again or divert. It is a precautionary manoeuvre at the discretion of the flight crew or at the request of air traffic control (for example in the event of the runway not being cleared by the preceding aircraft).

Hull Loss Accident - A hull loss accident is one where the aircraft is destroyed because of a mishap. It also includes aircraft which could have been repaired, but were not due to economic reasons.

Hot Fuelling - The process of refuelling an aircraft with the engines still running, which is now illegal in many parts of the world. Often used in cases where the APU is faulty or a ground start unit is unavailable or during quick turnarounds.

See and Avoid - A control strategy whereby each pilot has the responsibility to maintain separation from other aircraft. It may be in the form of unalerted see and avoid, (whereby the only way of ‘seeing’ other aircraft is by visual acquisition) alerted see and avoid, (where an aircraft in controlled visual flight rules conditions is told the location of another aircraft to avoid or follow) or as a last resort method to avoid collision when control procedures fail.

Souls - In referring to the occupants of an aircraft (especially following an accident), crew and passengers are collectively known as souls.

Technical Crew - This term refers to the on duty captain, first officer and possibly flight engineer and second officer of an aircraft. Sometimes referred to as the flight crew or flight deck crew.
### List of Acronyms and Abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>AAIB</td>
<td>Air Accidents Investigation Branch (UK)</td>
</tr>
<tr>
<td>ACAA</td>
<td>Australian Civil Aviation Authority</td>
</tr>
<tr>
<td>ACAS</td>
<td>Aircraft Collision Avoidance System (also known as TCAS)</td>
</tr>
<tr>
<td>AD</td>
<td>Airworthiness Directive</td>
</tr>
<tr>
<td>ADREP</td>
<td>Accident / Incident Data Reporting System (ICAO)</td>
</tr>
<tr>
<td>AGPS</td>
<td>Australian Government Publishing Service</td>
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<tr>
<td>AN</td>
<td>IATA code for Ansett Australia</td>
</tr>
<tr>
<td>ANA</td>
<td>Australian National Airways (later Ansett-ANA)</td>
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<tr>
<td>APCC</td>
<td>Annual Proficiency Check Course (Australian Airlines)</td>
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<tr>
<td>APS</td>
<td>Aircrew Perceptions Study (prepared exclusively for this thesis)</td>
</tr>
<tr>
<td>APU</td>
<td>Auxiliary Power Unit</td>
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<td>ASRS</td>
<td>Aviation Safety Reporting System (US)</td>
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<td>ATC</td>
<td>Air Traffic Control</td>
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<td>ATS</td>
<td>Air Traffic Services</td>
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<td>BASI</td>
<td>Bureau of Air Safety Investigation (Australia)</td>
</tr>
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<td>BASIS</td>
<td>British Airways Safety Information System</td>
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<td>BCAR</td>
<td>British Civil Aviation Requirement</td>
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<td>BFE</td>
<td>Buyer Furnished Equipment</td>
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<tr>
<td>BIE</td>
<td>Bureau of Industry Economics (Australia)</td>
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<td>BOAC</td>
<td>British Overseas Airways Corporation</td>
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<td>BoS</td>
<td>Breakdown of Separation (Near Miss or Air Miss)</td>
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<td>Civil Aviation Authority (UK)</td>
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<td>CAIR</td>
<td>Confidential Aviation Incident Reporting (Australia)</td>
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<td>CASA</td>
<td>Civil Aviation Safety Authority (Australia)</td>
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<tr>
<td>CAT</td>
<td>Clear Air Turbulence</td>
</tr>
<tr>
<td>CEO</td>
<td>Chief Executive Officer</td>
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<td>CFA</td>
<td>Country Fire Authority (Australia)</td>
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<td>CFIT</td>
<td>Controlled Flight Into Terrain</td>
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<td>CHIRPS</td>
<td>Confidential Human Factors Reporting System (UK)</td>
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<td>CRM</td>
<td>Crew (or Cockpit) Resource Management</td>
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<td>CTAF</td>
<td>Common Traffic Advisory Frequency</td>
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<td>Canadian Transportation Safety Board</td>
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<tr>
<td>CVR</td>
<td>Cockpit Voice Recorder</td>
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<tr>
<td>DFDR</td>
<td>Digital Flight Data Recorder</td>
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<tr>
<td>DME</td>
<td>Distance Measuring Equipment</td>
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<td>EP</td>
<td>Emergency Procedures</td>
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<td>English as a Second Language</td>
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<td>Federal Aviation Administration (US)</td>
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<td>Federal Aviation Regulation (US)</td>
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<td>FDR</td>
<td>Flight Data Recorder</td>
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<td>FIR</td>
<td>Flight Information Region</td>
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<td>FLOPS</td>
<td>Flight Operations</td>
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<td>Flight Attendant</td>
</tr>
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<td>F/E</td>
<td>Flight Engineer</td>
</tr>
<tr>
<td>F/O</td>
<td>First Officer</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GPWS</td>
<td>Ground Proximity Warning System</td>
</tr>
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<td>HEAR</td>
<td>Human Error and Accident Reduction Group (Qantas)</td>
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<td>IAPA</td>
<td>International Airline Passengers Association</td>
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<tr>
<td>IATA</td>
<td>International Air Transport Association</td>
</tr>
<tr>
<td>ICAO</td>
<td>International Civil Aviation Organisation</td>
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<tr>
<td>IED</td>
<td>Improvised Explosive Device (Bomb)</td>
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<tr>
<td>IFALPA</td>
<td>International Federation of Airline Pilot Associations</td>
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<td>IFR</td>
<td>Instrument Flight Rules</td>
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<tr>
<td>ILS</td>
<td>Instrument Landing System</td>
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<tr>
<td>IMC</td>
<td>Instrument Meteorological Conditions</td>
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<td>JAR</td>
<td>Joint Airworthiness Requirements (EU)</td>
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<td>KLM Royal Dutch Airlines</td>
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<td>LAME</td>
<td>Licensed Aircraft Maintenance Engineer</td>
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<td>LOFT</td>
<td>Line Oriented Flight Training</td>
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<td>MBZ</td>
<td>Mandatory Broadcast Zone Airspace</td>
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<tr>
<td>MEL</td>
<td>Minimum Equipment List</td>
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<td>MIT</td>
<td>Massachusetts Institute of Technology (US)</td>
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<tr>
<td>MLS</td>
<td>Microwave Landing System</td>
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<tr>
<td>MSAWS</td>
<td>Minimum Safe Altitude Warning System</td>
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<tr>
<td>MTAF</td>
<td>Mandatory Traffic Advisory Frequency Airspace</td>
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<tr>
<td>NASA</td>
<td>National Aeronautical and Space Administration (US)</td>
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<tr>
<td>NDB</td>
<td>Non Directional Beacon</td>
</tr>
<tr>
<td>NM</td>
<td>Nautical Miles</td>
</tr>
<tr>
<td>NOAA</td>
<td>National Oceanic and Atmospheric Administration</td>
</tr>
<tr>
<td>NSW</td>
<td>New South Wales</td>
</tr>
<tr>
<td>NT</td>
<td>Northern Territory</td>
</tr>
<tr>
<td>NTSB</td>
<td>National Transportation Safety Board (US)</td>
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<tr>
<td>OAT</td>
<td>Outside Air temperature</td>
</tr>
<tr>
<td>Octa</td>
<td>Cloud amount expressed in eighths</td>
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<tr>
<td>PA</td>
<td>IATA code for Pan American Airways</td>
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<td>PAPI</td>
<td>Precision Approach Path Indicator</td>
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<td>PDI</td>
<td>Power Distance Index</td>
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<td>QAR</td>
<td>Quick Access (Flight Data) Recorder</td>
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<td>IATA code for Qantas Airways</td>
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<td>RAAAF</td>
<td>Royal Australian Air Force</td>
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<td>RFFS</td>
<td>Rescue and Fire Flighting Service</td>
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<tr>
<td>RIV</td>
<td>Rapid Intervention Vehicle</td>
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<tr>
<td>Abbreviation</td>
<td>Explanation</td>
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<td>--------------</td>
<td>-------------</td>
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<tr>
<td>RoR</td>
<td>Review of Resources (Australian CAA)</td>
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<td>RPT</td>
<td>Regular Public Transport</td>
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<td>SCARF</td>
<td>Safety Courses for Airport Ramp Functions</td>
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<tr>
<td>SID</td>
<td>Standard Instrument Departure</td>
</tr>
<tr>
<td>STAR</td>
<td>Standard Arrival Route</td>
</tr>
<tr>
<td>SIGMET</td>
<td>Significant Meteorological Advisory</td>
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<tr>
<td>SIMOPS</td>
<td>Simultaneous Operations (of runways) (Australia)</td>
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<tr>
<td>SOIR</td>
<td>Simultaneous Operations on Intersecting Runways (US)</td>
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<tr>
<td>SODPROPS</td>
<td>Simultaneous Opposite Direction Parallel Runway Operations</td>
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<td>S/O</td>
<td>Second Officer</td>
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<td>Trans-Australia Airlines</td>
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<td>The Australian Advanced Air Traffic System</td>
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<td>TCAS</td>
<td>Traffic Alert and Collision Avoidance System</td>
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<tr>
<td>TOGA</td>
<td>Tropical Oceans and Global Atmosphere</td>
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<td>TRB</td>
<td>Transportation Research Board (US)</td>
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<td>TWA</td>
<td>Trans World Airways (US)</td>
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<td>VASIS</td>
<td>Visual Approach Slope Indicator System</td>
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<td>VOR</td>
<td>VHF Omnidirectional Range Radio Beacon</td>
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<td>VOLMET</td>
<td>Significant Meteorological Advisory for Volcanic Activity</td>
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<td>WA</td>
<td>Western Australia</td>
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</table>
Boeing's list of accident prevention strategies is shown below. They have been categorised into seven areas, namely, crew, flight operations, ATC, airport maintenance, weather, aircraft design/performance and maintenance.

<table>
<thead>
<tr>
<th>Group</th>
<th>Code</th>
<th>Accident Prevention Strategy</th>
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<tr>
<td>CREW</td>
<td>01</td>
<td>Flying Pilot adherence to procedure</td>
</tr>
<tr>
<td></td>
<td>02</td>
<td>Non Flying Pilot adherence to procedure</td>
</tr>
<tr>
<td></td>
<td>03</td>
<td>Flight Engineer adherence to procedure</td>
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<td></td>
<td>04</td>
<td>Cabin Crew adherence to procedure</td>
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<td></td>
<td>06</td>
<td>Captain’s crosscheck - performance as Non Flying Pilot</td>
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<td>07</td>
<td>First officer’s crosscheck - performance as NF Pilot</td>
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<td>10</td>
<td>Non Flying Pilot communication or action</td>
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<td></td>
<td>11</td>
<td>Flying Pilot communication or action</td>
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<td></td>
<td>12</td>
<td>Recognition and reaction to Pilot incapacitation</td>
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<td>13</td>
<td>Embedded Pilot skills</td>
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<td></td>
<td>15</td>
<td>Captain or Instructor Pilot exercise of authority</td>
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<td></td>
<td>16</td>
<td>Use of all available approach aids</td>
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<td></td>
<td>17</td>
<td>Go-around decision</td>
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<td>Approach path stability</td>
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<td>Flying Pilot awareness and attention</td>
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<td>Response to Ground Proximity Warning System</td>
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<td>Installation of GPWS</td>
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<td>Availability of approach aids</td>
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<td>26</td>
<td>Management of warning devices</td>
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<td></td>
<td>27</td>
<td>Weight and centre of gravity control</td>
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<td></td>
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<td>Control of crew fatigue</td>
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<td>Integrity of warning devices</td>
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<td>Other operational procedural considerations</td>
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<td>AIRLINE FLIGHT OPERATIONS</td>
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<td>ATC system performance</td>
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<td>41</td>
<td>ATC / Crew communications</td>
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<td>AIRPORT MANAGEMENT</td>
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<td>Eliminate runway hazards</td>
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<td></td>
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<td>53</td>
<td>Other airport services</td>
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<td>60</td>
<td>Weather information availability and accuracy</td>
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<td>AIRCRAFT DESIGN/PERFORMANCE</td>
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<td>Design improvement</td>
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<td>Performance data</td>
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<td>Emergency equipment</td>
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<td>73</td>
<td>Manufacturing process</td>
</tr>
<tr>
<td>MAINTENANCE</td>
<td>80</td>
<td>Maintenance or inspection action</td>
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</table>

