Threat and Error Management: An Analysis of Reported Safety Occurrences to the Civil Aviation Authority of New Zealand 1998–2007

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Abstract

Current safety reports indicate a rise in the number of reported incidents involving both medium and small aeroplanes and helicopters. The purpose of this study is to identify specific threats, errors and Undesirable Aircraft States (UAS), present in safety-related occurrences reported to the Civil Aviation Authority of New Zealand (CAANZ).

Threat and Error Management (TEM) is used to improve safety margins in aviation operations through the practical integration of human factors knowledge. The TEM framework is used to guide the investigation of reported safety-related occurrences in a way that systematically identifies specific threats, errors and UAS.

This research employs the predictive safety method by investigating reported historical events, followed by analysing each event to list threats, errors and UAS. If a threat, error or UAS is identified in an occurrence, it is then marked 'present' under the corresponding column of the TEM taxonomic. After the completion of the classifications, solutions can be developed to prevent similar occurrences in the future.

To test for accuracy and consistency of threat, error and UAS classifications, ten randomly chosen occurrences were provided to ten aviation professionals. These tests included Cohen's Kappa test and a percentage of agreement test. Cohen's Kappa results reached significant agreement with half of the respondents and an overall percentage of agreement of 68 per cent compared with the researcher's classifications.

Results from the TEM classifications show the majority of threats had environmental influences and procedural errors. The most common UAS resulted mainly from Ground Navigation and Aircraft Handling operational conditions.

The TEM technique enabled a focus on the events that contributed to an incident rather than an accident. By applying the results from this TEM taxonomic, it is hoped

that pilots will benefit from a better understanding of the importance of TEM and how frequently threat and errors contribute to incidents. This research would then help flight operators and pilots better prepare themselves to react to the likelihood of specific threats or errors, if and when they occur.

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Glossary

Accident: an occurrence that is associated with the operation of an aircraft and takes place between the time any person boards the aircraft with the intention of flight and such time as all such persons have disembarked and the engine or any propellers or rotors come to rest.

(1) A person is fatally or seriously injured as a result of

   a. being in the aircraft;
   b. direct contact with any part of the aircraft, including any part that has become detached from the aircraft; or
   c. direct exposure to jet blast

   except when the injuries are self-inflicted or inflicted by other persons, or when the injuries are to stowaways hiding outside the areas normally available to passengers and crew; or

(2) the aircraft sustains damage or structural failure that

   a. adversely affects the structural strength, performance or flight characteristics of the aircraft; and
   b. would normally require major repair or replacement of the affected component,

   except engine failure or damage that is limited to the engine, its cowlings, or accessories, or damage limited to propellers, wing tips, rotors, antennas, tyres, brakes, fairings, small dents, or puncture holes in the aircraft skin; or

(3) aircraft is missing or is completely inaccessible (CAANZ, 2009c).

Classifications: judgements or decisions made to determine whether a threat, error or UAS was present in each occurrence.

Errors: errors are defined as flight crew actions or inactions that:

(1) lead to a deviation from crew or organisational intentions or expectations,
(2) reduce safety margins, and

(3) increase the probability of adverse operational events on the ground or during flight (Merritt & Klinect, 2006).

Incident: any occurrence, other than an accident, that is associated with the operation of an aircraft and affects, or could affect, the safety of operation (CAANZ, 2009c).

Occurrence: an accident or incident (CAANZ, 2009c).

Threats: defined as events or errors that:

(1) occur outside the influence of the flight crew (i.e. not caused by the crew);

(2) increase the operational complexity of a flight; and

(3) require crew attention and management if safety margins are to be maintained (Merritt & Klinect, 2006).

Undesirable Aircraft States (UAS) is defined as a position, speed, attitude, or configuration of an aircraft that:

(1) results from flight crew error, actions, or inaction,

(2) clearly reduces safety margins (Merritt & Klinect, 2006).

1.0 Introduction

This thesis is a study of threat and error management in New Zealand's aviation sector. More specifically, the thesis analyses threats, errors and Undesirable Aircraft States (UAS) in reported occurrences as a necessary step prior to developing solutions to prevent similar occurrences in the future.

TEM is a systems' approach to aviation safety. The basic concept of TEM is to provide pilots with the skills necessary to manage and reduce the safety risks present in their everyday flying (Merritt & Klinect, 2006). TEM entails the effective detection of, and response to, internal or external factors that have the potential to degrade the safety of normal operations (Helmreich, Klinect & Wilhelm, 1999).

Air transport is continuing to grow rapidly (Oum, Zhang & Fu, 2009), along with the potential for accidents and incidents to occur more frequently. Industry Analysts have predicted that the projected growth rate in air traffic in the near future may result in one major commercial airline accident per week, if current accident levels are maintained (Sarter & Alexander, 2000; Huettner, 1996, as cited in Parasuraman & Byrne, 2003). To offset this growth in air accidents, efforts to reduce the frequency of accidents and incidents must continue.

Accident investigation alone is no longer sufficient to maintain the status quo in aviation safety. Air accident investigation is, by its nature, a reactive approach designed to investigate the failures that were present during the lead-up to an aircraft accident. Depending on the complexity of the accident, effective solutions can be drawn out; however, investigations require time, resources and are susceptible to political influence (Kilroy, 2008).

To continue advancement in aviation safety, Leveson (2004) argues the adoption of more proactive approach models is necessary to unlock further underlying causes, failures and breakdowns within the aviation system. Techniques such as incident investigation are becoming more proactive and predictive, and can produce timely interventions to improve safety (McFadden & Towell, 1999). These proactive measures identify threats, errors and UAS and can be reported through various programs, such as National Aeronautics and Space Administration's (NASA) (2006) Aviation Safety Reporting System (ASRS). That has been used to gain a greater insight into the nature of incidents that pilots experience during normal daily operations.

Indeed, various models and programs of threat and error management have been developed to help pilots and safety experts identify and diagnose threats or errors that may arise. One such program is Crew Resource Management (CRM), whose roots are traced back to a workshop, Resource Management on the Flightdeck, run by NASA in 1979 (Cooper, White & Lauber, 1980; as cited in Helmreich, Klinect & Wilhelm, 1999a). CRM programs are designed to offer a primary line of defence against the threats to safety that abound in the aviation system and against human error and its consequences (Helmreich, Klinect & Wilhelm, 1999). Such training programs have shown improvements in reducing the frequency of errors that pilots make and the threats they avoid and, more importantly, recognition of threats and errors (Helmreich, Merritt & Wilhelm, 1999).

TEM builds on already well established safety programmes, such as CRM and Line Operated Safety Audits (LOSA). This study is not a mere extension of the TEM framework to analyse a subset data of occurrences reported to the Civil Aviation Authority of New Zealand (CAANZ). Rather, this study is an extension of Merritt and Klinect's (2006) Aviation TEM taxonomic, applied in a New Zealand setting.

Ultimately, it is hoped that using proactive approaches towards flight safety helps identify the likelihood of a flight crew or a single pilot experiencing a threat, error or UAS. Making pilots aware of likely threats and errors will prepare them for these adverse events in future flights. Consequently, pilots would be able to better equip themselves to deal with any greater potential of an approaching a UAS before it is likely to occur.

2.0 Literature Review

2.1 Aviation Safety

Over the past 50 years, the number of fatal hull loss accidents has steadily declined. Previous accident rates during the 1960s (accident statistics) were 50 accidents for every million departures worldwide. During the 1970s, the accident rate improved to below five accidents per million departures (Wiegmann & Shappell, 2003).

Accident rates have continued to hold steady since the 1970s. The Bureau of Transportation Statistics (2007) reported the accident rate in 2006 for general aviation operations in the United States at 6.64 accidents per 100,000 flight hours, whereas the accident rate for air transport operations was 0.15 accidents per 100,000 flight hours. Statistics from International Air Transport Association (IATA) show 'the total number of fatalities from aviation accidents dropped from 692 in 2007 to 502 in 2008' (IATA, 2009). This resulted in a 56 per cent improvement in the fatality rate, from 0.23 fatalities per million passengers to 0.13 per million passengers. The global accident rate (measured in hull losses per million flights of Western-built jet aircraft) stood at 0.81, or one accident for every 1.2 million flights. This is a slight deterioration from 2007 performance, when the accident rate was 0.75, or one accident for every 1.3 million flights. There were 109 accidents in 2008 compared to 100 in 2007. The number of fatal accidents increased from 20 in 2007 to 23 in 2008 (IATA, 2009).

Reported statistics from CAANZ and Airways NZ show corresponding increases in both the number of aircraft movements (Airways Corporation of New Zealand, 2008) and reported incidents (CAANZ, 2008). Incident statistics indicate (CAANZ, 2009a) that aircraft incidents are trending up for helicopters, small fixed wing and medium fixed wing, while large fixed wing incidents remain constant. Table 1 defines each aircraft category by the regulations under which they operate. Airspace incidents are trending up for all categories of fixed wing aircraft, while helicopter incident involvement is trending down. Accidents involving medium fixed wing aircraft are trending up, while small fixed wing aircraft and helicopters are trending down. Large fixed wing is the only category of aircraft to remain constant. The overall accident rate is continuing to trend down. However, 2008 saw the accident frequency rise for the first time since 2007.

Table 1. Aircraft Statistics Category

Aircraft Statistics Category	Definition	Aircraft Class
Large Aeroplanes	Aeroplanes that must be operated under Part 121 when used for air transport	Aeroplane
Medium Aeroplanes	Aeroplanes that must be operated under Part 125 when used for air transport, except for those required to operate under Part 125 solely due to operating SEIFR	Aeroplane
Small Aeroplanes	Other Aeroplanes with Standard Category Certificates of Airworthiness	Aeroplane
Agricultural Aeroplanes	Aeroplanes with Restricted Category Certificates of Airworthiness limited to agricultural operations	Aeroplane
Helicopters	Helicopters with Standard or Restricted Category Certificates of Airworthiness	Helicopter
Sport Aircraft	All aircraft not included in the groups above	Aeroplane, Amateur Built Aeroplane, Amateur Built Glider, Amateur Built Helicopter, Balloon, Glider, Gyroplane, Helicopter, Microlight Class 1, Microlight Class 2, Power Glider

Source: CAANZ (2008a)

Li, Baker, Grabowski and Rebok (2001) found that 85 per cent of the general aviation accidents may have been caused by pilot error, meaning the percentage of probable cause has not changed since 1942. Other authors suggest figures around 70–80 per cent (Shappell & Wiegmann, 1996; as cited in Shappell & Wiegmann, 2000). These findings suggest that human error is still a major contributor to aviation occurrences, despite advancements and changes in aircraft technologies and flight training. This research helps pilots identify the common threats, errors and UAS that contribute to human error occurrences.

Safety improvement in the modern aviation industry has turned to forward-looking initiatives. The traditional view on human factors was to eliminate errors and improve design features to increase error tolerance. However, it was realised that error is inevitable, and today's environment focuses on more proactive incident prevention initiatives to raise the level of safety. Studies in TEM research have begun to prove their conceptual value, as they have continued to develop and apply working detection models. These models include SHELL, Swiss-cheese model, LOSA, Flight Operation

Quality Assurance (FOQA), ASRS and Human Factors Analysis and Classification System (HFACS) programs.

Using incidents as the main source of raw data will assist the aviation industry in raising awareness of the size of the submerged ‘iceberg’ (see Figure 1), and the frequency role at which threat, error or UAS events are likely to occur. Research into threat, error and UAS frequencies could further the development of focused, proactive flying defence strategies, based on reported data. Pilots will be able to further develop detection and mitigation skills in threat, error and UAS.

2.2 Accidents and Incidents

The TEM taxonomic is designed to analyse the incidents that happen below the waterline. Like an iceberg, whose mass is mostly beneath the waterline, the majority of errors do not result in actual accidents and mostly remain unnoticed (see Figure 1). Reducing the number of lower-order errors would help lower the rate of more serious incidents and accidents.

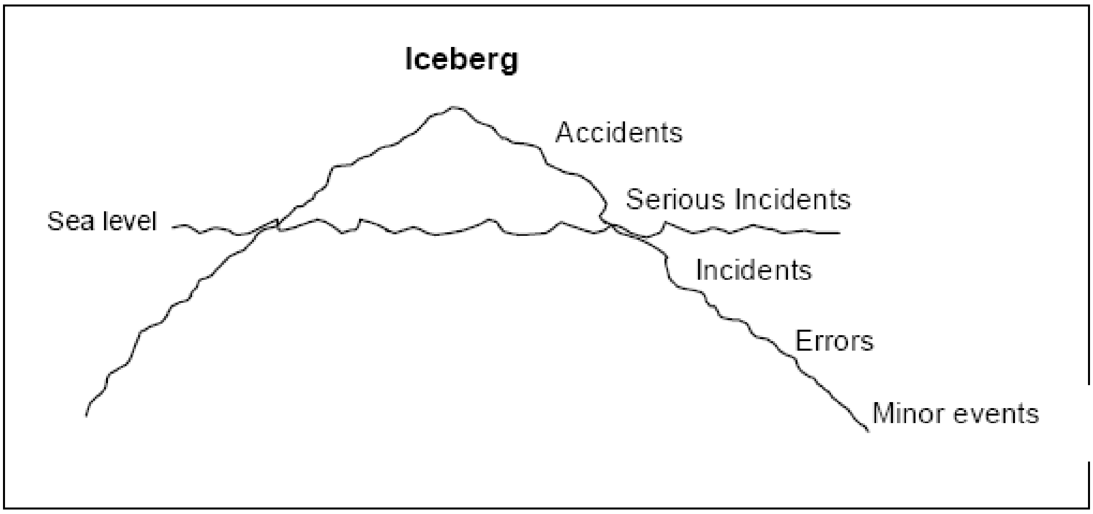


Figure 1. The ‘Iceberg Model’ of Accidents
Source: UK Civil Aviation Authority, 2002

In contrast, accidents are the observable manifestations of error (UK Civil Aviation Authority, 2002) and usually end in formal accident investigations. By focusing on incidents, proactive interventions can be used to eliminate or manage the presence of threat and error situation. This supports the pilot's efforts to bring the aircraft within acceptable safety margins (Leveson, 2004).