Page A5
The list was not suitable for direct use and hence needed tuning before it could be used as a methodological framework. Each category shown below next to its Boeing equivalent:

**Group One; Crew**

<table>
<thead>
<tr>
<th>Boeing Code</th>
<th>New Code</th>
<th>Category</th>
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<tbody>
<tr>
<td>01</td>
<td>A1</td>
<td>Flight crew culture</td>
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<td>02</td>
<td>A2</td>
<td>Cabin crew culture</td>
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<td>03</td>
<td>A3</td>
<td>Flight crew interaction</td>
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<td>04</td>
<td>A4</td>
<td>Experience levels and gradient</td>
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<td>05</td>
<td>A5</td>
<td>Go-around decision</td>
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<tr>
<td>06</td>
<td>A6</td>
<td>Basic airmanship</td>
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<tr>
<td>07</td>
<td>A7</td>
<td>Physiological condition</td>
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**Group Two; Airline Flight Operations**

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<td>20</td>
<td>B1</td>
<td>Availability and use of GPWS</td>
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<tr>
<td>21</td>
<td>B2</td>
<td>Availability and use of approach aids</td>
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<td>22</td>
<td>B3</td>
<td>Training programme</td>
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<td>23</td>
<td>B4</td>
<td>Aircraft loading</td>
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<td>24</td>
<td>B5</td>
<td>Crew scheduling / complement</td>
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<tr>
<td>25</td>
<td>B6</td>
<td>Integrity of warning devices</td>
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<td>26</td>
<td>B7</td>
<td>Route selection</td>
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<td>27</td>
<td>B8</td>
<td>Management priorities</td>
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**Group Three; Air Traffic Control**

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<td>40</td>
<td>C1</td>
<td>ATC system reliability</td>
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</tbody>
</table>
Australian Aviation Safety: A Systemic Investigation and Case Study Approach

41 ATC / Crew communications

C2 ATC / crew interaction / relations

C3 Traffic density

N/A

Group Four; Airport Management

50 Eliminate runway hazards

D1 Integrity of runway and surrounds

52 Airport crash, fire and rescue services

D2 Airport crash, fire and rescue services

53 Other airport services

D3 Other airport services

N/A

D4 Integrity of security

Group Five; Weather (Data)

60 Weather information availability & accuracy

E1 Weather info. availability & accuracy

70 Design improvement

E2 Aircraft type problems (re weather)

N/A

E3 Incidence of hazardous weather

N/A

E4 Minimum acceptable flying conditions

N/A

E5 Effect of relief

Group Six; Design / Performance

71 Performance data

F1 Aircraft performance limitations

72 Emergency equipment

F2 Emergency equipment

73 Manufacturing process

F3 Unforeseen aircraft type deficiencies

N/A

Group Seven; Maintenance

80 Maintenance or inspection action

G1 Airline’s maintenance / inspection action

N/A

G2 Regulated maintenance / inspection

N/A

Group Eight; Regulation

N/A

H1 Power of regulator

N/A

H2 Regulator’s priorities

N/A

H3 Response to occurrences

N/A

Group Nine; Cultural Influences

N/A

I1 Level of acceptable risk

N/A

I2 Level of risk exposure

N/A

I3 Political influence
The completed list of new codes is as follows:

**Group One; Crew**

- A1 Flight crew culture
- A3 Flight crew interaction
- A5 Go-around decision
- A7 Physiological condition
- A2 Cabin crew culture
- A4 Experience levels and gradient
- A6 Basic airmanship

**Group Two; Airline Flight Operations**

- B1 Availability and use of GPWS
- B3 Training programme
- B5 Crew scheduling / complement
- B7 Route selection
- B2 Availability and use of approach aids
- B4 Aircraft loading
- B6 Integrity of warning devices
- B8 Management priorities

**Group Three; Air Traffic Control**

- C1 ATC system reliability
- C3 Traffic density
- C2 ATC / crew interaction / relations

**Group Four; Airport Management**

- D1 Integrity of runway and surrounds
- D3 Other airport services
- D2 Airport crash, fire and rescue services
- D4 Integrity of security

**Group Five; Weather (Data)**

- E1 Weather info. availability & accuracy
- E3 Incidence of hazardous weather
- E5 Effect of relief
- E2 Aircraft type problems (re weather)
- E4 Minimum acceptable flying conditions

**Group Six; Design / Performance**

- F1 Aircraft performance limitations
- F3 Unforeseen aircraft type deficiencies
- F2 Emergency equipment

**Group Seven; Maintenance**

- G1 Airline maintenance / inspection
- G2 Regulated maintenance / inspection

**Group Eight; Regulation**

- H1 Power of regulator
- H3 Response to occurrences
- H2 Regulator’s priorities

**Group Nine; Cultural Influences**

- I1 Level of acceptable risk
- I3 Political influence
- I2 Level of risk exposure
An explanation of the remit of each area is given below as well as an indication of data sources required to ascertain the value of each.

**Group One; Crew**

**A1  Flight crew culture**

Does the flight crew culture have a significant effect on the safe operation of an aircraft?

This is concerned with the way individual crew members perceive their status and power compared to other players (and therefore components) in the operating system. It includes the notions of individuality and masculinity as defined by Hofstede once filtered by the recruitment process. Data is obviously largely qualitative and may be collected as a primary resource through a crew survey issued to domestic and international flight crew. At one point there was the possibility of using data from the NASA/UT/FAA Crew Research Project which had recently surveyed Air New Zealand, Qantas and RAAF personnel as part of its exploration of the effects of culture on CRM training. This would have provided extensive pre-processed data with valuable comparative data whose collection was outside the budget of this study. Unfortunately, the logistics of using this data were such that they could not be used in the end without being de-identified in such a way as to be of little use to this research.

**A2 Cabin crew culture**

Does the cabin crew provide an added safety margin in emergency situations?

Cabin crew vary in their expected tasks between companies to include various support tasks in the event of unexpected occurrences. This can affect the way they deal with primary (proactive) safety issues such as checking doors and controlling passengers to a secondary (reactive) safety issues such as fault reporting and evacuation. The expectations of crew can be extracted from the training programme and the success of such training may be represented or otherwise through the incident and accident records. Evidence may come from the flight crew professional bodies and a component of the crew survey.

**A3 Flight crew interaction**

Is flight deck interaction different to average and does this affect safety?

Flight crew interaction is about the subconscious issue of culture and subtle mental programming and the more conscious issue of operating practices as defined in training. As the individual’s perceptions are ultimately responsible for the way he acts, it is vital that flight crew interaction is examined at an individual level through a survey. The way individuals describe each other is a measure of respect and perceived approachability. The way they would expect to act in a number of unusual situations would also be a good indicator.
A4 Experience levels and gradient

Do Australian operations benefit from high crew experience levels or significantly flat experience gradients?

Experience levels go beyond hours on type as training programmes vary between airlines. The prerequisites of experience for recruitment may provide useful indicators of an airline's standards which should be compared against the incident record for experience deficit type occurrences. A company policy for cockpit gradients would also be an important indicator if such controls exist. It is difficult to quantify this area because of the multiplicity of dependent variables experienced between airlines.

A5 Go-around decision

Are Australian pilots more willing to make go-arounds than other nationalities and if so why?

The decision to abort a landing and go around should ultimately rest with the flying pilot or, if overruled, by the flight's commander. It is a controversial area of airmanship and takes place at a critical stage of flight. Therefore, incorrect decisions can have drastic consequences as the accident record demonstrates. A pilot's decision should be based on his training and experience, but may be seen to be influenced by commercial pressures such as the need to conserve fuel or attain on-time arrivals. The company's position on go-arounds can be expected to have an effect on the pilot's decision making process which is obviously an important system safety indicator. While formal policy must be documented, it will also be necessary to examine the pilots' perceived position on this subject through the crew survey.

A6 Basic airmanship

Is basic airmanship above average and if so, why?

Basic airmanship will be dictated by the scale and quality of training programmes. The training background of crews should be examined along with the initial and on-line tests of competency. This will involve a careful analysis of documented training programmes.

A7 Physiological condition

Are the regulations about fitness to fly stricter than average and if so, why?

The ability to fly an aircraft safely is based on certification standard performance and therefore performances below this level begin to compromise the ability to do this. This may be a function of short term tiredness or longer term problems such as unfitness or substance abuse. It is especially a problem with long haul intercontinental style flying where circadian...
disrythmia can affect performance levels as can the concept of long periods of minimal activity (cruise) followed by short bouts of intense activity (approach and landing). The incident record may reveal the extent of this problem which can be compared to company programmes to counteract the effects. How close to the regulator’s standards do airlines operate and do crews feel that there is a risk from legal yet dangerous fatigue. (Evidence may be gained through the crew survey.)

Group Two; Airline Flight Operations

B1 Availability and use of GPWS

Has GPWS made a significant contribution to the absence of CFIT accidents?

Controlled flight into terrain (CFIT) is the biggest primary cause of crew caused accidents and is where a perfectly serviceable aircraft is flown into contact with terrain (or water). As these accidents usually occur at cruise speeds and always without warning, there are usually no survivors. Ground Proximity Warning Systems (GPWS) were introduced to counteract this problem and have been shown to significantly reduce the incidence of CFIT in those fleets that have the equipment fitted. Its original integrity was dented somewhat due to the high frequency of false warnings and incorrect responses by aircrew. The date of introduction of such equipment may be seen as an indicator of safety mindedness. The frequency of use may also give a demonstration of the difference made by the use of such equipment. Documentary evidence to come from respective airlines or manufacturers.

B2 Availability and use of approach aids

Is the provision of approach aids above average and if so has this had a significant effect on preventing approach accidents

In the same way that installation GPWS equipment may indicate the safety mindedness of an airline, so may the level of approach aids that are provided for crew. This must be reconciled with the availability of compatible equipment at airports and the training provided to use new equipment.

B3 Training programme

Are Australian pilots trained to a significantly higher standard and if so, why?

Additional training (not covered above in categories A4 and A6) may include the amount of exposure to abnormal conditions in LOFT exercises and simulator time as well as emergency procedures training with other parties such as cabin crew. Evidence to come from respective airlines.
B4 Aircraft loading

Is the quality of ground handling significantly higher in Australia and has this had a significant effect on the air safety record?

The way an aircraft is loaded by ground staff, especially in the hold, can have an important effect on the outcome of a flight. Although generally employed for the physical task, it is important that ground handlers ensure no aircraft damage, load shifting of Cg imbalance. Other areas include the provision of the correct amounts of uncontaminated fuel. The incident record may provide a valuable insight into the integrity of ground service.

B5 Crew scheduling / complement

Are flight crew more protected from fatigue than average?

As mentioned for category A7, crew fatigue can compromise their ability to perform. Therefore it is necessary to examine how far airlines recognise and counteract this problem. The length of duty rosters and the complement of crew must be compared with the incident record and answers from the crew survey regarding fatigue.

B6 Integrity of warning devices

Are warning devices of a significantly higher than average quality or do flight crews react to them in a significantly different way?

What sort of Buyer Furnished Equipment (BFE) is carried to protect aircrew. This may include the extent of TCAS provision or non-standard cockpit equipment.

B7 Route selection

Do routes flown avoid significant hazards or does route selection make unusual efforts to avoid hazards?

Some routes may be found to be safer than others on account of airspace control and airport facilities. There may also be natural phenomena such as adverse weather or treacherous terrain to consider. Airlines should be asked whether routes are selected entirely by market forces or are airfield facility limitations considered (such as approach aids, level of RFFS cover etc.)? Are destinations used on the unofficial IFA PA blacklist and if so are there any operating restrictions? Evidence to come from expert witnesses at respective airlines and from airport operating authorities.
B8 Management priorities

Does management have a particularly safety-orientated approach to operations?
Do economic forces make this significantly easier?

Whilst a good safety record has long term benefits to an airline, the negative nature of reporting means that, in accounting terms, the short term returns of safety investment are negligible. It is necessary therefore to examine to what degree safety is deemed a priority against the pressures of economics. This needs the help of airline staff and expenditure figures from annual reports.

Group Three; Air Traffic Control

C1 ATC system reliability

Is the air traffic control system significantly better at preventing collisions?

The air traffic control system is responsible for ensuring safe separation for all aircraft within its control area. Its ability to do so is a function of its staff and equipment against traffic density. Failures of separation resulting in potential collision pairs will be reported as near-miss incidents. Data in this area is also available through the ongoing assessment of the airspace control system as being undertaken by VRJ Risk Engineers under contract to the CAA. Access has already been granted to the data.

C2 ATC / crew interaction / relations

Is there an above average interaction between ATC and pilots. Has this had a significant effect on ATC related incident rates?

The pilot and air traffic controller are extended components of each others crews and so effective and efficient interaction is vital. The use of standard phraseology is important as is a trust of each others ability to do the job properly. Obviously this may be quite different for international flights and so complaints by aircrew should be noted. Evidence from incident record and crew survey.

C3 Traffic density

Is traffic density directly proportional to collision risk?

There is a perceived notion that traffic density has a direct effect on accident rates. While a low traffic density can dilute the apparent accident rate of a country, the incidence of mid-air collision is a relatively low primary cause of civil aircraft losses. Near miss reporting should
reveal the frequency of such events and this should be compared to other systems of similar traffic density and ATC provision around the world.

D1 Integrity of runway and surrounds

Do Australian Airports offer a significantly high provision for the safe operation of aircraft?

Historical accident rates show that the majority of accidents occur within 3 km of the runway. This being the critical phase of flight when workload is greatest and the aircraft is aerodynamically inefficient, it is important that the airport facilities provide a safe environment for landing. The minimum length of runway, stopways and clearways are defined by ICAO but a decision to exceed these minima may be critical. The incident record and airport dimensions will indicate the magnitude of this margin of safety. Such factual data will come from ICAO annex documents and airport operators.

D2 Airport crash, fire and rescue services

Is rescue and fire fighting provision significantly above ICAO minima and has this had a major effect on the scale of incidents in Australia?

The provision of RFFS cover is guided by ICAO minima for extinguishing agent and vehicles. This provision may make the difference between lives lost or not. Do exceedances of minimum cover represent a CAA safety culture and have they prevented serious incidents becoming accidents? Data from ICAO annex documents and CAA RFFS’s archives.

D3 Integrity of security

Is the margin between security threat and provision significantly greater in Australia?

Whilst hijacking and terrorism are generally outside the remit of air safety research, it is recognised that such events have an effect on the public’s perception of safety. What is the resource allocated to security against the perceived threat. How much do politics account for the level of security breaches? Factual data from FAC, political effect from expert witnesses and secondary research.

Group Five; Weather (Data)

E1 Weather information availability & accuracy

Is the provision of weather data significantly more accurate than other similar countries? If so, why?

What weather information is available to aircraft and how up to date is it. Whose responsibility
is its provision and what is the cost and to whom. The prediction of hazardous conditions such as windshear, microburst and icing can have an important external effect on the safety of aircraft operations. Data from Bureau of Meteorology.

**E2 Aircraft type problems (re weather)**

Are the aircraft flown in Australia affected by severe weather problems?

Certain aircraft types are known to have problems with extreme weather conditions. Do these types fly within Australia and if so are there any particular operating restrictions placed upon them? Data from accident record and airline expert witnesses.

**E3 Incidence of hazardous weather conditions**

Are weather conditions in Australia more conducive to safe flying?

Weather conditions such as windshear and microburst have been recognised as the primary cause of a number of accidents around the world, especially in North America. Is the incidence of these phenomena relative to the accident record or do the accident rates reflect differing ways of flying through or around hazardous weather? Data from Bureau of meteorology, NASA, FAA secondary research projects. Confirmation through pilot survey.

**E4 Minimum acceptable flying conditions**

Is the margin of safety for minimum safe flying weather significantly wider than average?

There are certain weather conditions that certain pilots would choose not to attempt to fly through. The factors which influence this decision making process should be examined to test whether individual risk perception or company explicit or implicit policy dictate the decision to fly. Evidence from expert witnesses and through crew survey.

**E5 Effect of relief**

Does physical geography have an effect on flying safety in terms of weather phenomena or ease of approach paths?

Are weather patterns and types affected by relief and if so, does the physical geography around Australian airports make them more or less likely to experience hazardous weather phenomena? Further, does the ground level above sea height have an effect on cruising altitudes that make an aircraft more or less likely to encounter hazardous weather conditions? Data from Bureau of Meteorology, NASA, FAA secondary research projects.
Group Six; Design / Performance

F1 Aircraft performance limitations

Is there a greater than average margin of safety between airline specified performance limitations and those specified by the manufacturer?

Are aircraft flown to the same performance limitations as those recommended by the manufacturer? Data from airline expert witnesses and manufacturers.

F2 Emergency equipment

Do Australian aircraft carry a significantly different emergency equipment provision in its aircraft?

In the event of an emergency or precautionary evacuation, has the emergency equipment carried on the aircraft made a difference to the outcome of an incident and if so was this equipment in excess of the manufacturer’s standard.

F3 Unforeseen aircraft type deficiencies

Has aircraft selection policy had an unforeseen effect on safety?

Aircraft are selected by an airline on the basis of criteria such as range, payload, fuel consumption and price. Orders are often placed before a particular model is actually manufactured on the grounds of past experience and paper specifications. The accident record shows that some accidents have occurred due to deficiencies in aircraft types that were unforeseen at the time of order and hence out of the control of anyone other than the manufacturer. Examples include the Comet I metal fatigue accidents and the DC-10 rear hold door accidents. Although beyond the control of an airline, its selection policy may explain a part of its accident record in such circumstances. Data from accident record and Boeing.

Group Seven; Maintenance

G1 Airline’s maintenance / inspection action

Is airline maintenance / inspection significantly greater than average?

Although maintenance related primary cause accidents are a relatively low 3% of all accidents, maintenance tends to be a very frequent causal factor. Many ‘crew caused’ accidents are the result of bad handling of a technical defect and so by reducing the frequency of defects, the accident rate may be reduced. Maintenance excellence will be measured in MTBF, on-line failure rates and the second hand market for aircraft and engines. Data from airlines.
G2 Regulated maintenance / inspection

Is there a legal requirement for higher maintenance / inspection frequencies?

The frequency of maintenance checks and licensing of engineers is an indicator of the regulator's safety culture. Data from regulator expert witnesses.

Group Eight; Regulation

H1 Power of regulator

Is the regulator more effectively empowered than equivalent bodies in other countries?

The relationship between regulator and the regulated party is an important one that is established in the political powers that the regulator is given. This will set the tone of regulation a some point between policeman and advisor. The true measure of this position is, again, perception. Survey of crew and expert witnesses inside and outside of the regulator.

H2 Regulator's priorities

Is the regulator excessively orientated towards certain priorities?

A development of category H1, requiring expert opinion on the issues that take up the regulator's resources such as GA safety, RPT safety or cost recovery. It may be influenced to a greater or lesser degree by the corporate personality. Survey of crew and expert witnesses within and outside of the regulator.

H3 Response to occurrences

Is the response to occurrences significantly different to other comparable agencies?

To what extend can and do the industry's governors investigate and action against breaches or deficiencies in operating practices? What factors control the level of investigation and action (politics, cost recovery etc.)? Expert witnesses and legislative documentation.

Group Nine; Cultural Influences

H1 Level of acceptable risk

Does Australia have a significantly low acceptability of risk? Does it vary and if so what are the groupings?
Each person perceives a different level of acceptable risk based on knowledge and experience. As has been indicated in a number of other categories, it is this risk perception that will ultimately affect the decision making process. Do Australians or workers in the aviation industry or aircrew have different risk perceptions or levels of acceptable risk that craft their decision making to be more or less cautious in safety critical issues? Evidence from secondary research of accident rates within other disciplines and crew survey.

12 Level of risk exposure

Does Australia have a significantly low risk exposure? Does it vary and if so what are the groupings?

Risk exposure is a function of natural risk such as weather and terrain against the acceptable risk defined in societal norms. If the level of acceptable risk is less than the risk exposure then the risk should either be avoided or measures introduced to reduce the exposure level. If the level of acceptable risk exceeds the actual level of risk exposure then a margin of safety is created. Evidence from secondary research of risk exposure within other disciplines and countries. Case study evidence from other aspects of this project.

13 Political influence

Does the political attitude towards aviation have a significant effect on safety?

Aviation is a high profile, capital intensive form of transportation and hence attracts a great deal of political attention. As well as affecting resource allocation, this may also affect the standards demanded of the industry. This may also include social requirements for procedures such as noise abatement or movement restrictions and the effect this has on air traffic control and operations. Expert witnesses from all side of the aviation industry.
Appendix 3.2.2 Measures of Airline Safety According to Grose (1988)

**Personnel** (as transportation facilitators)
- Training - pilots, flight attendants, ATC controllers, aircraft and airport maintenance personnel, ticketing agents and security force
- Capability - intellectual, physical
- Currency in aircraft type
- Physical condition - general, during duty hours
- Incapacitation - drugs, personal turmoil, pain, aging
- Preoccupation - sexual, labour relations, boredom, "on-time-itis"
- Compatibility - within crew, crew-to-external parties
- Communication - language comprehension, s/n ratio
- Value hierarchy - prejudice, bias, chauvinism
- Follore - windshear, terrorism, chavinism
- Operational diversity for same function - airline-to-airline
- Requirements - education, experience, skill development
- IFR vs VFR - watching for other traffic, under-qualification
- Dependence on automation - lapse in fundamentals, low challenge
- Physiological factors - jet lag, biorythms, eyesight distancing
- Frustration relief - cancel warning devices, pout, be aggressive
- Scheduling - FARs omission of human behaviour factors
- Experience retention - study of past accidents for human error
- Unionization - scab-union hostility during strikes

**Aircraft** (as transportation vehicle)
- Thrust-to-weight ratio
- Initial cost
- Hull insurance
- Reliability
- Engine noise
- Passenger, freight and fuel capacity
- Fuel efficiency
- Operational costs
- Pilot response
- Degree of flight automation
- Maintenance
- Crashworthiness
- Range
- Variety of types (e.g. general vs air carrier)
- Operational procedures - checklists, manual-to-automated ratio
- Emergency evacuation potential
- Model-to-model-within-type possibility for confusion
- FOD (foreign object damage) criticality