Pilots can improve aviation safety by reporting threats and errors that cause UAS and by taking steps to minimise repeatable occurrences. The application of TEM to daily flight operations helps pilots identify potential safety risks in a timely manner, before they become a problem. These actions may not complete the task objectives; however, safety of the flight must remain paramount.

2.3 Human Error Models

One conceptual model (see Figure 2) of human factors was first proposed by Elwyn Edwards (1972, as cited in Hawkins, 1987), forming the 'building block' model. This model was further developed by Hawkins (1984, as cited in Hawkins, 1987) and became SHELL, following the addition of Liveware–Liveware interaction or the interaction between people. This model demonstrates the interface areas with which pilots interact and that can be sources of error during operations. The centre block of the model (Liveware) represents the human factors, surrounded on four sides by the other SHELL squares.

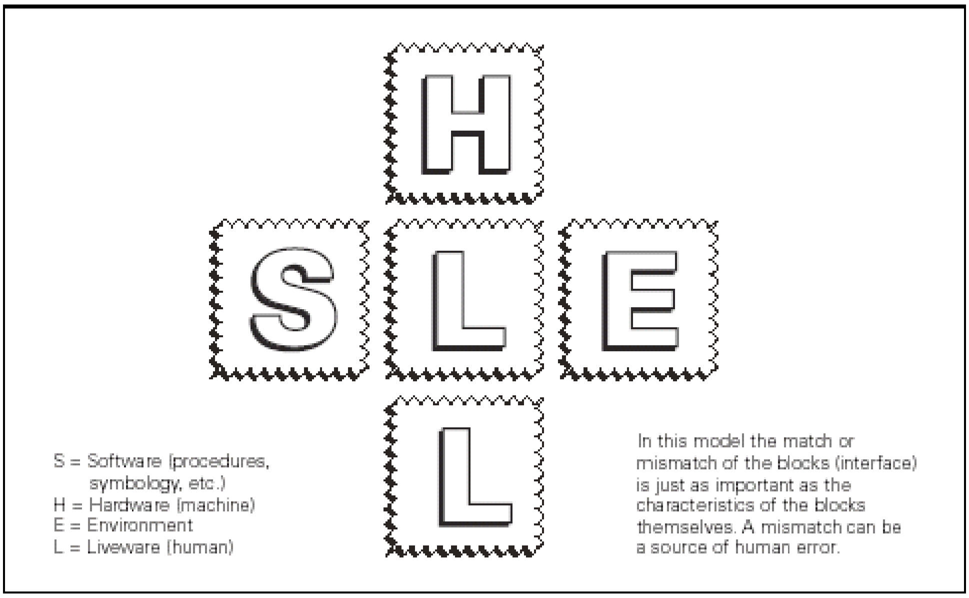


Figure 2. SHELL Model

Source: Hawkins, 1987

Reason's (1990) *Human Error* is a comprehensive book discussing the nature of human error. His Swiss-cheese model has become the base model for safety management since the concept was introduced and has been further developed into models such as the HFACS (Shappell & Wiegmann, 2000).

Human Error presents a framework for the study of error production, error detection, assessment and the reduction of errors. Reason introduces 'the human elements of accident causation' (1990), or the Swiss-cheese model (see Figure 3). Reason (1990) describes four levels of human failure, with each level influencing the next.

The Swiss-cheese model can follow or trace accident trajectories through the window of accident opportunity until the accident occurs or is stopped by one of the layers of safety. Unfortunately, Reason (1990) explains what the lines of defences are, but fails to explain what causes them to appear and the size of the holes in the defence layers.

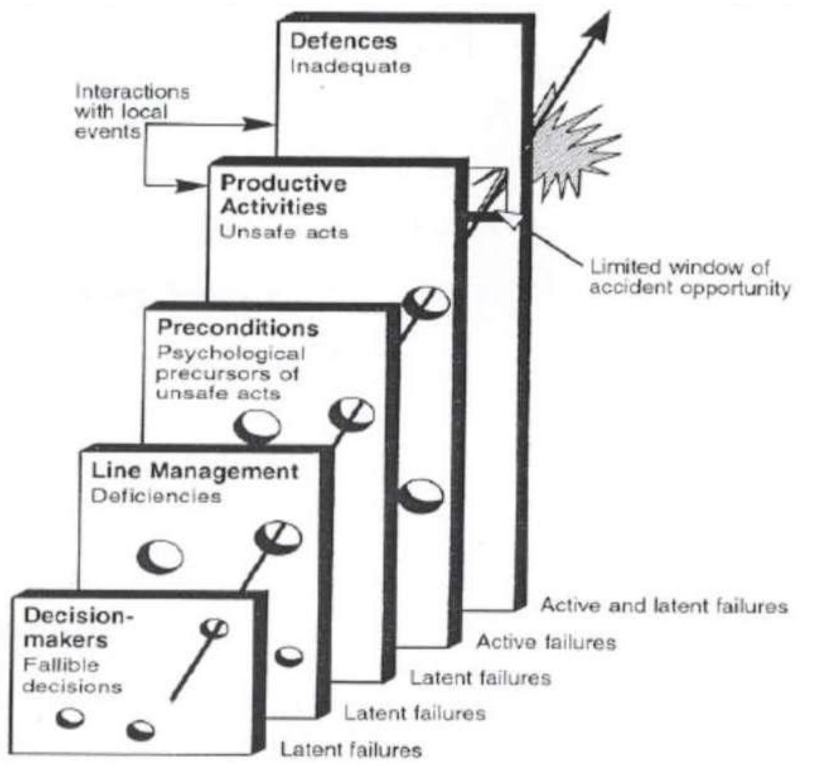


Figure 3. Human Elements of Accident Causation

Source: Adapted Swiss-Cheese Model (CrewReasourseManagement.net, 2009)

Shappell and Wiegmann's (1997) conceptual model, *The Taxonomy of Unsafe Operations*, is an accident investigation tool. It is designed to prevent accidents through the early identification of latent errors. Shappell and Wiegmann (1997) build on Hawkins' SHELL model and further investigate the complex interactions within the centre Liveware block, using Bird's domino theory (Bird, 1974; as cited in Shappell and Wiegmann, 1997). The taxonomic uses five dominos, each representing a layer of safety similar to Reason's (1990) Swiss-cheese model (see Figure. 3).

This taxonomic tool is cause-oriented rather than event-originated, to ensure that events are classified by their underlying causes. Shappell and Wiegmann (1997) suggest this is one reason for the discontinuity between classical theories of human error and the practical application of these theoretical approaches in accident investigation. Shappell and Wiegmann (1997) argue that this taxonomic bridges the gap between theory and practice, which provides accident investigators with classifications that allow for the inclusion of human causal factors.

Shappell and Wiegmann (1997) stress that most accident investigation reporting systems are designed and employed by engineers and front-line operators with limited background knowledge in human factors. They suggest this lack of understanding in human factors may have influenced the large reduction in mechanical causes but not human errors. Shappell and Wiegmann argue this is because traditional methods lack the interventions aimed at reducing occurrences or consequences of human performance failures.

The resulting problems for these post-accident databases make difficult the identification and development of viable human intervention strategies onerous (Wiegmann & Shappell, 1997). The human components of post-accident analysis are so narrow in scope that traditional reporting systems are limited to the identification of possible human failures and do not discuss why the failures occurred.

2.4 Human Factors Analysis and Classification System

The HFACS is a general human error framework, originally developed by Wiegmann and Shappell (1997) for the US military. It was developed as a tool for the investigation process, target training, prevention efforts and analysis of human causes of aviation accidents (Wiegmann & Shappell, 2001). Previously, Shappell and Wiegmann (2000) had argued that most accident reporting systems were inadequate for any comprehensive investigation into the human error element of the process. The HFACS framework has been based on Reason’s (1990) *Human Elements of Accident Causation* (see Figure 3) (Wiegmann & Shappell, 2001), which incorporates and expands on the four layers of human failure to better facilitate human error analysis.

The HFACS framework has been applied to military, commercial and general aviation sectors to systematically examine underlying human casual factors as a means of improving aviation accident investigations.

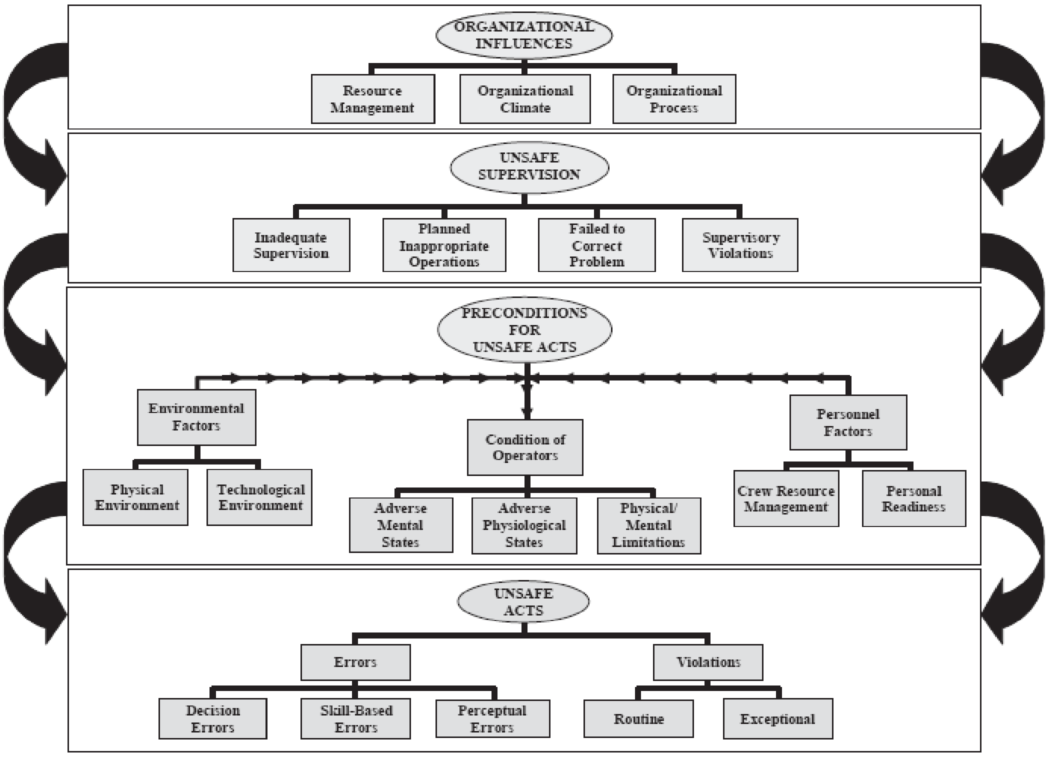


Figure 4. Human Factors and Classification System

Source: Wiegmann, Faaborg, Boquet, Detwiler, Holcomb & Shappell, 2005

Shappell and Wiegmann (2000) suggest adapting Reason's (1990) Swiss-cheese model of human error. Here, Reason's four levels of human failures (Organisational Failures, Unsafe Supervision, Preconditions for Unsafe Acts and Unsafe Acts) are expanded into further subcategories. Errors that result in accidents are able to fall through the 'holes in the cheese' until an accident occurs. Shappell and Wiegmann (2000) have argued that Reason's theory lacks details in application to real world settings and lacks a concrete description of the 'holes in the cheese'. Shappell and Wiegmann (2000) attempt to define and identify these 'holes', so the system failures can be detected and corrected before an accident occurs.

Shappell and Wiegmann (2000) give brief descriptions of each category of defence layers: (1) organisational influences (resource management, organisational climate, organisational process); (2) unsafe supervision (inadequate supervision, planned inappropriate operations, failure to correct a known problem and supervisory violations); (3) preconditions for unsafe acts (substandard conditions of operators and substandard practises of operators); (4) unsafe acts committed by aircrews (errors and violations).