**Airports** (as access/egress points for transportation)
- Location
- Weather characteristics - ground fog, windshear
- Flight approach / departure obstacles
- Gate access, location and quantity
- Proximity to mass population
- Security provisions
- Aircraft support facilities (fueling, deicing, repair)
- Baggage handling capability
- Management
- Noise abatement requirements
- Approach / departure flight control
- Runway number, condition, direction, width and length
- Competition from other airports - airborne traffic, airline volume
- Ground transportation capacity and frequency
- Emergency response capability
- General aviation traffic density
- Aircraft traffic mixture characteristics
- Government (local, state, Federal) controls
- Neighbouring airport similarities - confusion for approach
- Landing aids
- Bird and wildlife population
- Aircraft handling equipment
- Flight density and scheduling
- Runway overrun distance
- Passenger-to-aircraft distance
- Airport-to-airport traffic interference

**Airspace** (as medium through which passengers are transported)
Contaminants - volcanic ash, fowl, hail, precipitation
Weather phenomena - lightning, hurricane, tornado, thermals, wind
Air traffic separation
Magnetic anomalies
Cosmic radiation
Time-zone traversal
Icing levels
National and restricted airspace
Positive air traffic control zones
"See and avoid" concept

Airlines (as corporate entities that enable air commerce)
Management comprehension of operational factors
Value hierarchy - profit vs safety
Operational comprehension of profit factors
Fare wars - number of options, restrictions
Route competition / selection
Greenmail influence
Merger / takeover activity
Operational costs - labour, fuel, capital investment, food
Integration of merged airlines - operational differences
Frequent flyer programs / benefits
Published schedule credibility - on-time depart / arrive
Airborne security - terrorism control procedures
Trade association influence - ATA, ALPA, AOPA, IAFA
Classes of flight service - number, seating, fares, distribution
Scheduling of flights - time of day, frequency-per-city

Aviation (as technological community that supports transportation)
International competition - aircraft, avionics
Technology transfer from military programs - SOA advancement
Folklore / traditions - checklists, cockpit layout / visibility
Flight automation technology
Collision avoidance concepts / equipment

Government (as public advocates for safe transportation)
FAA - regulations, advisories, approvals

Congressional oversight - technical competence
DOT control of FAA - management conflict
NAS Plan - funding, implementation, priorities
Air traffic controllers - competence, labour strife, drug abuse
Pork barrel factors - airport location, routing demands
NTSB - objectivity, credibility of recommendations, influence
Source of pilots - military service background, RHIP
Safety surveillance - techniques, frequency, sanctions
Regulation / deregulation / regulation factors

Public (as influence - via government - on all other elements)
News media coverage of accidents
Litigious attitude
Explosive attorneys
Demand for rapid transportation over great distances
Increasing acceptance of air travel

Passengers (as transportation system throughput)
Fear of flying
Demand for services / amenities
Desire for low fares
Lack of concern for safety procedures
Handicapped rights - seating, briefing, role in evacuation
Diversity of age, agility, intelligence, size, weight, attitude
Terrorists - detectibility, cabin reaction
Alcohol consumption - onboard drunkenness, hostility
Smoking vs nonsmoking issue
Language / cultural variety - understanding briefings
Impatience for accompanying baggage - carry on vs checked luggage
Personal hygiene - washroom habits
Folklore - seating-for-survival, getting extra alcoholic drinks
Appendix 3.4 Sampling Frame

The questionnaire responses represented the following demographics:

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<th>Airline</th>
<th>Captain</th>
<th>First Officer</th>
<th>Second Officer</th>
<th>Flight Eng.</th>
<th>Nav.</th>
<th>Flight Steward</th>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>139</td>
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<td>0</td>
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<td>0</td>
<td>17</td>
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<td>ESO</td>
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<td>Training Officer</td>
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<td>Other</td>
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<td>Other</td>
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Appendix 3.4.2 Crew Perceptions Questionnaires

The following pages contain the six versions of the questionnaire used during this research.
In October 1993, we initiated a research project to examine the way that airlines in Australia have managed to 'stay safe'. No passenger has ever been killed in a commercial jet transport in Australia and with your help, we hope to discover why, so that we can keep it that way and the rest of the world can learn from our experience.

We would very much appreciate your co-operation in filling out this brief questionnaire and returning it to your club President as soon as possible. Please do not put your name on the paper as it is designed to be anonymous. If you have any extra comments or want to know more about this project then please call Graham on (03) 660 5512 and questions will be answered in total confidence. If you are unable to answer a question then please leave it blank.

Thank you for your time.

Graham Braithwaite
Rotary District 1190 Foundation Ambassadorial Scholar
Loughborough University / R.M.I.T.
Section One: (Test Sample).

1.1 What is your area of employment?

1. Aviation 1
2. Other Transport Modes 2
3. Management (other than in transport) 3
4. Manual Labour (other than in transport) 4
5. Other 5

1.2 What is your age group?

1. Under 30 1
2. 30-39 2
3. 40-49 3
4. 50+ 4

1.3 In which country did you complete the majority of your education?

1. Australia. 1
2. United States Of America. 2
3. United Kingdom. 3
4. Canada. 4
5. Other (please state).

1.4 Which of the following statements best matches your use of airlines?

1. I use air travel only for business purposes. 1
2. I use air travel mainly for business purposes. 2
3. I use air travel equally for business and leisure purposes. 3
4. I use air travel mainly for leisure purposes. 4
5. I use air travel only for leisure purposes. 5
6. I do not use air travel. 6

Section Two

2.1 Suppose you are to make a business journey to Sydney;

a) Which transport mode would you most likely use? (Circle One)

1. Private car 1
2. Scheduled Airline 2
3. Countrylink XPT (express train) 3
4. Coach 4
5. Other 5

If not "scheduled airline", why not?
b) What are the factors you would consider in choosing a mode of transport? Please rank your top THREE factors, numbering 1 for the most important.

1. Speed
2. Price
3. Comfort
4. Service frequency
5. Punctuality
6. Safety record
7. Facilities (e.g. food)
8. Other (please specify)

Section Three (Air Travel).

3.1. In choosing an international airline, what are the factors you would consider in making that choice? Please rank your top THREE factors, numbering 1 for the most important.

1. Service
2. Price
3. Schedule
4. Terminal Facilities
5. Frequent Flyer / Executive Club Membership
6. Punctuality
7. Safety record
8. Aircraft type / age
9. Cabin amenities
10. Other (please state)

3.2 Over the last five years, do you think Australian scheduled airlines (i.e. Qantas, Ansett and Australian) have become...? (Please circle one)

1. More safe.
2. Remained about the same.
3. Less safe.
4. Don’t know

3.3 In your own words, please tell us how you think Australia has managed to attain the record of zero fatalities for jet airliner operations;
Section Four (Risk).

The objective of this section is to help us develop an understanding of differences in risk perception and acceptability of different cultures. It is designed to help us explore what is special about Australia.

4.1 For the following activities, we would like you to mark how risky you consider each one would be to you personally if you participated.

For each activity, please circle between 1 (Not at all Risky) and 5 (Highly Risky).

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4.2 To what degree do the following factors affect your willingness to accept particular risks?

For each activity, please circle between 1 (No Effect) and 5 (Major Effect).

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This is the end of the survey. Thank you for your help!
In October 1993, we initiated a research project to examine why airlines in Australia apparently have such good safety records. With your help, we hope to discover why this is. The study will hopefully provide information that will be of benefit to the aviation industry worldwide.

We would very much appreciate your co-operation in filling out this questionnaire and returning it to **Flight Operations by August 14th**. Please do not put your name on the paper as it is designed to be anonymous. If you have any extra comments or want to know more about this project then please write to Graham Braithwaite, Dept. AAEIS, L.U.T, Loughborough, Leics LE11 3TU, England and questions will be answered in total confidence by return of post. If you are unable to answer a question then please leave it blank.

Thank you for your time.

Graham Braithwaite

There are two types of question: some where you will be asked to write in the answer and others where you may simply circle the answer. In the case of multiple choice type questions, please put your answer in the column at the right hand side:

For example.

0. Who makes the "A300 Aircraft"?


The answer was '2' - Airbus, so number 2 was circled on the right hand side.
1.1 What is your current job title?
1. Captain
2. First Officer
3. Second Officer
4. Flight Engineer

1.2 Do you hold any one of the following positions?
1. Management pilot
2. Check / training pilot
3. Line pilot

1.3 What type of aircraft do you currently fly?
1. Airbus A300
2. British Aerospace 146
3. Boeing 737
4. Boeing 747 Classic & SP
5. Boeing 747-400
6. Boeing 767

1.4 How long have you held your current rank?
1. Up to two years.
2. From two to five years.
3. From five to ten years.
4. Over ten years.

1.5 What is your age group?
1. Under 30
2. 30-39
3. 40-49
4. 50+

1.6 In which country did you complete the majority of your education?
1. Australia.
2. United States Of America.
3. United Kingdom.
4. Canada.
5. Other (please state).

1.7 How did you learn to fly?
1. Private flying school (own expense)
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3. Airline cadet programme (Australia)
4. Airline course (Overseas)
5. Military.
6. Other.
Section Two (Your occupation)

2.1 Which one of the following statements best matches your perception of the job of Captain?

1. The Captain is in charge and knows best in all situations
2. The Captain is the most experienced and skilled member of the flight crew.
3. The Captain is the manager of a team called "the flight crew".
4. The Captain is one component of a team called "the flight crew".
5. None of these statements is a fair assessment.

(Please circle one)

2.2 Which one of the following is the single most important thing about your job?

1. I get the remuneration that I deserve.
2. I am doing the job I really want to do.
3. I feel a sense of achievement at reaching the top of my profession.
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5. Other (Please state: )

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2.3 Which one of the following statements best matches your perception of flight attendants?

1. They are an integral part of the crew at all times.
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4. They are there to tend to the passengers' needs and requests.
5. They are waiters/waitresses in the sky.

(Please circle one)

2.4 Using THREE words of your own choice, please describe the majority of...

a) Superior Crew Members.
   1. ___________________ 2. ___________________ 3. ___________________

b) Subordinate Crew Members.
   1. ___________________ 2. ___________________ 3. ___________________

c) Managers.
   1. ___________________ 2. ___________________ 3. ___________________

d) Yourself.
   1. ___________________ 2. ___________________ 3. ___________________

2.5 Are there crew members you would prefer not to fly with?

1. "Yes"
2. "No"
3. "Don't Know"

(Please circle one)

If your answer is "yes", approximately how many?
2.6 Are there crew members you consider it unsafe to fly with?

1. "Yes"
2. "No"
3. "Don't Know"

If your answer is "yes":

a) approximately how many?
   b) Have you done anything about it?

1. "Yes"
2. "No"

2.7 Have you ever flown for this airline suffering from fatigue?

1. Never
2. Very Occasionally
3. Sometimes
4. Fairly Often
5. Often

2.8 Have you ever flown for this airline when you were medically unfit?

1. Never
2. Very Occasionally
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2.9 Which one of the following statements best describes your opinion of 'go-arounds'...?

1. I would consider I had made a serious error if I had to execute a go-around.
2. I would consider it to be an exceptional event if I had to execute a go-around.
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2.10 If you were the flying pilot and one of the flight crew called for a go-around during final approach, which of the following statements best describes your actions...?

1. I would ignore the call as I am flying pilot.
2. I would ignore the call unless it came from a senior officer.
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1. I would take off because my aircraft is equipped for all conditions.
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2.12 A senior manager introduces a new company rule you consider to be unsafe, which of the following statements best describes your actions?

1. I would simply ignore the new rule; its my life.
2. I would complain about the rule to my colleagues.
3. I would complain about the rule to my union representative.
4. I would complain about the rule to my fleet manager.
5. I would complain directly to the manager responsible for the rule.