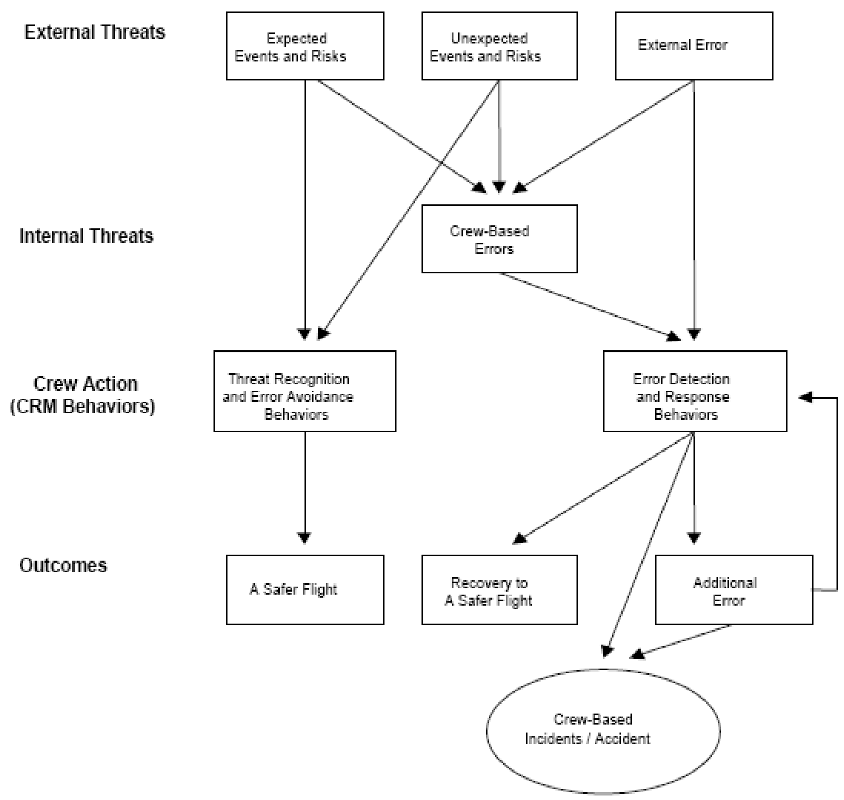


Figure 5. Model of Flight crew Error Management
Source: Helmreich, Wilhelm, Klinect & Merritt, n.d.

Helmreich et al. (1999) present a flowchart to illustrate the path along which threats and errors are likely to take place (see Figure 5). Threats are defined as situations, events or errors that occur outside the flight deck (Thomas, 2004). These errors start at the top of the model (see Figure 5) and travel downwards until risk levels have been mitigated or until an incident or accident is experienced. Threats are able to enter the system via three possible entry points: Expected Events/Risks, Unexpected Events/Risks and External Error.

Helmreich et al. (1999) suggest that expected events may stem from forecasted weather, terrain and airport conditions, while those unexpected events may include

ATC commands, system malfunctions and operational pressures. An increase in risk may also come from external sources of error, such as ATC, maintenance, dispatch and management.

The last defensive layer of the model is provided by the CRM behaviours of the flight crew. The flight crew's actions determine whether threats and errors are trapped and the risk is either mitigated, avoided or mismanaged, which may lead to additional error or, at worst, an incident or accident.

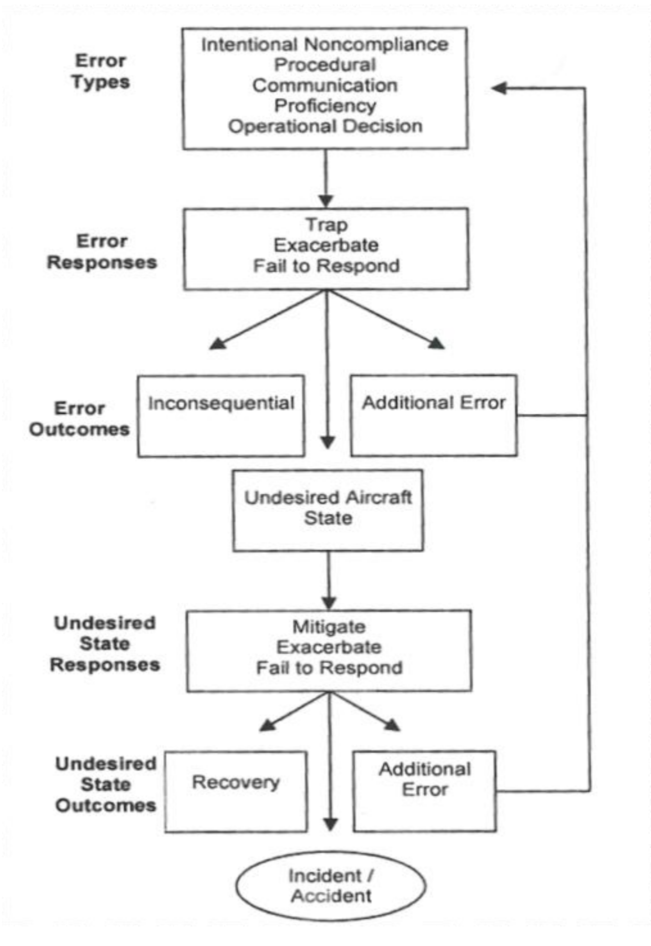


Figure 6. Model of Flight Crew Error

Source: Helmreich, Klinect & Wilhelm, 1999

Figure 6 shows a Model of Flight Crew Error from Helmreich et al. (1999), which depicts possible outcomes when an error is present. This model is designed to facilitate the analysis of errors, responses and outcomes. The error starts at the top of the model and works down until the error is either resolved, becomes an incident/accident or induces an additional error and begins the cycle again. Depending on the error response, errors can become inconsequential, induce additional error or develop into a UAS. If a UAS occurs, pilots can either mitigate, exacerbate or fail to respond to the situation. This may either lead to a recovery of the situation, induce additional cycle of error and management or end in a crew-based incident or accident.

Reason (2000) reviews two basic different views or approaches to the human error management problem: namely, the person or the system approach. The person 'approach focuses on the unsafe acts—error and procedural violations—of people at the sharp end' (Reason, 2000, p. 768). In the aviation environment, these people include pilots, dispatchers, maintenance personal, ground handling and ATC. Reason (2000) further suggests examples of error countermeasures for the person approach, such as safety poster campaigns, changes or additions to Standard Operating Procedures (SOPs), disciplinary measures, threat of litigation and retraining.

Alternatively, the system approach focuses on the 'conditions under which the individuals work and tries to build defences to avert errors or mitigate their effects' (Reason, 2000, p. 768). This approach focuses on identifying recurrent error traps and the processes in an organisation that gives rise to these errors. Reason (2000) further argues that system defences, such as barriers and alarms, can then be engineered for a person (pilot, ATC, mechanic), procedures or administrative controls. The system approach focuses on why and how the system defences failed, rather than blaming an individual (Reason, 2000). Examples of system defences include terrain and aircraft collision warning systems, stall warnings and check lists.

Using the personal approach, Reason (1997; 2000) suggests that effective management risk depends crucially on establishing a reporting culture and trust. Without these, there would be no way of uncovering mishaps, incidents or near misses until a serious incident or accident happens. However, the weakness of the personal approach lies in the fact that it focuses on the individual origin of error, isolating unsafe acts from their system context. Further, greater safety is compromised when error-provoking properties are not sorted out and removed from the whole system (Reason, 2000).

The system approach anticipates the worst scenario and equips organisations to deal with errors at all levels. It uses human variability in the shape of compensations and adaptations to changing events as the most important safeguard (Reason, 2000). The system approach is able to reconfigure itself to suit changing local circumstances (from routine to emergency mode), where local on-site experts take control of unusual situations in times of need. Error management limits the incidence of dangerous errors and creates systems that are better able to tolerate the occurrence of errors and isolate the consequences.

Each error in the model either resolves itself, is successfully managed, or (if unsuccessfully managed) may precipitate further errors, which can be analysed in the same way. As each error is analysed, it is possible to look for more than one specific threat, error detection safeguards, knowledge or training deficiencies and mitigation strategies. Helmreich and Musson (2000) also point out that for each error, investigation is needed into the surrounding conditions that that may have helped the error develop. Finally, the analysis of errors or incidents should lead to the identification of systemic threat and deficiencies within the organisation in question.

Wiegmann et al. (2005) applied the HFACS model to general aviation accidents in an attempt to capitalise on the gains realised by the HFACS studies conducted previously for miltary. Overall, it was concluded that ‘these analyses have helped identify general trends in the types of human factors issues and aircrew errors that have contributed to civil aviation accidents’ (Wiegmann & Shappell, 2003; as cited in Wiegmann et al., 2005, p. 3).

Wiegmann et al.’s (2005, p. 4), study used general aviation ‘accident data from calendar years 1990–2000, [which] were obtained from databases maintained by the

National Transportation Safety Board (NTSB) and the FAAs National Aviation Safety Data Analysis Centre (NASDAC)'. This study analysed 14,346 accidents of general aviation fixed wing aircraft, helicopters and gyrocopters. It included over 25,000 aircrew causal factors, which were submitted to further analysis using the HFACS framework. Seven certified general aviation instructor pilots (each with sixteen hours of HFACS training and a minimum of 1,000 general aviation flight hours) analysed the narrative and tabular accident data to classify each human casual factor using HFACS. Wiegmann et al.'s (2005) results indicated that nearly 80 per cent of all general aviation accidents were associated with at least one skill-based error and about 60 per cent of these skill-based errors, a human causal factor was first in the accident sequence. Fourteen per cent of general aviation accidents analysed involved at least one violation. Pilots that commit violations as their first unsafe act were found to be three times more likely to be involved in a fatal accident than a non-fatal accident. Decision errors were present in about a third of all accidents. A closer examination of decion errors revealed that many of the errors involved weather evaluation planning, both in flight and on the ground (Wiegmann et al., 2005). Perceptual errors such as spartial orientation contributed to only 5.7 per cent of accidents. However, Wiegmann et al. (2005) suggested that due to the relatively small numbers of perceptual errors coded, it was difficult to draw any conclusions.

Shappell et al.'s (2007) study applied the HFACS framework to commercial aviation (air carrier and commuter/on demand) from the already developed military version. The aim of their study was to extend the HFACS framework into commercial aviation, combining theoretically derived human error framework with traditional situational and demographic variables, examining any relationships over a period. Shappell et al. (2007) collected accident data from 1990 to 2002, 1,020 accidents (181 air carrier and 839 commuter/on demand) from the NTSB and the FAAs NASDAC. Using an expanded Swiss-cheese model, Shappell and Wiegmann (1997) expand on the four levels of human failure and identify the unique threats and errors in commercial aviation.

Next, Shappell et al.'s (2007) used six certified instructor pilots (each with sixteen hours of HFACS training and a minimum of 1,000 flight hours) to analyse the narrative and tabular accident data to classify each human casual factor using HFACS. The result indicated that the majority of accident causal factors were found at the unsafe act level (refer to Figure 4). Accidents that were associated with at least one skill-based error totalled 56.5 per cent and accidents with decision errors totalled 36.7 per cent. Accidents associated with violations totalled 23.1 per cent. Operating in impoverished visual conditions usually resulted in the majority of violations. The least common unsafe acts were perceptual errors, which involved fewer than seven per cent of accidents. This study showed the majority (70 per cent) of commuter/on demand accidents happened in Visual Meteorological Conditions (VMC), where 70 per cent of total accidents happened during daylight hours. Also, findings suggest that 70 per cent of accidents could be associated with some degree of organisational, supervisory or aircrew failure error.

The majority of safety improvements have been made in mechanical, structural and advancement of avionics. Safety improvements in these areas are considered the low-hanging fruit of aviation safety (Shappell, et al. 2007). Examples include the development of airframe materials and construction techniques that have increased the strength and durability performance in airframe construction. Improvements in this area of safety in the aviation industry are quickly disappearing or have already been exhausted; any additional improvements are becoming fairly minor.

Unfortunately, however, the same cannot be said about the reduction of human factor causation involvement in aviation accidents. Progress in this area of aviation safety did not gain traction until the 1990s. During this time, some key human error studies from Reason (1990) and Shappell and Wiegmann (1997) were completed, influencing the direction research would take.

2.5 Crew Resource Management

One error prevention program used in the aviation industry is CRM (Royal Aeronautical Society, 1999). Helmreich, Klinect & Wilhelm (1999) stated that CRM courses are designed to provide a primary line of defence against the threats to safety that abound in the aviation system and against human error and its consequences. They place CRM training at the interface between safety departments, flight training and flight operations. Benefits of CRM include improved morale and enhanced efficiency of operations (Helmreich & Merritt, 1998, as cited in Helmreich et al., 1999). This program is designed to help flight crew's work together to reduce the possibility of human error occurring on the flight deck.

According to Helmreich, Merritt & Wilhelm (1999a), CRM was first developed from training programs designed to increase managerial effectiveness. The first generation of CRM included diagnoses of managerial style, emphasising changing individual styles and correcting deficiencies in individual behaviour. Byrnes and Black (1993, as cited in Helmreich et al., 1999) notes that second generations of CRM programs started to become more modular, team-originated and aviation-specific.

The third generation of CRM saw programs integrated within technical training and expanded to other parts within the airlines, such as cabin crew, Air Traffic Control (ATC), dispatchers and maintenance personnel. Helmreich et al. (1999) believed the original goals of CRM have faded since its introduction, partly due to the extension into other domains apart from the cockpit. Helmreich et al. (1999a) suggest that airlines have also argued that CRM should disappear as a separate entity altogether, as it becomes fully integrated into technical training.

The fourth generation of CRM saw the beginning of these concepts proceduralised by adding specific behaviours to airline checklists. Also, the introduction of Advance Qualification Program (AQP) from the Federal Aviation Administration (FAA) meant that airlines had to develop CRM concepts for all aspects of training (Helmreich et al., 1999).

The fifth generation of CRM focuses on the normalisation of error and the development of strategies for managing error (Helmreich, 1997). According to Helmreich et al. (1999), CRM programs are now using positive examples of how errors are detected and managed. They suggest that the error management approach should provide more compelling justification for CRM and the human factors training pilot receive.

Adoption of CRM techniques helps pilots minimise the chance that threats and errors will affect the safety of a flight. These programs need to be tailored to suit the cultural environment of each individual organisation that uses it. Additionally, the use of LOSA to perform CRM assessments is used as a measure to gauge the uptake of CRM concepts under normal operations.

2.6 Flight Performance Assessment

Line Orientated Safety Audits (LOSA) is a proactive safety data collection program developed to provide information about the management of human error in the cockpit of a modern airliner. LOSA data can provide a picture of normal operations and allow estimation within organisations of the degree of risk associated with certain environments, fleet or types of manoeuvres (Helmreich et al,. 1999). The audit provides a diagnostic snapshot of a flight crew's strengths and weaknesses, including an overall assessment of flight crew performance during normal operations. According to Klinect et al. (1999), one of LOSA's strengths is the process that identifies examples of superior performance that can be reinforced and developed for use as models for training. For Helmreich et al. (1999), this information can be used almost immediately to prevent adverse events sooner.

During the LOSA audit, appropriately qualified observers are located in the jump seat of the cockpit. Their function is to: (1) document external threats; (2) record flightcrew errors in terms of their type, management response and outcome; and (3) rate the crew on several CRM behavioural markers (Klinect et al., 1999). These highly trained observers are there to collect data about flight crew's behaviour and situational factors on 'normal flights' (International Civil Aviation Organisation (ICAO), 2002). LOSA operates on a purely voluntarily basis, and it is essential that both airline management and the pilots (or professional association) support the program. Flight crews that refuse LOSA audits too many times may have trust issues with the system. All LOSA data is de-identified and treated as confidential, unless there are major safety concerns found and the appropriate channels are informed. LOSA observers are encouraged not to record names, flight numbers, dates and any other information that could lead to the identification of the flight crew (ICAO, 2002). When more trust in these sorts of systems arise, this data could be included for additional processing.

LOSA observers are trained to a normalisation standard at which the difference in observation interpretations is reduced between observers. All records are sent to a trusted third party, where the processing of the data is completed. The collected data is checked for consistency and verified to maintain data integrity (ICAO, 2002). Data outcomes determine the targets for enhancement programs.

The influence of variables such as the type of airspace, geography, weather patterns and amount of traffic in an area changes the probability of a pilot encountering a specific threat or error. These provide targets for later training enhancement once the LOSA observation is completed (Shappell & Wiegmann, 2000). Like most modern safety information gathering systems, LOSA uses a non-punitive approach, and flight crews are not punished if observed to commit a violation or error (Klinect et al., 1999). When a flight is being audited, observers are required to record and code potential threats to safety; how these threats are addressed; the errors such threats generate; how flight crews manage these errors; and specific behaviours that have been known to be associated with incidents and accidents (ICAO, 2002).

The University of Texas Human Factors LOSA monitoring project has conducted eight audits that include over 3,500 observational flights, with three different airlines (Helmreich et al., 1999). LOSA revealed large differences between airlines and between fleets within airlines. The number of threats and errors are each recorded as an average number of external threats per flight segment, and consequential error management scores are then calculated.

Helmreich et al. (1999) also calculated the percentages of error types (e.g. intentional non-compliance and procedural) within airline fleets against different crews with two different types of aircraft (advanced technology and conventional technology). This calculation returned an even distribution of results: one crew from each fleet scored high intentional non-compliance and had a lower procedural error rate, whereas the other crews scored high procedural error had a low intentional non-compliance. LOSA was also used to calculate the percentage of external threats by phase of flight; the Descent/Approach/Land phase being the most frequent at 39 per cent, followed by take off/climb (28 per cent) and pre-flight/taxi (22 per cent). The external threats that arose from the Pre-flight/Taxi phase were most surprising for the researchers, as these external threats are different from the external threats an aircraft is subject to in flight.

Klinect et al. (1999) analysed the distribution of error types and the percentage of event that result in consequential outcomes. The most common error type they audited was intentional non-compliance errors, totalling 54 per cent, with two per cent becoming consequential. Proficiency error totalled five per cent, with 69 per cent becoming consequential. Operational decision error totalled six per cent, with 43 per cent becoming consequential. Klinect et al. (1999) states that during the most of audits, flight crews failed to respond to errors after they were committed; however, if the error turned into a UAS, then flight crews were very successful in mitigating their consequences.

2.7 Personal Pilot Mail-out Studies

It is suggested that human error contributes in some way to aviation accidents in at least 70–80 per cent of the time (Sarter & Alexander, 2000). Decades of research have now gone into efforts to reduce these causes. However, investigating human error in a complex technological-social environment such as aviation requires a systematic approach.

It is claimed that ‘very little is known about the actual flying activities patterns of pilots in civil aviation, particularly those in the recreational and general aviation sectors’ (O'Hare & Chalmers, 1999, p. 1). To help discover these causes, studies have focused on human error pilot groups and have attempted to gather information on a wide range of pilot groups; these studies include Platenius and Wilde (1989), Hunter (1995) and O'Hare and Chalmers (1999). An information gap exists about the flying activities and flying time of non-accident private (both rotary and fixed wing), glider, hang glider, microlight and other pilots involved in other aviation activities.

Platenius and Wilde (1989) carried out a large-scale personal pilot study of Canadian pilots covering life events, hobbies, humour and characteristics that might influence susceptibility to ‘pilot error’ accidents and their causes. This 302-item questionnaire can be likened to aid identification of the five hazardous attitudes, as described by Civil Aviation Safety Authority (2007). This questionnaire was sent out to approximately 70,000 holders of a Canadian pilot licence of which 12,701 (18 per cent) were usable responses. Approximately twelve per cent of respondents were from the main group of English-language speaking male pilots. This study did not elaborate upon defining the remaining respondent groups. Pilots were split into groups depending on the type of licence they held. This included airline transport, commercial, senior commercial, helicopter and private pilot categories.

Platenius and Wilde (1989) used a stepwise multiple discriminant analysis to show that ‘accident marker’ items can be used retrospectively to identify accident pilots. The analysis succeeded in classifying around 70 per cent of respondents correctly, according to their accident criterion. The intuitively categorised item-sets included some of the following: life events and preoccupations, risk acceptance, lack of humour appreciation, asocial or sedentary hobbies. Only six of their nineteen items were designed to examine the relationship between past accidents and impulsiveness,which was found to be significantly associated with accidents.

The focus of Hunter's (1995) Airman Research Questionnaire, sponsored by the FAA, was to collect flying experience data, underlying information about qualifications, participation in training activities, involvement in critical aviation incidents, usual practises in terms of planning and conduction of flight, pilot attitudes about flying issues and experiences. The primary goal of the research was to collect 'normative' data on the whole pilot population to determine accident risk factors and develop a database of pilot behaviours, attitudes and other characteristics to target the development of Aeronautical Decision Making (ADM). This survey involved a mail-out to a random sample of just under 20,000 active pilots (out of a total population of 561,486). Hunter (1995) states that almost 7,000 or 35 per cent of the overall sample group pilots completed the questionnaire.

Initially the survey was to be used to support research data on ADM. However, it was found that the data on US pilots who had not experienced an accident was not available. Information on characteristics on pilots who had experienced an accident was readily available and routinely tabulated (NTSB, 1989; as cited in Hunter, 1995); however, information was lacking for non-accident pilots. This was of particular concern for the 'ADM research, because of the need to focus interventions on those groups of pilots most at risk for accident involvement' (Hunter, 1995, p. 1). Previously, comparisons between characteristics of pilots that have been involved in an accident and those who had not been involved in an accident had not been possible.

Hunter (1995) divided results into three categories depending on the respondent's licence type: private, commercial and Airline Transport Pilot (ATP), which include both rotary and fixed wing. Results showed that nine per cent private pilots had experienced at least one accident, compared to eighteen per cent of ATP pilots. Just under half of private pilots had experienced at least one on-airport precautionary/forced landing, compared to 65 per cent of ATP pilots. A quarter of private pilots had flown VFR into Instrument Meteorological Conditions (IMC) at least once; seventeen per cent became ‘lost’ at least once, while 72 per cent had turned around because of bad weather at least once. About 45 per cent of private pilots had experienced a mechanical failure at least once, compared to 84 per cent of ATP pilots.

O’Hare’s and Chalmers’ (1999) study on ‘The Incidence of Incidents’ investigated the flying activities of general aviation pilots and their involvement in accidents and incidents. O'Hare’s and Chalmers’ (1999) study combined two nationwide surveys, in one mail-out, to approximately 8,500 CAANZ licensed pilots in New Zealand and received a response rate of sixteen per cent.

The first survey, related to pilot activity questionnaire, asked respondents to report flight time entries in a recorded logbook. This information was combined with the official accident data and showed substantial differences in comparative accident rates between different categories of aircraft. Other results indicated there was no sex differences found after controlling for time exposure (O’Hare & Chalmers, 1999).

O’Hare and Chalmers (1999, p. 2) stated that ‘it has been proposed that total hours flying experience is a risk factor for accident involvement and that there is a period of special vulnerability at ‘around the 100 hour mark’ (Olsen & Rasmussen, 1989, p. 17) or between “100 and 300 hours total” (Jensen, 1995, p. 101)’. O’Hare and Chalmers (1999, p. 2) ‘aimed to test this hypothesis by comparing the proportion of accident-involved pilots in these bands with the proportions found in the pilot population as a whole’. Results concluded that there was no evidence of any increase of accident involvement, and instead suggested that the trend went in the opposite direction. O’Hare and Chalmers (1999) also questioned the ability of most pilots to acquire and maintain the range of skills to continue to operate an aircraft safely in the range of conditions in which they operate. Private and recreational pilots recorded an average annual flight time of 22 hours, whereas 50 per cent of all commercial pilots in New Zealand are flying less than 102 hours per annum.

O'Hare's and Chalmers' (1999) second survey of exposure to hazardous events found the most common incident experienced was mechanical failure (49.4 per cent) followed by making an unscheduled on-airport landing (48.6 per cent). A quarter of all pilots surveyed had experienced VFR flight into IMC, while the least experienced events consisted of stalling an aircraft (11.5 per cent) and being lost (10.6 per cent). The majority of incidents grouped by phase of flight showed that most occurred during the cruise phase, while the majority of accidents happened during the landing phase.

O'Hare and Chalmers (1999) used Hunter's critical aviation incidents and included a section in which pilots could write their own personal experiences in either an accident or incident. In contrast, Hunter (1995) had only given pilots a list of possible scenarios that were preset and only required a frequency of involvement answer. In O'Hare and Chalmers' (1999) study, respondents were able to describe one incident or accident in more detail, which offered more insight into the vast variety of actual experienced events. This is somewhat similar to studies involving natural settings versus ad hoc settings. Shappell and Wiegmann (1997) and ICAO (2002) suggest that findings from a natural setting are more realistic and, hence, more relevant than findings from ad hoc settings, as the best results come from the observation of normal operations (Helmreich, et al., n.d.).

O'Hare and Chalmers (1999) replicated the 'Critical Aviation Incident' piece of Hunter's (1995) section in their study to ensure that pilots who were involved in more than one incident were able to provide frequency information for greater insight into their involvement into incidents. Results from the flight activity data collected by O'Hare and Chalmers (1999) showed substantial differences in comparative accident rates between different categories of aircraft. They found the accident rate for microlights was 176 times greater than for that of large fixed wing (>13,610Kg Maximum Take Off Weight [MTOW]) and eight times that of small fixed wing aircraft (<2,730Kg MTOW).

2.8 Pilot Involvement in Hazardous Events

Craig (2001) suggests that there is a zone in which pilots with certain range of flight hours are more likely to have an incident or accident. Craig (2001) obtained accident reports from the NTSB from 1983 to 2000 and cross-referenced accidents that have occurred among pilots during their first 1000 hours of flight experience. Craig (2001, p. 7) stated that '57 per cent of all accidents happened to pilots between 50 and 350 hours', which is consistent with previous other studies (e.g. Olsen & Rasmussen, 1989). Craig (2001) notes that once past 350 flight hours, accident numbers drop off and reduce significantly as pilot build on their experience and airmanship. Craig (2001) continued to break down the different types of aircraft accidents, including Controlled Flight into Terrain (CFIT), take off and landing, mid-air collisions, human factors, fuel management, night flying and icing accidents.

A similar study using the CAANZ database, Wackrow (2005) investigated only fixed wing accidents over a ten-year period, from 1995 to 2004. Wackrow (2005) identified several trends and factors but stops at assigning any common causes. Wackrow (2005) only focused on standard-category fixed wing aircraft, separating fixed wing into single-engine and multi-engine aircraft, excluding rotary wing, balloons, microlight, amateur built light aircraft, gliders and sports aircraft. The report covered 461 fixed wing accidents that resulted in 123 fatalities. Fixed wing aircraft accidents were experiencing a decline in the number of accidents up until 2000; however, during 2001 a small increase in accident frequencies occurred until 2003, where a new downward trend has started (Wackrow, 2005).

Wackrow's (2005) study identified pilot competency and flight currency issues as key safety indicators. The data show that pilots with low flying hours are at less risk than pilots with moderate flying time (200–2000 hours). However, these pilots have low 90 day currency and are no longer under supervision from an instructor; thus, a higher incident/accident risk is likely present. Wackrow (2005) describes pilots with the highest risk as someone who gains their licence after age 50 with one or two years' flying experience, whereas a pilot with the lowest risk appears to be someone who gained their licence before 35 years old with eight years of experience, who is also flying 40 hours (or more) every 90 days.