2.13 Do you consider internal communications in Flight Operations to be....?

1. Excellent.
2. Quite good.
3. Acceptable.
4. Poor.
5. Very poor.

2.14 Do you consider internal communications in the rest of Qantas to be....?

1. Excellent.
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3. Acceptable.
4. Poor.
5. Very poor.

Section Three. (Safety).

3.1 Please rank the TOP THREE factors you consider pose the greatest threat to your flying safety? (With "1" representing the factor that concerns you most.)

a. Engine failure.
b. Snow / ice accumulation.
c. Windshear / microburst.
d. Weather (other than 'b' or 'c'.)
e. Judgment error (self).
f. Judgment error (others).
g. Mid-air collision.
h. Maintenance related failure (other than 'a')
i. Controlled Flight Into Terrain.
j. Security breach.
k. Runway incursion.
l. Management error.
m. Inappropriate regulations.
n. Other (Please specify)
3.2 How confident are you of not being involved in a flying accident? (Please circle one)
1. Very confident
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4. A little nervous
5. Very nervous

3.3 How confident are you that your crew will perform properly in the event of an abnormal situation?
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3.4 How confident are you that management in general will reduce your possibility of having a flying accident to the absolute minimum?
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3.5 Over the last five years, do you think Australian civil aviation in general has become...?
1. More safe.
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3.6 Over the last five years, do you think your airline has become...?
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3.7 In your own words, please tell us how you think Australia has managed to attain the record of zero hull losses for jet RPT operations;
3.8 Which of the following factors do you consider have been highly significant in Australia's safety record for commercial RPT jets?

1. Aircraft types flown. 1
2. Low incidence of snow / ice. 2
3. Low incidence of windshear / microburst. 3
4. Flight crew experience. 4
5. Flight crew training. 5
6. Ease of interaction between crews. 6
7. Maintenance integrity. 7
8. Relatively flat terrain. 8
9. Integrity of security. 9
10. Integrity of airport facilities. 10
11. Management commitment to safety. 11
12. Appropriate regulation by the CAA. 12
13. Availability of flying aids (e.g. GPWS, TCAS etc.) 13
14. Air traffic control. 14
15. Low traffic density. 15
16. Luck. 16
17. Other (Please Specify) ____________________________

(Circle as many as relevant)

3.9 In your own words, what do you consider will pose the greatest threat to the safety of RPT carriers in Australia in the future?

________________________________________________________________________
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________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
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Section Four (Risk).

The objective of this section is to help us develop an understanding of differences in risk perceptions of air crew compared to the general public. It is designed to help us explore what is special about flight crews.

4.1 For the following activities, we would like you to mark how risky you consider each one would be to you personally if you participated.

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Loughborough University of Technology and
Royal Melbourne Institute of Technology.

Aviation Safety Research Project.

Ansett Australian Aircrew Perceptions Study 1995.

In October 1993, we initiated a research project to examine the way that airlines in Australia have managed to "stay safe". No passenger has ever been killed in a commercial jet transport in Australia and with your help, we hope to discover why, so that we can keep it that way and the rest of the world can learn from our experience.

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There are two types of question: some where you will be asked to write in the answer and others where you may simply circle the answer. In the case of multiple choice type questions, please put your answer in the column at the right hand side:

For example.

0.0 Who makes the "Skystar A320 Aircraft"?


The answer was '2' - Airbus, so number 2 was circled on the right hand side.
1.1 What is your current job title?
1. Captain
2. First Officer
3. Second Officer
4. Flight Engineer

1.2 Do you hold any one of the following positions?
1. Management Pilot
2. Check / training pilot
3. Line pilot

1.3 What type of aircraft are you currently certified to fly?
1. Airbus A320 Skystar
2. British Aerospace 146
3. Boeing 727
4. Boeing 737
5. Boeing 747
6. Boeing 767
7. Fokker F28

1.4 How long have you held your current rank?
1. Up to two years.
2. From two to five years.
3. From five to ten years.
4. Over ten years.

1.5 What is your age group?
1. Under 30
2. 30-39
3. 40-49
4. 50+

1.6 In which country did you complete the majority of your education?
1. Australia.
2. United States Of America.
3. United Kingdom.
4. Canada.
5. Other (please state).

1.7 How did you learn to fly?
1. Private flying school (own expense)
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2.4 Using THREE words of your own choice, please describe the majority of...

a) Superior Crew Members.
   1. ____________ 2. ____________ 3. ____________

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2.5 Are there crew members you would prefer not to fly with?

1. "Yes"
2. "No"
3. "Don't Know"

If your answer is "yes", approximately how many?

(Please circle one)
2.6 Are there crew members you consider it unsafe to fly with?

1. "Yes"
2. "No"
3. "Don't Know"

If your answer is "yes":

a) approximately how many?
b) Have you done anything about it?

1. "Yes"
2. "No"

2.7 How often do you feel your ability to perform has been impaired by tiredness?

1. Never
2. Very Occasionally
3. Sometimes
4. Fairly Often
5. Often

2.8 Have you ever flown for this airline when you were medically unfit?

1. Never
2. Very Occasionally
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2.9 Which one of the following statements best describes your opinion of 'go-arounds'...

1. I would consider I had made a serious error if I had to execute a go-around.
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2.13 Do you consider internal communications within Ansett to be...

1. Excellent.  
2. Quite good.  
3. Acceptable.  
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Section Three. (Safety).

3.1 Please rank the TOP THREE factors you consider pose the greatest threat to your flying safety? (With "1" representing the factor that concerns you most.)

a. Engine failure.  
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3.4 How confident are you that management will reduce your possibility of having a flying accident to the absolute minimum?

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(Circle as many as relevant)

1. Aircraft types flown.
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14. Air traffic control.
15. Low traffic density.
16. Luck.
17. Other (Please Specify)

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4.2 To what degree do the following factors affect your willingness to accept particular risks?

For each activity, please circle between 1 (No Effect) and 5 (Major Effect).

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This is the end of the survey. Thank you for your help!
Loughborough University of Technology and
Royal Melbourne Institute of Technology.

Aviation Safety Research Project.


In October 1993, we initiated a research project to examine the way that airlines in Australia have managed to "stay safe". No passenger has ever been killed in a commercial jet transport in Australia and with your help, we hope to discover why, so that we can keep it that way and the rest of the world can learn from our experience.

We would very much appreciate your co-operation in filling out this questionnaire and returning it to The Directorate of Flying Safety by July 14th. Please do not put your name on the paper as it is designed to be anonymous. If you have any extra comments or want to know more about this project then please call Graham on (03) 9660 5512 and questions will be answered in total confidence. If you are unable to answer a question then please leave it blank.

Thank you for your time.

Graham Braithwaite

There are two types of question: some where you will be asked to write in the answer and others where you may simply circle the answer. In the case of multiple choice type questions, please put your answer in the column at the right hand side:

For example.

0.0 Who makes the "PC-3 Orion Aircraft"?


The answer was '2' - Lockheed, so number 2 was circled on the right hand side.
1.1 What is your current job title?

1. Captain
2. Co-pilot
3. Navigator
4. Flight Engineer
5. Load Master
6. Flight Steward

1.2 Do you hold any one of the following positions?

1. Flying Executive
2. Check / training crew
3. Line crew member

1.3 What type of aircraft are you currently certified to fly?

1. Boeing 707.
2. DHC Caribou.
3. HS 748.
4. Lockheed P-3C Orion.
5. Lockheed C130 Hercules.
6. Dassault Falcon 900.

1.4 How long have you held your current rank?

1. Up to two years.
2. From two to five years.
3. From five to ten years.
4. Over ten years.

1.5 What is your age group?

1. Under 30
2. 30-39
3. 40-49
4. 50+

1.6 In which country did you complete the majority of your education?

1. Australia.
2. United States Of America.
3. United Kingdom.
4. Canada.
5. Other (please state).
Section Two (Your occupation)

2.1 Which one of the following statements best matches your perception of the job of Captain?

1. The Captain is in charge and knows best in all situations 1
2. The Captain is the most experienced and skilled member of the flight crew. 2
3. The Captain is the manager of a team called "the flight crew". 3
4. The Captain is one component of a team called "the flight crew" 4
5. None of these statements is a fair assessment. 5

2.2 Which one of the following is the single most important thing about your job?

1. I get the remuneration that I deserve. 1
2. I am doing the job I really want to do. 2
3. I feel a sense of achievement at reaching the top of my profession 3
4. I am able to fly state of the art equipment. 4
5. Other (Please state:) 5

2.3 Using THREE words of your own choice, please describe the majority of...

a) Aircraft Captains. 1.__________ 2.__________ 3.__________

b) Other Crew Members. 1.__________ 2.__________ 3.__________

c) Flying Executives. 1.__________ 2.__________ 3.__________

d) Yourself. 1.__________ 2.__________ 3.__________

2.4 Are there crew members you would prefer not to fly with?

1. "Yes" 1
2. "No" 2
3. "Don't Know" 3

If your answer is "yes", approximately how many?
2.5 Are there crew members you consider it unsafe to fly with?

1. "Yes"
2. "No"
3. "Don't Know"

If your answer is "yes":

a) approximately how many?
b) Have you done anything about it?

1. "Yes"
2. "No"

2.6 Have you ever flown for the RAAF suffering from fatigue?

1. Never
2. Very Occasionally
3. Sometimes
4. Fairly Often
5. Often

2.7 Have you ever flown for the RAAF when you were medically unfit?

1. Never
2. Very Occasionally
3. Sometimes
4. Fairly Often
5. Often

2.8 Which one of the following statements best describes your opinion of 'go-arounds'...?

1. I would consider I had made a serious error if I had to execute a go-around.
2. I would consider it to be an exceptional event if I had to execute a go-around.
3. I would consider making a go-around as an option in every landing.
4. I would have no problems with executing a go-around if I felt it necessary.
5. None of these statements is a fair assessment.

2.9 If you were the flying pilot and one of the flight crew called for a go-around during final approach, which of the following statements best describes your actions...?

1. I would ignore the call as I am flying pilot.
2. I would ignore the call unless it came from a senior officer.
3. I would inquire as to the reason for the call.
4. I would ask for confirmation and then execute a go-around.
5. I would execute an immediate go around.
2.10 You are ready for departure, but the weather is getting steadily worse. Which of the following statements best describes your thoughts...?

1. I would take off because my aircraft is equipped for all conditions.
2. I would take-off to increase my experience of adverse conditions.
3. I would feel obliged to take-off to complete my sortie / mission.
4. I would take-off if the rest of the crew were encouraging me to do so.
5. I would take-off only if both my colleagues and I were completely confident.

2.11 A senior officer introduces a new operating rule you consider to be unsafe, which of the following statements best describes your actions?

1. I would simply ignore the new rule; its my life.
2. I would complain about the rule to my colleagues.
3. I would complain about the rule to my Wing Commander.
4. I would complain directly to the officer responsible for the rule.
5. I would obey the rule as it is my job to obey the rules.

2.12 Do you consider internal communications within the RAAF to be....?

1. Excellent.
2. Quite good.
3. Acceptable.
4. Poor.
5. Very poor.

Section Three. (Safety).

3.1 Please rank the TOP THREE factors you consider pose the greatest threat to your flying safety? (With "1" representing the factor that concerns you most.)

a. Engine failure.
b. Snow / ice accumulation.
c. Windshear / microburst.
d. Weather (other than 'b' or 'c').
e. Judgment error (self).
f. Judgment error (others).
g. Mid-air collision.
h. Maintenance related failure (other than 'a')
i. Controlled Flight Into Terrain.
j. Security breach.
k. Runway incursion.
l. Management error.
m. Inappropriate regulations.
o. Other (Please specify)
3.2 How confident are you of not being involved in a flying accident?

1. Very confident 1
2. Fairly confident 2
3. Mixed feelings 3
4. A little nervous 4
5. Very nervous 5

3.3 How confident are you that your crew will perform properly in the event of an abnormal situation?

1. Very confident 1
2. Fairly confident 2
3. Mixed feelings 3
4. A little nervous 4
5. Very nervous 5

3.4 How confident are you that management will reduce your possibility of having a flying accident to the absolute minimum?

1. Very confident 1
2. Fairly confident 2
3. Mixed feelings 3
4. A little nervous 4
5. Very nervous 5

3.5 Over the last five years, do you think Australian civil aviation in general has become...?

1. More safe. 1
2. Remained about the same. 2
3. Less safe. 3
4. Don't know 4

3.6 Over the last five years, do you think the RAAF has become...?

1. More safe. 1
2. Remained about the same. 2
3. Less safe. 3
4. Don't know 4

3.7 In your own words, please tell us how you think Australia has managed to attain the record of zero hull losses for jet RPT operations;
Which of the following factors do you consider have been highly significant in Australia's safety record for commercial RPT jets?

1. Aircraft types flown.
2. Low incidence of snow / ice.
3. Low incidence of windshear / microburst.
4. Flight crew experience.
5. Flight crew training.
6. Ease of interaction between crews.
7. Maintenance integrity.
8. Relatively flat terrain.
9. Integrity of security.
10. Integrity of airport facilities.
11. Management commitment to safety.
12. Appropriate regulation by the CAA.
13. Availability of flying aids (e.g. GPWS, TCAS etc.)
14. Air traffic control.
15. Low traffic density.
16. Luck.
17. Other (Please Specify)

In your own words, what do you consider will pose the greatest threat to the safety of RPT carriers in Australia in the future?
Section Four (Risk).

The objective of this section is to help us develop an understanding of differences in risk perceptions of air crew compared to the general public. It is designed to help us explore what is special about flight crews.

4.1 For the following activities, we would like you to mark how risky you consider each one would be to you personally if you participated.

For each activity, please circle between 1 (Not at all Risky) and 5 (Highly Risky).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Not at all Risky</th>
<th>Highly Risky</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Motorcycle riding</td>
<td>1</td>
<td>2 3 4 5</td>
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<tr>
<td>b. Car Travel (self driving)</td>
<td>1</td>
<td>2 3 4 5</td>
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<tr>
<td>c. Car Travel (other driving)</td>
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<tr>
<td>d. Flying as a passenger in a light aircraft</td>
<td>1</td>
<td>2 3 4 5</td>
</tr>
<tr>
<td>e. Flying as the solo pilot of a light aircraft</td>
<td>1</td>
<td>2 3 4 5</td>
</tr>
<tr>
<td>f. Flying as a passenger in an RAAF transport aircraft</td>
<td>1</td>
<td>2 3 4 5</td>
</tr>
<tr>
<td>g. Flying as the pilot of an RAAF transport aircraft</td>
<td>1</td>
<td>2 3 4 5</td>
</tr>
<tr>
<td>h. Cycling</td>
<td>1</td>
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4.2 To what degree do the following factors affect your willingness to accept particular risks?

For each activity, please circle between 1 (No Effect) and 5 (Major Effect).

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This is the end of the survey. Thank you for your help!
RAAF ATC Perceptions Study 1995.

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We would very much appreciate your co-operation in filling out this questionnaire and returning it to Your Commanding Officer by July 14th. Please do not put your name on the paper as it is designed to be anonymous. If you have any extra comments or want to know more about this project then please call Graham Braithwaite on (03) 9660 5512 and questions will be answered in total confidence. If you are unable to answer a question then please leave it blank.

Thank you for your time.

Graham Braithwaite
Loughborough University UK / R.M.I.T. Australia.

There are two types of question; some where you will be asked to write in the answer and others where you may simply circle the answer. In the case of multiple choice type questions, please put your answer in the column at the right hand side:

For example.

0.0 Who makes the "P3-C Orion Aircraft"?


The answer was '2' - Lockheed, so number 2 was circled on the right hand side.
### Section One. (Test Sample).

#### 1.1 What is your current job title?
1. SATCO
2. ESO
3. Tower / Approach Supervisor
4. Training Officer
5. ATCO

#### 1.2 What type of airfield are you working at?
1. Joint civil / military airfield
2. Military airfield

#### 1.3 What ratings do you currently hold?
1. Approach / Approach Coordinator
2. Tower
3. Both

#### 1.4 How long have you held your current rank?
1. Up to two years.
2. From two to five years.
3. From five to ten years.
4. Over ten years.

#### 1.5 What is your age group?
1. Under 30
2. 30-39
3. 40-49
4. 50+

#### 1.6 In which country did you complete the majority of your education?
1. Australia.
2. United States Of America.
3. United Kingdom.
4. Canada.
5. Other (please state).
Section Two (Your occupation)

2.1 Which one of the following statements best matches your perception of the job of ESO?

1. The ESO is in charge and knows best in all situations.
2. The ESO is the most experienced and skilled member of the section.
3. The ESO is the manager of the team called "the section".
4. The ESO is one component of a team called "the section".
5. None of these statements is a fair assessment.

(Please circle one)

1  2  3  4  5

2.2 Which one of the following is the single most important thing about your job?

1. I get the remuneration that I deserve.
2. I am doing the job I really want to do.
3. I feel a sense of achievement at reaching the top of my profession
4. I am able to use state of the art equipment.
5. Other (Please state:)

(Please circle one)

1  2  3  4  5

2.3 Using THREE words of your own choice, please describe the majority of...

a) Military Pilots.
   1.__________  2.__________  3.__________

b) Civil Pilots.
   1.__________  2.__________  3.__________

c) Senior Officers.
   1.__________  2.__________  3.__________

d) Junior Officers.
   1.__________  2.__________  3.__________

e) Yourself.
   1.__________  2.__________  3.__________

2.4 Are there controllers you would prefer not to work with?

1. "Yes"
2. "No"
3. "Don't Know"

(Please circle one)

1  2  3

If your answer is "yes", approximately how many?

_____
2.5 Are there controllers you consider it unsafe to work with? (Please circle one)

1. "Yes" 1
2. "No" 2
3. "Don't Know" 3

If your answer is "yes":

a) approximately how many?

b) Have you done anything about it?

1. "Yes" 1
2. "No" 2

2.6 Have you ever worked for the RAAF suffering from fatigue?

1. Never 1
2. Very Occasionally 2
3. Sometimes 3
4. Fairly Often 4
5. Often 5

2.7 Have you ever worked for the RAAF when you were medically unfit?

1. Never 1
2. Very Occasionally 2
3. Sometimes 3
4. Fairly Often 4
5. Often 5

2.8 If your supervisor / ESO gave you a control instruction you considered to be ill advised, which of the following statements best describes your actions...?

1. I would ignore the call as I am the active controller. 1
2. I would ignore the call unless it came from a senior ranking officer. 2
3. I would inquire as to the reason for the call. 3
4. I would ask for confirmation and then execute the instruction. 4
5. I would execute the instruction immediately. 5

2.9 You are on duty and become faced with an extremely busy situation. Which of the following statements best describes your thoughts...?

1. I would continue because my I am qualified for all traffic conditions. 1
2. I would continue so as to increase my experience of adverse conditions. 2
3. I would feel obliged to continue to complete my assigned task. 3
4. I would continue if the rest of the shift were encouraging me to do so. 4
5. I would have no hesitation in asking for assistance if I felt it was justified. 5
### 2.10 A senior officer introduces a new operating rule you consider to be unsafe, which of the following statements best describes your actions?

1. I would simply ignore the new rule; it's my life. 
2. I would complain about the rule to my colleagues. 
3. I would complain about the rule to my SATCO or higher. 
4. I would complain directly to the officer responsible for the rule. 
5. I would obey the rule as it is my job to obey the rules.

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### 2.11 Do you consider internal communications within the RAAF to be...?

1. Excellent.  
2. Quite good.  
3. Acceptable.  
4. Poor.  
5. Very poor.

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### Section Three. (Safety)

#### 3.1 Please rank the **TOP THREE** factors you consider pose the greatest threat to flying safety? (With "1" representing the factor that concerns you most.)

- Engine failure. 
- Snow / ice accumulation. 
- Windshear / microburst. 
- Weather (other than 'b' or 'c'). 
- Judgment error (self). 
- Judgment error (others). 
- Mid-air collision. 
- Maintenance related failure (other than 'a'). 
- Controlled Flight Into Terrain. 
- Security breach. 
- Runway incursion. 
- Management error. 
- Inappropriate regulations. 
- Acts of aggression. 
- Other (Please specify) ________________________________

#### 3.2 How confident are you of not being involved in an accident?

1. Very confident  
2. Fairly confident  
3. Mixed feelings  
4. A little nervous  
5. Very nervous

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3.3 How confident are you that your section will perform properly in the event of an abnormal situation?

1. Very confident 1
2. Fairly confident 2
3. Mixed feelings 3
4. A little nervous 4
5. Very nervous 5

3.4 How confident are you that management will reduce your possibility of being involved in an accident to the absolute minimum?

1. Very confident 1
2. Fairly confident 2
3. Mixed feelings 3
4. A little nervous 4
5. Very nervous 5

3.5 Over the last five years, do you think Australian civil aviation in general has become...?

1. More safe. 1
2. Remained about the same. 2
3. Less safe. 3
4. Don't know 4

3.6 Over the last five years, do you think the RAAF has become...?

1. More safe. 1
2. Remained about the same. 2
3. Less safe. 3
4. Don't know 4

3.7 In your own words, please tell us how you think Australia has managed to attain the record of zero hull losses for jet RPT operations;
3.8 Which of the following factors do you consider have been highly significant in Australia's safety record for passenger transport jets? (Circle as many as relevant)

1. Aircraft types flown. 1
2. Low incidence of snow / ice. 2
3. Low incidence of windshear / microburst. 3
4. Flight crew experience. 4
5. Flight crew training. 5
6. Ease of interaction between crews. 6
7. Maintenance integrity. 7
8. Relatively flat terrain. 8
9. Integrity of security. 9
10. Integrity of airport facilities. 10
11. Management commitment to safety. 11
12. Appropriate regulation by the CAA. 12
13. Availability of flying aids (e.g. GPWS, TCAS etc.) 13
14. Air traffic control. 14
15. Low traffic density. 15
16. Luck. 16
17. Other (Please Specify) ___________________________ 18

3.9 In your own words, what do you consider will pose the greatest threat to the safety of RAAF Transport / RPT carriers in Australia in the future?

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Section Four (Risk).

The objective of this section is to develop an understanding of differences in risk perceptions of air traffic controllers compared to the general public. It is designed to help us explore what is special about the aviation community.

4.1 For the following activities, we would like you to mark how risky you consider each one would be to you personally if you participated.

For each activity, please circle between 1 (Not at all Risky) and 5 (Highly Risky).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Not at all risky</th>
<th>Highly Risky</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Motorcycle riding</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>b. Car Travel (self driving)</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>c. Car Travel (other driving)</td>
<td>1 2 3 4 5</td>
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</tr>
<tr>
<td>d. Flying as a passenger in a light aircraft</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>e. Flying as the solo pilot of a light aircraft</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>f. Flying as a passenger in a commercial airliner</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>g. Flying as a passenger in an RAAF transport aircraft</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>h. Cycling</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>i. Smoking 20 cigarettes a day</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>j. Drinking 20 pots of medium strength beer a week</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>k. Smoking 'soft drugs' e.g. cannabis</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>l. Australian rules football / rugby league</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>m. Snow skiing</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>n. Rock climbing</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>o. Freefall skydiving</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

4.2 To what degree do the following factors affect your willingness to accept particular risks?

For each activity, please circle between 1 (No Effect) and 5 (Major Effect).