The Wackrow's (2005) study suggests that safety risk changes depending on the type of operation being performed. The level of safety required by law depends on the capacity of aircraft operations. Instrument Flight Rules (IFR) multi-crew passenger transport and training operations have a relatively low risk, compared to higher-risk Visual Flight Rules (VFR) single pilot operations. Multi-engine aircraft tended to have fewer accidents (ten), compared to single-engine aircraft (45). However, the average number of fatalities for multi-engine aircraft was 4.5 per accident compared to 1.9 per accident for a single-engine aircraft. Wackrow (2005) concluded that the first four years after obtaining a pilot's licence is the riskiest time period, and that the majority of pilots who have suffered an accident do so within the first year of obtaining a pilot's licence.

2.9 Threat and Error Management

This research uses Merritt and Klinect's (2006) threat and error management as a tool to 'promote a proactive philosophy and provide techniques for maximising safety margins despite the complexity of one's flying environment' (p. 1). Using the threat and error management technique enables the focus on the events that contributed to an incident rather than accidents. The higher frequency of incidents over accidents means that researchers are able to study more situations or 'events' in the current environment.

Previous research into human error and involvement in hazardous events has already been carried out using mail-out surveys (Platenius & Wilde, 1989; Hunter, 1995;

O'Hare & Chalmers, 1999), which gathered personal data about the pilot decisions and experiences in both a flying and non-flying activities. Using a mail-out survey allows pilots to remain anonymous; however, doing so has the potential to introduce unknown biases, generally associated with large nonresponse rates (Hansen & Hurwitz, 2004). Where others studies have used observational data to identify and locate sources of pilot error (ICAO, 2002; Klinect, Wilhelm & Helmreich, 1999). Observational data collection methods rely on memory or the interpretation of a jump seat observer.

Merritt and Klinect's (2006) TEM continues to build on previously developed conceptual models of human error, including LOSA and CRM. TEM is designed to help promote a proactive safety philosophy and provide techniques for pilots to maximise the safety margins of a flight. Merritt and Klinect (2006) have suggested that TEM has been around since the beginning of flight, starting with the Wright Flyer in 1903. Since then, tools and techniques have been conceptually developed industry-wide as training tools to reduce the number of safety occurrences.

Merritt and Klinect's (2006) definition of threats are events or errors that occur outside the influence of the flight crew; that increase the complexity of the flight; and that require crew attention and management if safety margins are to be maintained. Merritt and Klinect (2006) also state that UAS are defined as a position, speed, attitude or configuration of an aircraft that results from flight crew error, actions or inaction and that clearly reduces safety margins. An example of a UAS is a pilot who is not flying on their assigned altitude and who experiences a reduced separation event when flying unknowingly too close to another aircraft.

Threats and UAS are an extension of studies into human error and aviation safety. This technique aids in the identification of the risks and outcomes in each safety occurrence event, and to help explain why incidents and accidents occur. Pilot error provides only an internal focus on actions or inactions of the pilot and flight crew during safety occurrence investigation.

The inclusion of threats provides an option to investigators to include any external or internal events that may have affected the outcome on the flight crew. A UAS is the end situation or result when flight crews have become unsuccessful in mitigating the threat or error. Knowing possible end situations allows investigators to better understand how threats and errors are affecting flight crews in these situations. These findings are used for educational purposes to allow student pilots to be alert and take preventive/corrective actions timely.

2.10 Incident Reporting Systems

One early concept of an incident reporting system came from McFarland's (1946) book on Human Factors in Air Transport Design. In the 'analysis of near accidents', McFarland (1946) argued for pilots and engineers to suggest safety adjustments in systems design or operating procedures to help reduce the chance of an unsafe occurrence.

McFarland (1946) recognised the need to report events that reduce the margin of safety during the operation of an aircraft. He recognised that reporting such events and sharing them with other pilots and aircraft engineers/designers would increase the awareness of the possibility of an incident or accident. McFarland (1946) also stated that one of the biggest difficulties is enlisting complete confidence of the flight crew.

In 1975, the FAA established the ASRS (NASA, 2006) following the TWA 514 accident in December 1974. After the accident, the NTSBs recommended a reporting system be established to record safety-related occurrences (Blazy, 1997). Blazy (1997) describes the ASAP as a voluntary, confidential and non-punitive incident reporting system designed to provide information to the FAA and the aviation community to assist in reaching the goal of reducing and ultimately eliminating unsafe conditions in the aviation operating environment.

To encourage the submission of safety reports, control of the FAA funded program was transferred to an independent, non-regulatory agency, and grants limited immunity from FAA enforcement action (Blazy, 1997). NASA in 1976 became responsible for the collection, de-identification, analysis, issue alert messages, disseminate reports and conduct ASRS evaluations and reviews (Blazy, 1997). Over 474,000 safety reports have been submitted by pilots, mechanics, flight attendants and other airline personnel since implementation of the program in 1976 (NASA, 2006).

An allied safety reporting system focused on major US air carriers was established in October 1998. The Air Transportation Safety Oversight Service (AVO) was a new risk-management programme for airlines at the ten largest carriers in the United States (US Department Of Transportation, 2002). This new safety program also took a more non-punitive approach to the disclosure of errors.

The FAA also has a variety of other different programs to aid pilots and help the system to become increasingly safer. There are FOQA, LOSA and Advanced Qualification Program (AQP) (Helmreich et al., 1999).

ASAP gives pilots an option of reporting their 'close call', mistake or error without the fear of being punished. These safety programs are based on trust between the pilot and the report receiver that information remains anonymous, while at the same time it develops a safety culture. The introduction of a non-punitive incident reporting system (e.g. ASRS) is a step in the right direction in terms of the development of a reporting culture, and this is a crucial prerequisite for developing an 'informed safety culture' (Reason, 1998).

The two objectives for the ASAP program are '(1) voluntary submission of safety information that would otherwise be unknown through conventional means and (2) to use the information gathered so that corrective actions can be developed to reduce the potential of reoccurrence of incidents, accidents or safety-related problems' (Harper & Helmreich, 2003, p. 1). The model of threat and error management used with the ASAP program can be split into two parts: categorisation of the type of event that occurred, and the associated crews errors and threats that contributed to the occurrence event.

The second part includes the assessment of the severity of the event and categorisation of how each error and threat were managed by the crew (Harper & Helmreich, 2003). The popularity of this program is partly shown in the response rate of the willingness to submit a report. Harper and Helmreich (2003) state that one to three reports are received each day since its introduction in January 2002, while McFadden and Towell (1999) state that about 3,000 reports per year have been received from pilots at American Airlines alone, since its implementation. Wilson (1998, as cited in McFadden & Towell, 1999) stated that less than a half per cent of the errors committed would have been known to the FAA without the implementation of ASAP, while Harper and Helmreich (2003) suggest that 88 per cent of reported events were not known by the FAA or airline management. These programs have been so successful that similar reporting programs have been developed for other activities in the industry including ATC, dispatchers, maintenance and engineering (McFadden and Towell, 1999).

2.11 The CAANZ Safety Reporting System

The CAANZ is responsible for the collecting, analysing and the reporting of finding in safety occurrences in New Zealand (CAANZ, 2009). This reporting system covers all aircraft listed under Civil Aviation Rules (CAR) Part 12 Incidents, Accidents and Statistics (CAANZ, 2008a). Safety-related occurrence information is used by the CAANZ to help identify incident causes and prevent them happening again (CAANZ, 2009). This data and information are used to positively influence the behaviour of participants to achieve good safety performance of the aviation system (CAANZ, 2009).

Under CAR Part 12.1 (b), the following aviation activities operated under the associated parts are not required to report incidents: gyrocopters and parasails, unmanned balloons, kites, rockets and model aircraft operated under CAR Part 101, microlight aircraft operated under CAR Part 103, gliders operated under CAR Part 104, parachutes operated under CAR Part 105 and hang gliders operated under CAR Part 106 (CAANZ, 2008a).

Incidents as mentioned above are reported to their own respective association. For example, the New Zealand Hang Glider and Paraglider Association (NZHGPA) uses the 'OPMF07' form for incidents that are sent to the operations manager (NZHGPA, 2008), whereas gliding incidents use an OPS 10 form and are sent to the Regional Operations Officer (ROO) (Gliding New Zealand Incorporated, 2009). However, if incident trends do occur, these associations voluntarily submit this data to the CAANZ.

Aviation accidents are treated slightly differently under CAR Part 12.51, which states that if the accident causes serious injury or death, operators or witnesses shall notify the CAANZ as soon as is practical (CAANZ, 2002), regardless of the type of aviation activity. These accidents may be further investigated by the Transport Accident Investigation Commission (TAIC), depending whether TAICs logic guide recommends that an inquiry be opened. Part 1 considers the circumstances of the accident, have significant implications for transport safety, or may allow recommendations to increase overall safety. Part 2 states that if an inquiry has not been opened during Part 1 for an ICAO event, then the circumstances are to be explored further and reviewed again and any decision to open made at Part 1 (TAIC, 2007).

Voluntary safety reports are called Aviation Related Concerns (ARC) and are submitted by concerned witnesses of aviation events that have compromised the safety of the aviation system. ARCs are not focused on one single aviation activity; rather, they are designed to allow a reporting channel for all activity types. They are usually generated from a witness of an aviation activity, where a perceived drop in safety has placed people or property at a greater risk. One drawback is that this reporting channel is susceptible to personal bias and the motivation to report.

3.0 Research Methodology and Data

This research is based on an analysis of reported safety occurrences in New Zealand from 1998 to 2007. It aims to help increase safety margins within the aviation industry by identifying common threats and errors present in accident/incident reports. By identifying the frequency of threat and error, predictions can be made as to what threats and errors are most likely to occur during a flight. Merritt and Klinect's (2006) taxonomic of threats, errors and UAS (see Appendix 1) have been applied to each reported safety occurrence in the CAANZ database.

This research employs the predictive safety method by investigating reported historical events, followed by analysing each event to list threats and errors in the order of frequency. The approach classifies occurrences in the CAANZ database into the categories of threat, error and UAS and their associated subcategories on an annual basis. Additionally, aircraft type, flying hours, time of occurrence and reporting frequency are also compared. This research would then help flight operators and pilots better prepare themselves to react to the likelihood of specific threats or errors, if and when they occur.

This research refers to the term 'incidents', which has been shortened from 'aircraft incidents'. CAR Part 12.3 (CAANZ, 2008a) describes the following definitions:

"Aircraft incident means any incident, not otherwise classified, associated with the operation of an aircraft" (CAANZ, 2008a, p.5). These are referred to as 'incidents' for the remainder of this study.

"Aerodrome incident means an incident involving an aircraft operation and an obstruction located in the aerodrome area, a defective visual aid, a defective surface, or any other defective aerodrome facility" (CAANZ, 2008a, p.5).

"Airspace incident means an incident involving deviation from, or shortcomings of, the procedures or rule for avoiding a collision between aircraft or avoiding a collision between aircraft and other obstacles when an aircraft is provided with an air traffic service" (CAANZ, 2008a, p.6).

"Accident means an occurrence that is associated with the operation of an aircraft and takes place between the time any person boards the aircraft with the intention of flight and such time as all such persons have disembarked and the engine or any propellers or rotors come to rest, being an occurrence in which a person is fatally or seriously injured, the aircraft sustains damage or structural failure and the aircraft is missing or is completely inaccessible" (CAANZ, 2009c).

"Bird incident means an incident where there is a collision between an aircraft and one or more birds; or when one or more birds pass sufficiently close to an aircraft in flight to cause alarm to the pilot" (CAANZ, 2008a, p.6).

"Occurrence means an accident or incident" (CAANZ, 2009c).

"Security incident means an incident that involves unlawful interference" (CAANZ, 2008a, p.7).

3.1 Research Focus

The primary focus of this study is the classification of threats, errors and UAS in accordance with the phase of flight and category of aircraft. Further analysis pertained to time of occurrence, pilot flying hours at time of occurrence, geographic location of safety occurrence and which flight rules were used in what meteorological conditions.

Previous research into accidents and incidents was focused solely on pilot error. With the introduction of TEM, concepts such as threats and UAS have been introduced (Klinect, Wilhelm & Helmreich, 1999). Threats, also known as external errors

(Helmreich, 2000), and UAS have been combined with pilot error to create the next generation of CRM. The identification and classification of threats, errors and UAS give the aviation industry a framework for ways to increase the levels of safety.

3.2 The CAANZ Database

Reported safety occurrences from the CAANZ database provides data on real world events that have been witnessed or experienced by an observer or pilot. This study uses both voluntary reports from ARCs and compulsory incident reporting methods required by CAR 12.1b (CAANZ, 2008a). The CAANZ database uses both occurrences required to be reported under CAR Part 12—Accidents, Incidents and Statistics, and information from other non-mandatory aircraft classes (CAANZ, 2008a). These are reported to CAANZ with Form CAA005, CAA005D or automated submissions by centralised operations, Airways NZ and ARCs.