<table>
<thead>
<tr>
<th>Factor</th>
<th>No Effect</th>
<th>Major Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. How much you are paid to accept that risk.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>b. Whether the risk could incur a financial penalty to you.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>c. Whether the risk could involve some injury to you.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>d. Whether the risk could result in your death.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>e. Who else is also accepting that risk.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>f. Whether your risk taking increases the risk to your family.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>g. Whether your risk taking increases the risk to other people.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>h. How much you understand about the risks of an activity</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

This is the end of the survey. Thank you for your help!
Britannia Aircrew Perceptions Study 1995

In October 1993, Loughborough University began research to examine the way that various airlines manage to "stay safe". Australia and the UK have good records for airline safety and it is our aim to discover what are the positive contributing factors as well as highlighting some areas for improvement. The results will be used around the world and feedback is guaranteed for all that help us out.

We would very much appreciate your co-operation in filling out this questionnaire and returning it to the address on the last page by March 18th. Please do not put your name on the paper as it is designed to be anonymous. If you have any extra comments or want to know more about this project then please call Graham on (01509) 228159 and questions will be answered in total confidence. If you are unable to answer a question then please leave it blank.

Thank you for your time.

Graham Braithwaite
Loughborough University, U.K.

There are two types of question: some where you will be asked to write in the answer and others where you may simply circle the answer. In the case of multiple choice type questions, please put your answer in the column at the right hand side:

For example.

Who makes the 'A320' Aircraft?

1. Boeing;
2. Airbus;
3. Lockheed;
4. BAe;

(Please circle one)

The answer was '2' - Airbus, so number 2 was circled in the answer column.
Section One. (Test Sample).

1.1 What is your current job title?

1. Captain
2. First Officer

1.2 Do you hold any one of the following positions?

1. Management Pilot
2. Check / Training Pilot
3. Line crew member

1.3 How long have you held your current rank?

1. Up to two years.
2. From two to five years.
3. From five to ten years.
4. Over ten years.

1.4 Have you done the Integrated Crew Training Course?

1. Yes
2. No

1.5 What is your age group?

1. Under 30
2. 30-39
3. 40-49
4. 50+

1.6 In which country did you complete the majority of your education?

1. United Kingdom.
2. United States Of America.
3. Australia.
4. Canada.
5. Other (please state).

1.7 How did you learn to fly?

1. Private flying school (own expense)
2. Private flying school (scholarship)
3. Airline cadet programme (UK)
4. Airline course (Overseas)
5. Military.
6. Other.
Section Two (Your occupation)

2.1 Which **one** of the following statements best matches your perception of the job of Captain?

1. The Captain is in charge and knows best in all situations  
2. The Captain is the most experienced and skilled member of the flight crew.  
3. The Captain is the manager of a team called "the flight crew".  
4. The Captain is one component of a team called "the flight crew"  
5. None of these statements is a fair assessment.

(Please circle one)

2.2 Which **one** of the following is the single most important thing about your job?

1. I get the remuneration that I deserve.  
2. I am doing the job I really want to do.  
3. I feel a sense of achievement at reaching the top of my profession  
4. I am able to fly state of the art equipment.  
5. Other (Please state:)

2.3 Which **one** of the following statements best matches your perception of cabin crew?

1. They are an integral part of the crew at all times.  
2. They are a useful support in emergency situations.  
3. They can provide a support facility when asked to do so.  
4. They are there to tend to the passengers' needs and requests.  
5. They are waiters/waitresses in the sky.

2.4 Using **THREE** words of your own choice, please describe the majority of...

*For example: Please describe the majority of skydivers?*

\[x\] 1. athletic 2. daring 3. wayward

a) Aircraft Captains.  
1. 2. 3.

b) Other Crew Members.  
1. 2. 3.

c) Managers.  
1. 2. 3.

d) Yourself.  
1. 2. 3.
2.5 Are there crew members you would prefer not to fly with?

1. "Yes"
2. "No"
3. "Don't Know"

If your answer is "yes", approximately how many?

2.6 Are there crew members you consider it unsafe to fly with?

1. "Yes"
2. "No"
3. "Don't Know"

If your answer is "yes":

a) approximately how many?

b) Have you done anything about it?

1. "Yes"
2. "No"

2.7 Have you ever flown for Britannia suffering from tiredness?

1. Never
2. Very Occasionally
3. Sometimes
4. Fairly Often
5. Often

2.8 Have you ever flown for Britannia suffering from fatigue?

1. Never
2. Very Occasionally
3. Sometimes
4. Fairly Often
5. Often

2.9 Have you ever flown for Britannia when you were medically unfit?

1. Never
2. Very Occasionally
3. Sometimes
4. Fairly Often
5. Often

2.10 Which one of the following statements best describes your opinion of 'go-arounds'...?

1. I would consider I had made a serious error if I had to execute a go-around.
2. I would consider it to be an exceptional event if I had to execute a go-around.
3. I would consider making a go-around as an option in every landing.
4. I would have no problems with executing a go-around if I felt it necessary.
5. None of these statements is a fair assessment.
2.11 If you were the flying pilot and the non-flying pilot called for a go-around during final approach, which of the following statements best describes your actions? (Please circle one)

1. I would ignore the call as I am flying pilot.  
2. I would ignore the call unless it came from a senior officer.  
3. I would inquire as to the reason for the call.  
4. I would ask for confirmation and then execute a go-around.  
5. I would execute an immediate go around.

2.12 You are ready for departure, but the weather is getting steadily worse. Which of the following statements best describes your thoughts? (Please circle one)

1. I would take off because my aircraft is equipped for all conditions.  
2. I would take-off to increase my experience of adverse conditions.  
3. I would feel obliged to take-off to keep on schedule.  
4. I would take-off if the rest of the crew were encouraging me to do so.  
5. I would take-off only if both my colleagues and I were completely confident.

2.13 A senior manager introduces a new company rule you consider to be unsafe, which of the following statements best describes your actions? (Please circle one)

1. I would simply ignore the new rule; its my life.  
2. I would complain about the rule to my colleagues.  
3. I would complain about the rule to the Chief Pilot.  
4. I would complain directly to the manager responsible for the rule.  
5. I would obey the rule as it is my job to obey the rules.

2.14 Do you consider internal communications in Flight Crew Division to be? (Please circle one)

1. Excellent.  
2. Quite good.  
3. Acceptable.  
4. Poor.  
5. Very poor.

2.15 Do you consider internal communications in the rest of Britannia to be? (Please circle one)

1. Excellent.  
2. Quite good.  
3. Acceptable.  
4. Poor.  
5. Very poor.

2.16 Over the last five years, do you think Britannia has become...? (Please circle one)

1. More safe.  
2. Remained about the same.  
3. Less safe.  
4. Don't know
3.1 Please rank the **TOP THREE** factors you consider pose the greatest threat to your flying safety? (With "1" representing the factor that concerns you most.)

- b. Snow / ice accumulation.
- c. Windshear / microburst.
- d. Weather (other than 'b' or 'c').
- e. Judgment error (self).
- f. Judgment error (others).
- g. Mid-air collision.
- h. Maintenance related failure (other than 'a').
- i. Controlled Flight Into Terrain.
- k. Runway incursion.
- l. Management error.
- m. Inappropriate regulations.
- o. Other (Please specify)

(Please circle one)

1
2
3
4
5

3.2 How confident are you of not being involved in a flying accident?

1. Very confident
2. Fairly confident
3. Mixed feelings
4. A little nervous
5. Very nervous

3.3 How confident are you that your crew will perform properly in the event of an abnormal situation?

1. Very confident
2. Fairly confident
3. Mixed feelings
4. A little nervous
5. Very nervous

3.4 How confident are you that management will reduce your possibility of having a flying accident to the absolute minimum?

1. Very confident
2. Fairly confident
3. Mixed feelings
4. A little nervous
5. Very nervous
3.8 Which of the following factors do you consider have been highly significant in the UK's good safety record for commercial jet airliners?

(Circle as many as relevant)

1. Aircraft types flown.
2. Low incidence of snow / ice.
3. Low incidence of windshear / microburst.
4. Flight crew experience.
5. Flight crew training.
6. Ease of interaction between crews.
7. Maintenance integrity.
8. Relatively flat terrain.
9. Integrity of security.
10. Integrity of airport facilities.
11. Management commitment to safety.
12. Appropriate regulation by the CAA.
13. Availability of flying aids (e.g. GPWS, TCAS etc.)
14. Air traffic control.
15. Low traffic density.
16. Luck.
17. Other (Please Specify)

3.9 In your own words, what do you consider will pose the greatest threat to the safety of Britannia in the future?

____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
The objective of this section is to help us develop an understanding of differences in risk perceptions of air crew compared to the general public. It is designed to help us explore what is special about flight crews.

4.1 For the following activities, we would like you to mark how risky you consider each one would be to you personally if you participated.

For each activity, please circle between 1 (Not at all Risky) and 5 (Highly Risky).

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<td></td>
<td>k. Smoking 'soft drugs' e.g. cannabis</td>
</tr>
<tr>
<td>1 2 3 4 5</td>
<td></td>
<td>l. Rugby union / league</td>
</tr>
<tr>
<td>1 2 3 4 5</td>
<td></td>
<td>m. Snow skiing</td>
</tr>
<tr>
<td>1 2 3 4 5</td>
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</tr>
<tr>
<td>1 2 3 4 5</td>
<td></td>
<td>o. Freefall skydiving</td>
</tr>
</tbody>
</table>

4.2 To what degree do the following factors affect your willingness to accept particular risks?

For each activity, please circle between 1 (No Effect) and 5 (Major Effect).

<table>
<thead>
<tr>
<th>No Effect</th>
<th>Major Effect</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5</td>
<td></td>
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</tr>
<tr>
<td>1 2 3 4 5</td>
<td></td>
<td>h. How much you understand about the risks of an activity</td>
</tr>
</tbody>
</table>

This is the end of the survey. Thank you for your help!
Appendix 7 - Future threats to the system’s safety health

Each version of the questionnaire included an open ended question regarding the individual’s perceptions of future threats:

**3.9 In your own words, what do you consider will pose the greatest threat to the safety of RPT carriers in Australia in the future?**

The results were quite varied, ranging from a single named problem to a voluminous description of the future perceived threats. Each form was processed by the principal investigator and classified into a number of categories for coding. The categories (up to 35 categories were used depending on the sample group) were devised from the responses following an initial ‘pass’ of the data and are designed to best reflect the spirit of the answers. Each of the groups’ responses are presented in the following graphs and then discussed individually and then as group factors.

**Qantas Airways**

The two most highly rated threats to the safety of RPT operations within Australia, according to Qantas technical crew (see figure A7.1) were classified as Commercial Pressure and Economic Rationalisation. Although the two categories may seem similar in nature and indeed, some responses may be interpreted as meaning both, there is a subtle, yet important difference. In the context of this survey, commercial pressure may be considered to be ‘the pressure to do more with the same amount of resources’. Economic Rationalisation may be defined as the process of ‘doing the same with less’. In tandem, the two may combine to be the pressure to do more with less. For a comment to be registered twice, it needed to fulfil both characteristics separately and therefore double scoring was not a feature of this response.

Commercial pressure within Qantas increased with the move from government to public ownership and the need to record a return on investment for the share-holders. Prior to this, the merger with Australian Airlines brought both the need and opportunity for economic streamlining and the reduction of duplicated functions. Australian Airlines (latterly Qantas Domestic) had been forced to compete in a deregulated environment following the ending of the ‘Two Airline Agreement’ in 1990. Such pressure does not have to lead to a degradation of safety as organisational efficiency and safe operation are two related goals. However, there was a genuine concern that safety margins were being eroded by tightening of resources.