ARCs are voluntary reports about aviation safety concerns that can be lodged by any person with the CAANZ. These concerns are investigated and, where necessary, remedial recommendations made for the certificate holder, other organisations or the CAANZ itself (ICAO, 2002a). People submitting these reports can remain anonymous if requested. ARCs are treated like any other reported occurrence but remain voluntary. There has been no special treatment of ARCs in this research, and they are classified the same as other occurrences.

The safety occurrence database contains 4,009 occurrences from January 1992 until September 2008. This study only used data that was held electronically, under the discontinued reporting regulations, the Civil Aviation (Accident Investigation) Regulations 1978/112 Part III. This study only uses safety occurrences dated from 1 January 1998 because of different reporting requirements prior to the introduction of CAR Part 12 on 1 April 2007. Statutory regulations were different prior to this date, consequentially data utilised for this study is for the period 1 January 1998 to 31 December 2007. This totals 3,326 reported safety occurrences.

The dataset covers a large amount of variables (see Appendix 1 for a complete list). Examples include description of the event, times, date, locations, Global Positioning System (GPS) coordinates and weather. Data analysis of each reported safety occurrence is classified using Merritt and Klinect's (2006) TEM taxonomic, whichidentifies the different type of threats (Environmental and Airline), errors (Aircraft Handing, Procedural and Communication) and UAS.

The CAANZ occurrence database includes a wide range of aircraft classes, including model aircraft, microlights, parasails, hot air balloons, hang gliders, gliders, agricultural aircraft, general aviation aircraft/rotary wing and commercial aircraft. The boundaries of this study include New Zealand, all territorial islands (except Cook Islands) and New Zealand Oceanic control. The majority of safety occurrences come from the New Zealand Flight Information Region (FIR) and the Auckland Oceanic FIR, which totals 34 million square kilometres (Airways Corporation of New Zealand, 2009) of airspace.

However, there are seven occurrences where New Zealand registered aircraft have been involved in occurrences outside of the study boundary stated above. These have only been included because the number of occurrences is so small; the researcher is inclined to include them due to their minimal effect on results.

Gyrocopters and parasails, unmanned balloons, kites, rockets and model aircraft operated under CAR Part 101, microlight aircraft operated under CAR Part 103, gliders operated under CAR Part 104, parachutes operated under CAR Part 105 and hang gliders operated under CAR Part 106 (CAANZ, 2008a) are aircraft classes not included in the mandatory reporting system. However, these aircraft types are included when involved in an accident or incident that has compromised the safety of aircraft and been reported to CAANZ under CAR Part 12.

All safety occurrences that were entered into the CAANZ electronic database were made available to the researcher. This included safety occurrences that were open and still under investigation.

3.3 Data Processing

The CAANZ provided this researcher with a digital safety occurrence database in a Microsoft Access 2007® document format. After all duplicate and blank entries were removed, occurrences were listed in chorological order. Only safety occurrences that had a full year of reporting under CAR Part 12 rules were processed. A total of 3,595 safety occurrences were reported under CAR Part 12; however, due to incomplete data sets for years 1997 and 2008, these were not included. The initial safety occurrence database contained 4,009 individual safety occurrences, of which only 3,326 occurrences were analysed.

Types of occurrences included Accident, Incident, ARC, Airspace Incident, Aerodrome Incident, Bird and Security Occurrences. Refer to Appendix 4 for a list of all the occurrence database fields.

Not all the occurrence fields contained information for each safety occurrence. Obviously, some of the data fields would not be applicable to every situation. However, basic information, such as occurrence number, date and UTC time, occurrence type and code, location, flight rules, departure point, destination point, aircraft ID, aircraft registration and brief description are the only fields that have a complete data set.

The majority of the threat and error types used in the analysis were from Merritt and Klinect's (2006) taxonomic list. These were split into three categories of Threat, Error and UAS. Underneath these three categories are a middle set of subgroup taxonomies (the main threat, error and UAS categories). These taxonomies are displayed in Figures 8 to 13. The next or lowest level subcategories represent the specific threats, errors and UAS 'events' that are of interest in this study.

A tally chart was used to record the frequency of threats, errors and UAS present in each occurrence. Each safety-related occurrence is individually classified and takes into consideration all the supplied information from CAANZ. Threats, errors and UAS that are identified as present in an occurrence are marked down as a ‘1’ in a column that best represents each classification. If a specific threat, error or UAS was present twice or more in a selected occurrence it still was only counted as ‘1’. Threats, errors and UAS are only recorded once, as the research only records if a threat, error or UAS is present in the occurrence, not the frequency. After all occurrences are classified, they are split into the years they occurrence and are totalled for further analysis. Refer to Appendix 2 for a TEM taxonomic with threat, error and UAS frequencies.

3.3.1 Data Analysis

Data analysis of the Safety Occurrences database started with setting out the TEM taxonomic from Merritt and Klinect (2006) on a spreadsheet in Microsoft Excel 2007®. Seven individual worksheets were used for each of the categories of threats, errors and the UAS. Several other worksheets were created to store information in an orderly manner. The worksheets were called, respectively, Environmental Threats, Airline Threats, Aircraft Handling Errors, Procedural Errors, Communication Errors, UAS and Phase of Flight.

Each worksheet had listed occurrence numbers down the first column and each individual threat, error and UAS across the top row. Each safety occurrence was individually analysed by the researcher and entered into the worksheets. Each time a threat or error appeared in an occurrence, a ‘1’ was placed in the worksheet cell to indicate the nature of threat or error present. If no threat or error was present in the occurrence, the cell was left empty. When an aircraft entered into a UAS this was coded the same way as threats and errors under the most applicable UAS category.

Each safety occurrence was only coded once. For any threat, error or UAS detected during coding, a ‘1’ was entered into the appropriate box. If a specific threat, error or UAS repeated itself in a single occurrence, it was coded for the first event.

However, in some circumstances the same occurrence event can be reported twice but under different registration marks and occurrence numbers. These occurrences are treated as separate occurrences and were coded in the normal manner.

During coding for the phase of flight analysis, occurrences where two or more aircraft were present in the same phase were only coded once. However, if the aircraft were in different phases, both would be recorded accordingly. Therefore, results do not equal the 3,326 occurrences, as stated earlier.

A laptop and a second computer screen were used during the researchers' TEM classifications of the CAANZ occurrence database. This enabled occurrence data to be displayed on one screen, while data was entered into the TEM taxonomic on the other. The data were interpreted, analysed, coded and recorded, in order to identify the frequency of threats and errors present in each occurrence. After completing the coding of the database, frequency totals were derived and graphs were created to facilitate interpretation of the TEM and UAS data.

The safety occurrence database was analysed a second time by the researcher for the purposes of cross-checking the data entry and interpretation of each occurrence brief for accuracy. Approximately ten per cent of occurrences required amendment. Usually this was simply a matter of moving the data entry into its correct cell. About 0.2 per cent of occurrences were interpreted incorrectly, due to incorrect classifcation.

Upon finishing the initial cross-checking, an extra 1,000 randomly selected occurrences were rechecked for a third time, from numbers generated by a calculator. This was done for assurance reasons to confirm that no occurrences had been misinterpreted and were correctly coded. After finalising the data entry, a double check of the occurrence number, location, time, date was conducted and the totals for the occurrences all added up to the correct totals. This was undertaken before any graphs were made to ensure that all safety occurrences were accounted for.

Researching the location of occurrences required using a combination of internet-based maps and/or GPS coordinates that were included with the CAANZ database. The majority of the well-known locations were not difficult to separate into each region. Unknown locations were looked up using internet-based maps (either Google Maps (maps.google.co.nz) and Wises (www.wises.co.nz). If these locations were not found on the map or by an internet search engine, GPS coordinates were used to pinpoint the location of the occurrence site. This was conducted on the website MapQuest (www.mapquest.com/maps). Geographic locations that were not located by either means were placed in the unknown column.

The class of aircraft (e.g. fixed wing, helicopter) was able to be determined from the aircraft registration. Using the CAANZ allocation of registration marks, different types of aircraft were identified by filtering aircraft registrations in the registration column of the database.

In New Zealand, helicopters are 'ZK-H**' or 'ZK-I**', gliders are 'ZK-G**', balloons are 'ZK-FA*' and 'ZK-FB*', and gyrocopters are 'ZK-RA*', 'ZK-RB*', 'ZK-RC*' and 'ZK-RD*'. For aircraft that do not have registration marks (e.g. hang gliders, parapentes, kites), a filter was used to identify the aircraft types in the 'Brief Description' column.

The majority of aircraft reported in ARCs did not have aircraft registrations. This might be due to a witness' inability to clearly identify the aircraft registration mark. However, all ARCs identified an aircraft class. Word filters were used to locate occurrences with these aircraft classes: model aircraft, hang gliders, parapentes, kites, balloons, microlights and parachutes.

Data present flight time in hours of the Pilot in Command (PIC). These included total flying time, last 90 days flying time and flight time on type. Occurrences that had no aircrew flight time entries were excluded from the data. Occurrence types were then divided into accidents, incidents and airspace incidents and grouped by flight time.

Occurrences without flight time information on pilot flying hours were excluded from each occurrence category. Pilot flight time has been divided up into the three different occurrence categories depending on the CAANZ classification (Accident, Incident and Airspace Incident).

‘Hours on type’ (see Figure 25) shows how many hours a pilot has been flying on a particular type of aircraft before they experience a safety occurrence. If a pilot experiences an incident at 210 flying hours on type but has 400 hours of total flight time, then this would be marked down in the 200–249 column in blue.

Graphs involving flight rules are divided by the meteorological conditions at the time and by the flight rules under which the pilot was operating. These were VFR or IFR and VMC or IMC. The data was tabulated by year the occurrence happened.

3.3.2 Data Classification Examples

To illustrate the mechanics of data coding, examples are given below.

The text below demonstrates the classification of occurrence number 03/3123:

> *The left passenger side rudder pedal turned slightly due to insufficient tension on the pedal restraining clip and it snagged the right pedal, causing a minor pedal jam.*

This was classified as Flight Controls, Maintenance Error in Airline Threats and Incorrect Aircraft Configuration, Flight Control under UAS.

An example of occurrence number 01/3587:

> *Strike. Up to 3 unknown. Final RWY02.*

This was coded as a Bird Strike, an environmental threat.

Example 07/320 illustrates occurrence brief with a lot more information about what happened:

> *Airways reported that ZK-*** was a VFR flight to NZOM. The WN Radar Controller advised WB TWR that ZK-*** was transiting controlled VFR across Cook Strait to NZOM and would call WB TWR for entry to the WB CTR/D. Subsequently a radar target was observed to enter the WB CTR and transit direct to NZOM <u>without a clearance</u>. Numerous attempts to contact the aircraft failed. The pilot advised WB TWR by phone that he was <u>transmitting</u> on an <u>incorrect radio frequency</u> with no reply and <u>assumed</u> WB TWR was off watch.*

This occurrence was coded Radio/Transponder Frequency in Aircraft Handling Errors, Entering Controlled Airspace without Clearance, SOP Adherence in Procedural Errors, Missed Calls in Communication Errors and Entering Military/Controlled or Restricted Airspace without Clearance as a UAS.

4.0 Results and Discussion

To aid in TEM analysis of the CAANZ occurrence database, a survey was conducted to help the researcher identify threats, errors and UAS present in each occurrence. A questionnaire was designed to increase the classification reliability before the researcher undertook classifications of the entre database (see Appendix 6). By using a percentage of agreement test and Cohen's Kappa test, responses were analysed to find agreement and reliability with the researcher.

Cohen's Kappa was chosen because it is recognised as an unbiased evaluation of classifier accuracy (Ben-David, 2008), while the percentage of agreement test was used due to its simplicity.

To test the reliability of the researcher's coding of the occurrence database on to the TEM and UAS framework, a coding reliability check was undertaken to test the level of coding agreement. Ten flying and academic staff from Massey University School of Aviation were asked to participate in the reliability check. Eight respondents completed the task.

These tests enabled the researcher to modify their TEM classifications techniques for the remainder of the CAANZ occurrence database. The researcher studied each of the respondents' completed questionnaires and noted the differences between respondent's and the researchers' own classifications. Any differences in the TEM classifications were noted, compared and analysed to perceive why they were different. Occurrences where respondent and researcher did not agree lacked detail in the CAANZ database brief and were geographically located in areas where several different classes of airspace converged.

TEM classifications for the remaining occurrences from the CAANZ occurrence database were completed after the reliability survey was analysed. After identifying the areas of common agreement by the participants, the researcher was able to amend their classification technique to incorporate any missed classification techniques.

Threat, error and UAS classifications were tallied on the TEM framework taxonomic. Threats, errors and UAS were further split up into small subcategories, including Environmental and Airline threats, Aircraft Handling, Procedural and Communication Errors. These are further broken down into even smaller subcategories. For example, Environmental Threats are divided further into Adverse Weather, ATC, Airport and Environmental Operational Pressure (EOP) (see Appendix 1). Results are tallied and displayed in graphs according to the year the occurrence happened, for an annual analysis.

4.1 Classification Consistency Results

A percentage of agreement test and a Cohen’s Kappa test were used to find agreement and reliability in the researcher's results. The null hypothesis accepts the researcher’s TEM classifications, which shows a high level of agreement and reliability between the researcher and each respondent.

The overall percentage of agreement was 68 per cent (see Table 2), which failed to reach a level of significance. Only half of the respondents in the Cohen’s Kappa test were significant; therefore, the null hypothesis failed to be rejected. Higher agreement results may have been achieved if a larger sample size of both the number of respondents, the number of occurrence to be classified and more information was made available from the CAANZ.

Table 2. Classification Consistency Results

	Cohen's Kappa	Significance	Percentage of Agreement
Researcher and R1,	$K = 0.127$	$\underline{p = 0.001}$	Pr(*a*) = 0.78
Researcher and R2,	$K = 0.270$	$\underline{p = 0.000}$	Pr(*a*) = 0.74
Researcher and R3,	$K = 0.074$	$p = 0.190$	Pr(*a*) = 0.68
Researcher and R4,	$K = 0.340$	$\underline{p = 0.000}$	Pr(*a*) = 0.76
Researcher and R5,	$K = 0.077$	$p = 0.160$	Pr(*a*) = 0.56
Researcher and R6,	$K = 0.195$	$\underline{p = 0.001}$	Pr(*a*) = 0.72
Researcher and R7,	$K = 0.066$	$p = 0.197$	Pr(*a*) = 0.61
Researcher and R8,	$K = 0.080$	$p = 0.148$	Pr(*a*) = 0.57

Results from four respondents had a significant agreement with the researcher, whereas the other four had little or no significance. The mean of the percentage of agreement was 68 per cent. The lowest score of agreement was respondent eight with 56 per cent, while the highest was respondent one with 78 per cent. The lowest three scores of agreement ranged between 56 per cent and 61 per cent, while the fifth highest score was respondent three, just outside the significance range at 68 per cent.

The end of the classifications answer sheets contained questions on personal involvement and flight experience of the respondents. There were only two respondents with 76 per cent and 72 per cent of agreement, who had over 2000 hours of flight time over nine years. Also, one respondent had a 61 per cent of agreement, with 4000 flight hours over eighteen years' experience. The respondent's aviation experience did not influence any of the results of the questionnaire.

The researcher expected a percentage of agreement to be around 60 per cent, when taking into consideration the small sample size and large variations in flying experience. The overall percentage of agreement reached 68 per cent, which did not achieve statistical significance of 0.001 or greater. The researcher was expecting an average of 75 per cent agreement with the respondents in identifying the presence of threats, errors and UAS. Feedback from the respondents indicated that critical information was missing from the occurrence description brief. Therefore, the researcher does not accept the current TEM classifications.

Threats, errors and UAS have been displayed according to the year they occurred and the subcategory to which they belong. This gives a year-on-year data analysis where annual results can be interpreted. Results are not separated according to the type of flying operation under which they occur.

4.1.1 Classification Reliability

The researcher provided the respondents with no TEM training. The researcher relied on the respondents' previous aviation knowledge and experience to complete the TEM reliability check. Merritt and Klinect's (2006) definitions of threat, error and UAS were provided to the respondents on the reliability check form, in order to ensure uniform definition of coding to the respondents.

Six of the eight respondents completed additional personal data about their flying experience, current job position and involvement in the aviation industry. Respondent PIC flying hours ranged between eight and 4000. The average time involved in the aviation industry was nine years. Five of the eight respondents were current full-time flight instructors, while the other three were involved with aviation research.

Participant classifications were analysed using Cohen's Kappa using the computer program SPSS version 17.0 to calculate the crosstab equations. After that, a percentage of agreement was calculated.

The reliability check measures each participant's classifications against the researchers. There are no inter-rater comparisons made against each participant's classifications. The participant's classifications were checked for any clustering of 'present' responses that did not match the researchers. Any clustering of classifications found was checked against the information provided in the CAANZ database and reviewed. The researcher reviewed their own classification techniques to pick up these missed threats, errors and UAS.

There were some disagreements between the participants and researcher over the classifications of each occurrence. These may include interpretations of the occurrence brief or consideration of other factors, such as airspace boundary conflicts, prevailing weather conditions or the involvement of other aircraft.

A briefing with sample occurrences would improve average participant agreement. By providing a TEM framework briefing, participants would better understand what is to be achieved and how, and what the participants have to do to complete the classification exercise.

Providing example occurrences and model TEM classifications for the participants to study and would give the participants a better understanding of classifications and the boundaries of different threats, errors or UAS. Participants would also be able to familiarise themselves with the TEM taxonomic and have time to ask the researcher questions.

TEM classification consistency and reliability survey should have been repeated for a second time to ensure that both consistency and reliability is achieved and that all respondents achieve significant agreement. Repetition of the survey may increase the number of significant agreements with the research and therefore lift the reliability of the TEM classifications.

4.1.2 Classification Consistency Checks

Merritt and Klinect's (2006) TEM taxonomic is made up of 161 different threat, error, UAS categories and five phases of flight. The respondents identified whether or not a threat or error was present in each of ten reported occurrences, and which UAS resulted. To reduce the effect of noise during reliability testing, comparisons that did not total greater than or equal to ‘one’ were excluded from the kappa calculations. This reduced the number of comparisons to n = 267.

Reasons for classification disagreements stem from several areas, including the quality of the data provided, the way the taxonomic has been set out and the understanding of the limit envelope of each specific threat, error or UAS. In some cases, the occurrence information provided by the CAANZ was limited and the content not rich enough to make an informed analysis to determine the presence of a threat, error or UAS. The taxonomic could have been changed to include a written answer from the respondent, so that the respondent can state clearly which threats, errors and UAS were present in the occurrence.

A group briefing before the respondents started the questionnaire could possibly increase the agreement between the researcher and the respondents. This would make it consistent with Klinect et al. (1999) as they held a briefing before they conducted their LOSA audits on flight decks, which enforced consistency among LOSA auditors. In addition, an inter-rater agreement would show whether the respondents agreed with one another, not just with the researcher. This would pick-up areas of classification groupings that the researcher might have failed in identifying.

4.2 Threats

Threats made up 23 per cent of total TEM results (see Figure 19). These were split into two main categories: Environmental (17 per cent) and Airline (6 per cent). Results indicated that Terrain with 3.5 per cent and Traffic with 3.7 per cent consisted of the majority of total subcategory events (see Table 7). The most frequent Environmental and Airline threats combined make up 11 per cent, or half of total classifications (see Figure 7). These were the most reported threats in the database. The frequency of Airline threats included Systems, Other Aircraft Threats and Engines, made up just over 3 per cent of total threat and error classifications. The most frequent Environmental and Airline threats combined make up 11 per cent or half of total classifications (see Figure 7).

Results displayed in Figure 7 represent the total percentages of the most frequent threats. After rounding results to one decimal place, only results that scored 0.7 per cent and over are presented. For a subcategory threat to make up 1 per cent of total classifications, there would have to be 211 individual event occurrences.

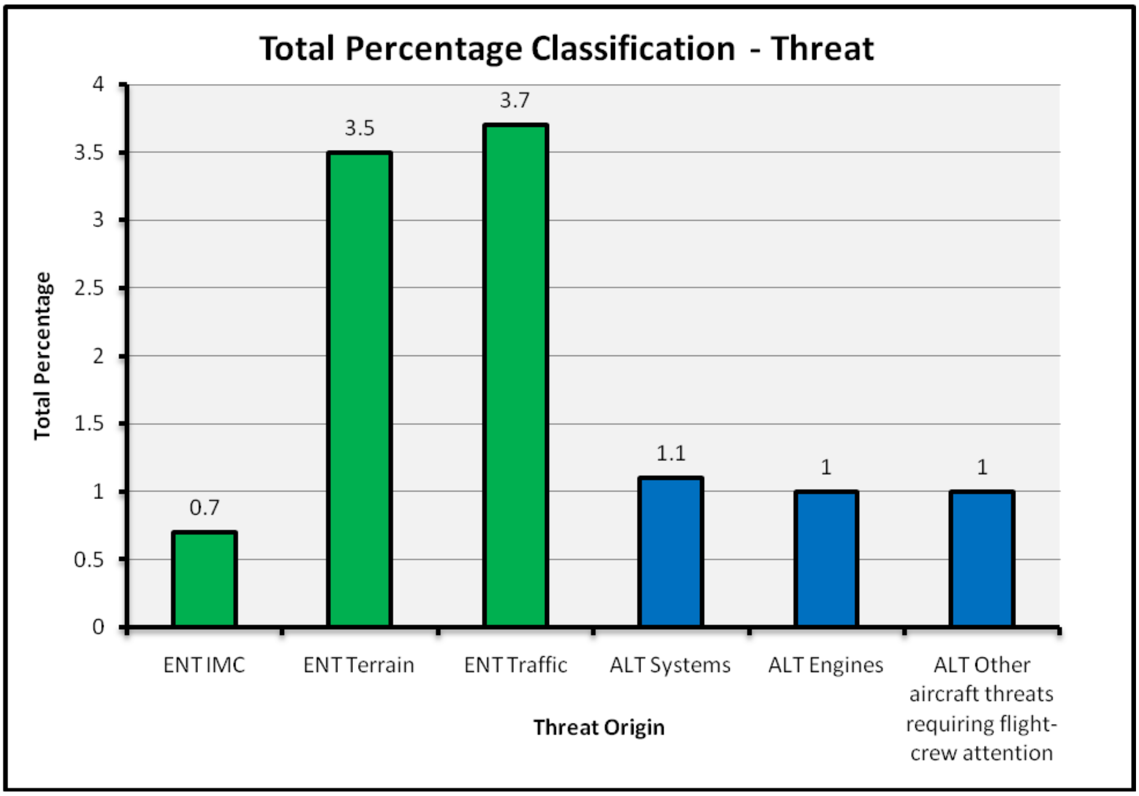
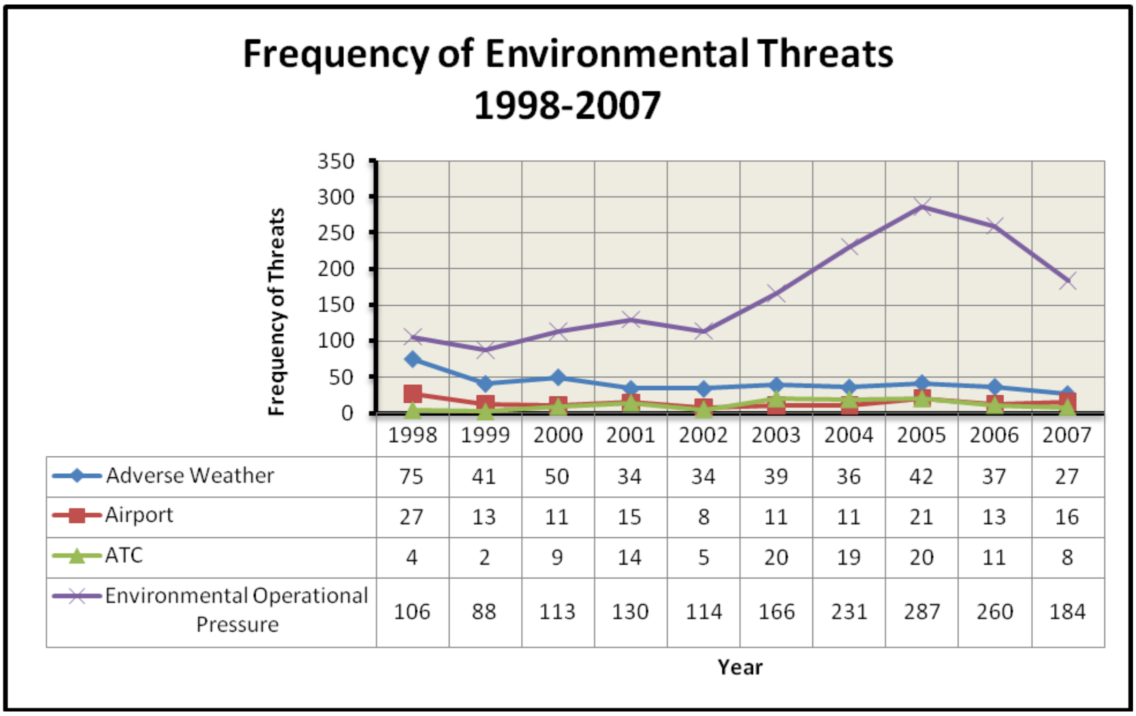


Figure 7. Total Percentage Classification —Threat

Note: ENT, Environmental Threats; ALT, Airline Threats

4.2.1 Environmental Threats



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Adverse Weather	75	41	50	34	34	39	36	42	37	27
Airport	27	13	11	15	8	11	11	21	13	16
ATC	4	2	9	14	5	20	19	20	11	8
Environmental Operational Pressure	106	88	113	130	114	166	231	287	260	184

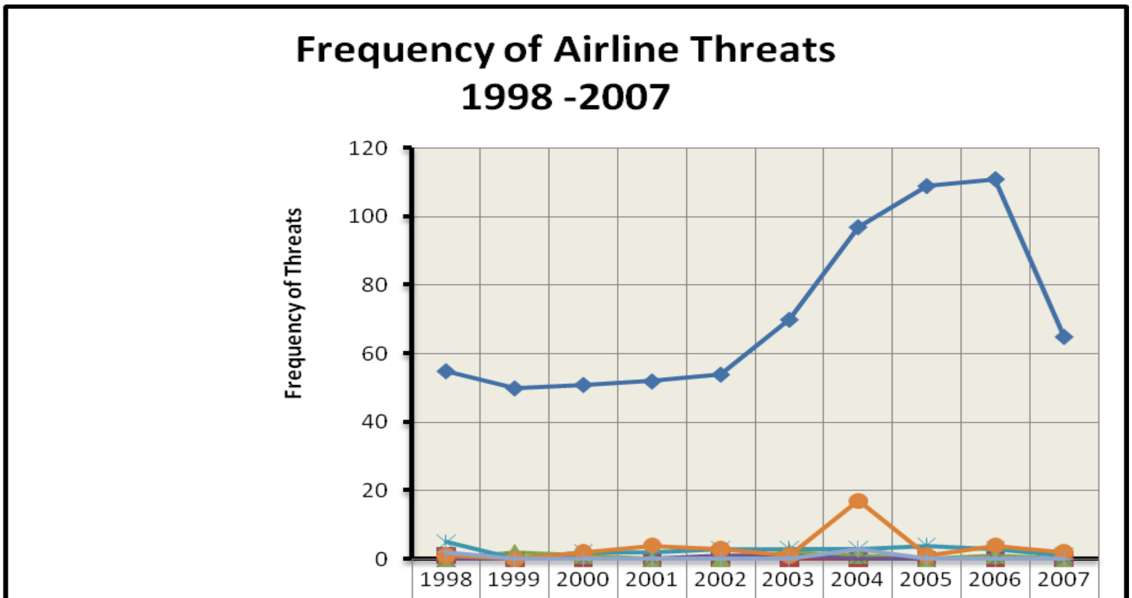
Figure 8. Frequency of Environmental Threats

Environmental threats originate from the external uncontrollable surroundings of the pilot and aircraft. EOP is the most commonly classified environmental category threat (see Figure 8). EOP frequencies peaked in 2005 before dropping off to levels previously seen in 2003. Events that contributed to the majority of EOPs were Terrain and Traffic threats, while the number of Adverse Weather occurrences has also steadily declined. The major threat contributor was IMC conditions. Airport category events remained constant over the research period. Contaminated Runway/Taxiway threats had been classified as a major contributor to this subcategory. The most frequent ATC category event was Controller Error threats.