One such example was voiced through concerns regarding fatigue which were claimed to be the result of poor rostering and duty times closer to their legal limits, especially in the domestic fleet and when international crews transited through several time zones. Poor training and lower maintenance standards stood out, particularly as Qantas has an excellent reputation in...
3.9 In your own words, what do you consider will pose the greatest threat to the safety of RPT carriers in Australia in the future?

<table>
<thead>
<tr>
<th>Issue</th>
<th>Percentage Who Chose Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Pressure</td>
<td>35%</td>
</tr>
<tr>
<td>Economic Rationalisation</td>
<td>30%</td>
</tr>
<tr>
<td>Fatigue</td>
<td>25%</td>
</tr>
<tr>
<td>Misdirected Regulation</td>
<td>20%</td>
</tr>
<tr>
<td>Political Interference</td>
<td>15%</td>
</tr>
<tr>
<td>ATC Inadequacies</td>
<td>10%</td>
</tr>
<tr>
<td>Increased Traffic</td>
<td>5%</td>
</tr>
<tr>
<td>Poor Training</td>
<td>2%</td>
</tr>
<tr>
<td>Sydney Airport</td>
<td>1%</td>
</tr>
<tr>
<td>Complacency</td>
<td>1%</td>
</tr>
<tr>
<td>Low Maintenance Standards</td>
<td>1%</td>
</tr>
<tr>
<td>Low Experience</td>
<td>1%</td>
</tr>
<tr>
<td>Poor Management</td>
<td>1%</td>
</tr>
<tr>
<td>Deregulation</td>
<td>1%</td>
</tr>
<tr>
<td>Mid Air Collision</td>
<td>1%</td>
</tr>
<tr>
<td>QF Privatisation</td>
<td>1%</td>
</tr>
<tr>
<td>Security Deficiencies</td>
<td>1%</td>
</tr>
<tr>
<td>Poor Aids</td>
<td>1%</td>
</tr>
<tr>
<td>Crew Dissatisfaction</td>
<td>1%</td>
</tr>
<tr>
<td>Foreign Crews</td>
<td>1%</td>
</tr>
<tr>
<td>Speed of Change</td>
<td>1%</td>
</tr>
<tr>
<td>Ergonomic Mismatch</td>
<td>1%</td>
</tr>
<tr>
<td>Post Dispute Effects</td>
<td>1%</td>
</tr>
<tr>
<td>MEL Carry Overs</td>
<td>1%</td>
</tr>
<tr>
<td>Airspace Management</td>
<td>1%</td>
</tr>
<tr>
<td>No TCAS A/C</td>
<td>1%</td>
</tr>
<tr>
<td>No Consultation</td>
<td>1%</td>
</tr>
<tr>
<td>Overseas ATC Inadequacies</td>
<td>1%</td>
</tr>
<tr>
<td>Weather</td>
<td>1%</td>
</tr>
<tr>
<td>Runway Incursion</td>
<td>1%</td>
</tr>
<tr>
<td>Extended Retirement Age</td>
<td>1%</td>
</tr>
<tr>
<td>Bogus Parts</td>
<td>1%</td>
</tr>
<tr>
<td>Older Aircraft</td>
<td>1%</td>
</tr>
</tbody>
</table>

Figure A7.1 Perceived Greatest Future Threats to RPT Safety (Qantas Pilots)
both of these areas. Comments regarding an increase in carry-over MEL items seem valid, but comments regarding training should be viewed in the light of above average expectations. Qantas crews may believe that their training has declined, but on an international level, it may remain well above average. Observations were also directed at the General Aviation and ab initio training areas which were undergoing difficult times prior to the survey.

Misdirected regulation and political interference were of no surprise at a time when the Civil Aviation Authority was in crisis and about to be reformed as CASA and Airservices Australia. A significant number of responses focused particularly on the role of Dick Smith who had become an outspoken critic of the CAA in the years following his term as Board Chair. The fact that he then went on to be appointed as Board Chair for CASA in early 1998 suggests the possibility of another crisis of confidence in the ability of CASA Board to operate. Only history will be able to answer this question. Political interference was also related to issues of airspace configuration and in particular, noise abatement and Sydney airport (which existed as a separate category for specific comments). Complicated and recurrently changed procedures, some of which were felt to affect operational performance (e.g. crosswind elements) were cited as future threats for the aviation system. ATC inadequacies were highly rated as was increased traffic suggesting a lack of confidence in the existing (and planned) system to maintain safe separation. Belief that increased traffic would be a threat to safety also lends weight to the belief that low traffic has played a significant role in the aviation safety record.

Ansett Australia

In Ansett Australia (see figure A7.2), the results were reasonably similar to their colleagues at Qantas with commercial pressure and economic rationalisation as the top two factors. This came at a time when Ansett was adapting to operating in the deregulated environment and had cut ticket prices to compete with Compass MkI and MkII. Ansett had also commenced International Operations which were expected to make significant losses during its initial operations.

ATC inadequacies and airspace management were rated more highly by the Ansett crews which seemed to be the result of jet RPT aircraft operating into MTAF / CTAF aerodromes where in effect they flew see-and-avoid at speeds were collision avoidance capabilities were minimised. Comments were also directed at control procedures around Sydney, especially at peak hours and in the form of cancelled or altered standard arrivals (STARs) or standard departures (SIDs). STARs and SIDs which were cancelled and then restarted were the source of major concern, especially as high capacity RPT aircraft need considerable reprogramming of their flight management systems at a time when head up observation was required.

Fatigue was listed well below the Qantas result, not least because of the lack of transmeridian operations. Specific comments cited overnight or 'back of the clock' services between Perth and the East Coast as an area of concern in reference to fatigue.
3.9 In your own words, what do you consider will pose the greatest threat to the safety of RPT carriers in Australia in the future?

Figure A7.2 Perceived Greatest Future Threats to RPT Safety (Ansett Australia Pilots)
Poor training was also highlighted as a factor in line with the perceptions of Qantas crews as was low experience which is often a related factor. Once again, this should be played off against the high standards expected in the RPT operators and the comparatively high level of experience which has historically been the norm.

Low maintenance standards was also flagged, but with MEL carry-overs ranked much higher than in Qantas. This is indicative of changing practices within the carriers which although they may lead to reduced safety margins, are not necessarily a major problem. If MEL carry-overs related to items such as passenger entertainment systems and the money saved by returning the aircraft to traffic means that the company can afford other safety specific purchases then it is not such a bad thing. However, the perception that increased MEL carry-overs and lower maintenance standards are indicative of a degradation of the ‘safety first’ company culture then it is cause for concern.

**RAAF Transport**

Within the RAAF Transport crews (see figure A7.3), the number one factor which they felt threatened the safety of the Australian system was increased traffic (which was ranked seventh by both Qantas and Ansett crews). This must also be viewed in the light of airspace management being rated fourth and ATC inadequacies being ranked sixth. The apparent belief that traffic increase by itself is enough to lead to a degradation of safety is a concern as this is one change which is all but guaranteed within the aviation industry. One myth that must be exploded is a belief that traffic density is directly linked to collision risk in a system of controlled airspace. However, there were also genuine concerns expressed about the ability of the current air traffic services system to safely execute both airspace management and other air traffic control functions.

Commercial pressure and economic rationalisation were also highly ranked (as joint second and third) albeit by a much smaller percentage of respondents than from within the airlines. The RAAF Transport crews may be reasonably expected to keep a close eye on developments within the civilian RPT sector as a large proportion will apply for jobs there following their tour of duty.
3.9 In your own words, what do you consider will pose the greatest threat to the safety of RPT carriers in Australia in the future?

Figure A7.3 Perceived Greatest Future Threats to RPT Safety (RAAF Transport Pilots)
CAA ATC

Air traffic controllers from the CAA (see figure A7.4) were no different in rating commercial pressure and economic rationalisation highly on the list, but different from the pilots in that poor training was highlighted at number two. This sits true with the observations of Ratner Associates review of air traffic services and the state of confusion which surrounds the introduction of Airspace 2000 alongside the introduction of TAAATS. Comments are not exclusively aimed at air traffic controllers, but also include observations about flight crew based on failures to comply, misunderstandings and anecdotal evidence.

Further concern surrounds the speed of change within the Australian system. Proposals for widespread changes to Australian Airspace to align more closely with the ICAO model under a scheme known as Airspace 2000 have been somewhat controversial and the source of multiple revisions. Proposed in October 1992, the introduction was still being deferred in early 1998 after a number of provisional implementation dates had passed. Airspace 2000 came at the same time that the ACAA and then Airservices Australia were attempting to introduce the innovative TAAATS. As the latter system requires a significant level of retraining to introduce a highly computerised system, confusion regarding the ‘shifting goalposts’ of Airspace 2000 has led to genuine concern about the process of change and change management.

These changes are further compounded by other events within the Australian aviation system which include the opening of Sydney’s third runway, closure and subsequent re-opening of Sydney’s crosswind runway, noise sharing procedures and general changes in the regulatory structure. In the last ten years, the air traffic control provider has gone from a Government run service provider within the Department of Aviation to a Government Business Enterprise within the Civil Aviation Authority (a body also tasked with regulation) to Airservices Australia, a government owned service provider separated from the regulator (CASA).

A high listing for ‘poor management’ is indicative of what was perceived to be the cause of poor change management and a lack of comprehensive training. Air traffic controllers often work in isolation from white collar and executive management and in some cases even in isolation from other controllers. Whilst handing over of aircraft between control zones requires a certain level of teamwork skills, it is not the style of ‘crew’ operation that is found within the flight deck of an aircraft. Proposals to introduce ‘CRM-type training’ into Airservices Australia have so far been delayed by the concentration of resources on projects such as TAAATS. Structured risk management is now a priority, but this is a comparatively recent development which has come from the Airservices Board after it became a separate entity from ACAA / CASA in 1995.

Whilst ATC inadequacies and poor airspace management rated further down the list than the rankings ascribed by pilots, the high placing for ‘increased traffic’ is a little concerning (5th place - 23.5%). Air traffic controllers are arguably in a better place than anyone to see the
3.9 In your own words, what do you consider will pose the greatest threat to the safety of RPT carriers in Australia in the future?

Figure A7.4 Perceived Greatest Future Threats to RPT Safety (CAA Air Traffic Controllers)
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potential benefit of TAAATS for improving the integrity of system. They are also likely to be more aware that it is not traffic that is the crucial factor in maintaining separation, rather it is the integrity of the control being provided. With a high proportion of comments relating to poor training, management and the speed of change, perhaps the controllers are doubting their own ability to cope with increased traffic in spite of proposed changes to equipment and airspace?

The situation as perceived by military air traffic controllers is of even more concern (see figure A7.5). Four of the top five categories relate directly to their own ability to maintain the integrity of air traffic control. Low experience and increased traffic is combined with airspace management problems and general ATC inadequacies. Economic pressures are also high, and possibly related to issues such as low experience (through a lack of training and relatively high turnover of staff), but commercial pressure is perceived to rank down the list in eighth place.
3.9 In your own words, what do you consider will pose the greatest threat to the safety of RPT carriers in Australia in the future?

Figure A7.5 Perceived Greatest Future Threats to RPT Safety (Military Air Traffic Controllers)
Publications

Papers and Presentations related to this research are as follows;


Braithwaite, G. R. (1997) Get The Message! - Education is the Smart Side of Research. Paper
presented to the First Australian Aviation Universities Association Conference 'Aviation Education beyond 2000'. Bankstown, Australia. November 28th.