4.2.2 Airline Threats

A total of 790 Airline Threats were classified in the CAANZ database. Figure 9 shows the Aircraft category had the highest number (90 per cent) of subcategory events. The Aircraft category comprises of Systems (1.09 per cent), Other Aircraft Threats

Requiring Flight Crew Attention (1.04 per cent) and Engines (0.97 per cent). The rest of Airline Threats involved Ground Maintenance and Ground/Ramp categories.



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Aircraft	55	50	51	52	54	70	97	109	111	65
Airline Operational Pressure	1	0	0	0	0	0	0	0	0	0
Cabin	0	2	1	0	0	2	1	0	1	0
Dispatch/Paperwork	0	0	0	0	1	1	0	0	0	0
Ground/Ramp	5	0	2	2	3	3	3	4	3	1
Ground Maintenance	1	0	2	4	3	1	17	1	4	2
Manuals/Charts	2	0	0	0	0	0	3	0	0	0

Year

Figure 9. Frequency of Airline Threats

Results from Klinect, Wilhelm & Helmreich (1999) research show more pilot involvement in mechanical failure incidents than this research indicates. O'Hare's and Chalmers' (1999) research into hazardous events found that 50 per cent of the pilots surveyed had experienced a mechanical failure, while 8 per cent of pilots have experienced it four times or more. Hunter's (1995) survey results suggest that 45 per cent of private, 67 per cent of commercial and 84 per cent of air transport pilots have experienced a mechanical failure over pilots who have not experienced a mechanical failure. When interpreting these results, exposure and aircraft complexity needs to be taken into consideration. However, all studies show some involvement with some sort of mechanical failure.

Only seven reported threats originated from the Cabin category, whereas the majority of these threats came in the form of distractions. Two sources of threat that originated from the Dispatch/Paperwork category were Load Sheet errors and Changes or Errors in paperwork. Even minor errors in load sheets may cause severe consequences. Miscalculations in take off performance documentation, for instance caused an Emirates A340 to suffer from a tail strike because data entries were 100 tons under weight (Aviation Safety Network, 2009). Therefore, mitigating strategies for these sorts of errors may include cross-checking of inputs from the other pilot.

4.3 Errors

According to Figure 19, errors made up a total of 77 per cent. The error categories that were the most frequent throughout the study period were aircraft handling errors (see Figure 11) and procedural errors (see Figure 13), which both made up 31 per cent, while communication errors (see Figure 13) made up the rest (15 per cent).

Figure 10 displays results for the most commonly reported errors. The figure shows that Deviation from SOPs was the highest recorded error, while Missed Calls was the second most frequent. For a subcategory error to make up 1 per cent of total classifications, 211 individual events would have to occur.

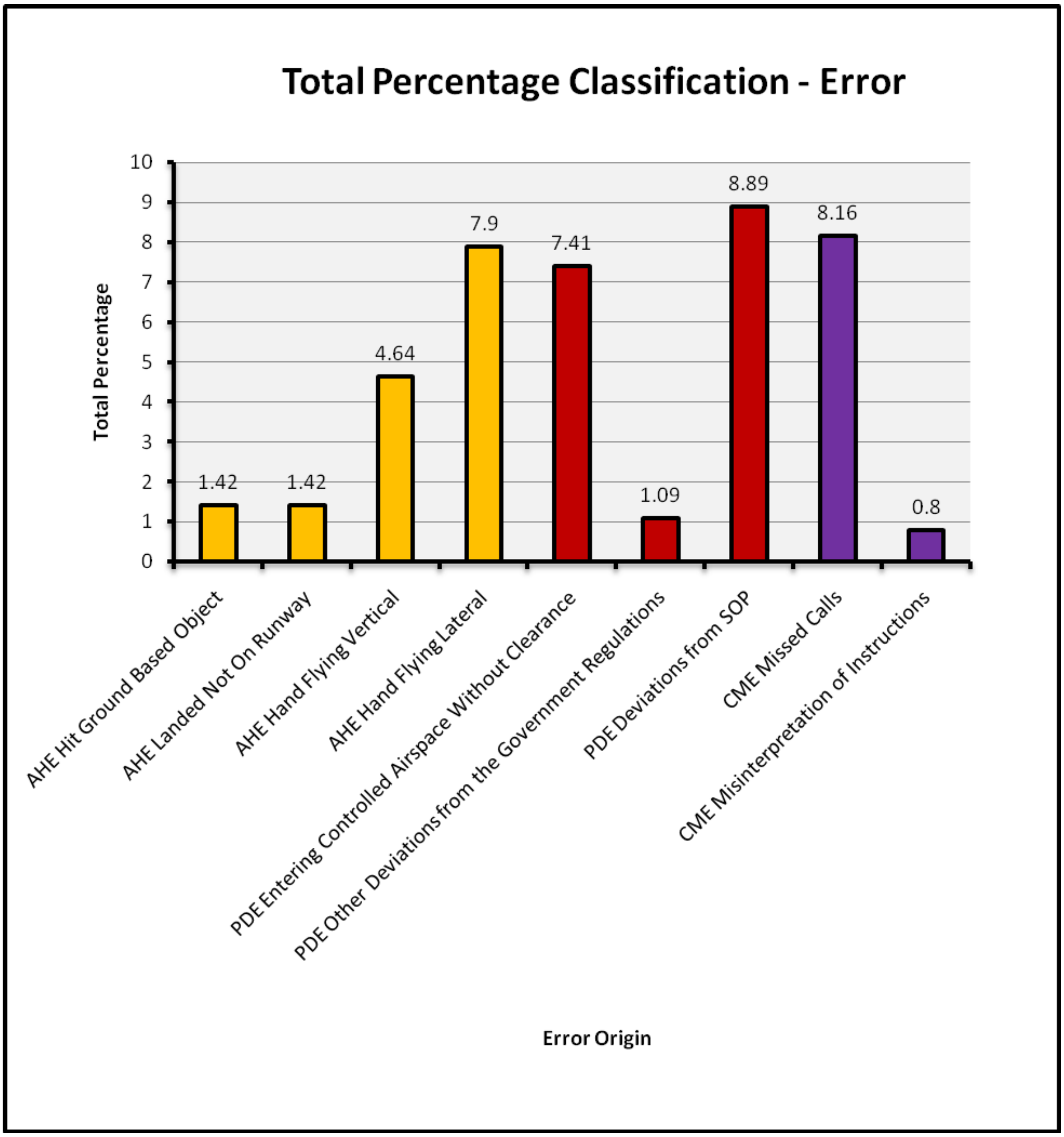
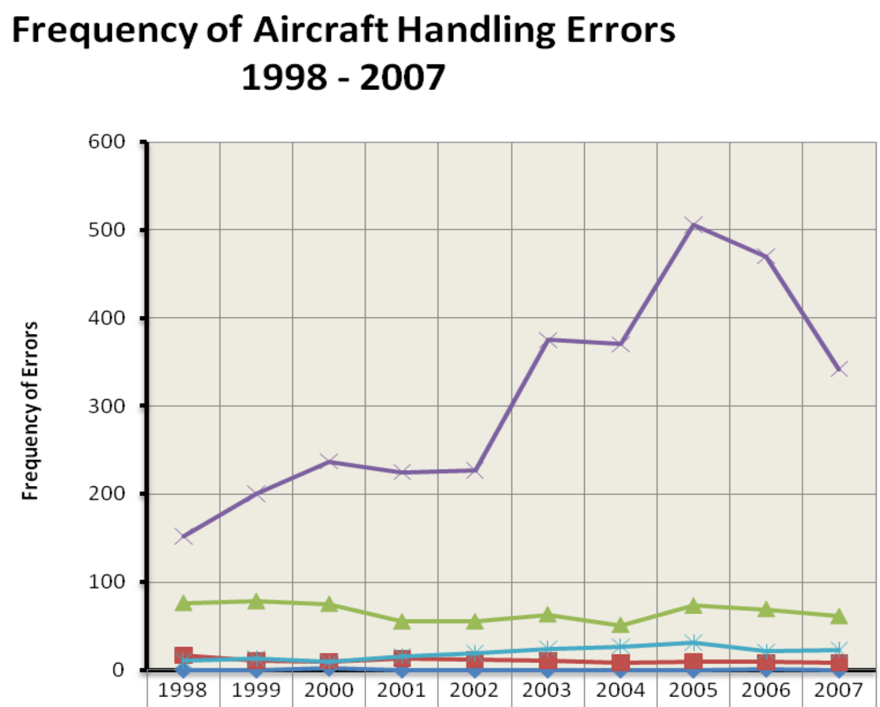


Figure 10. Total Percentage Classification —Error

Note: AHE, Aircraft Handling Error; PDE, Procedural Error; CME, Communication Error

4.3.1 Aircraft Handling Errors

A total of 4,066 errors were classified as Aircraft Handling Errors (see Appendix 2). Manual Flying was the most frequent Aircraft Handling error category, with 3,104 classifications. This was followed by Ground Navigation totalling 707 classifications (see Figure 11).



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Automation	0	0	2	0	0	0	0	0	1	0
Flight Control	17	11	10	13	12	11	8	10	9	8
Ground Navigation	76	78	75	55	55	63	51	73	69	61
Manual Flying	152	200	237	225	227	375	370	506	470	342
Systems/Radio/Instruments	11	13	9	16	19	24	27	31	21	23

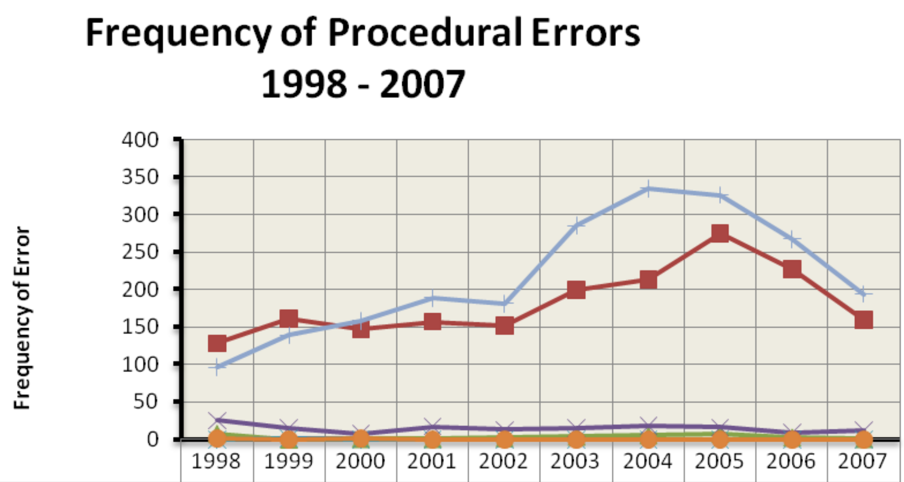
Year

Figure 11. Frequency of Aircraft Handling Errors

Manual Flying was the most frequent Aircraft Handling error category (see Figure 11). This subcategory was made up of Hand Flying Lateral Deviations and Hand Flying Vertical Deviations. Figure 10 shows an increase in the number of reported errors until 2005, when frequencies start to drop off. Ground Navigation errors show a slight overall decrease in the reported occurrences and were the second most frequent Aircraft Handling subcategory. The majority of these were made up of Landing Not on Runway and Hitting a Ground Based Object errors. Events found in Systems/Radio/Instruments showed a slight increase in the number of reported occurrences. These included Radio/Transponder Frequency Issues, where over half of the Flight Control subcategories were Power Setting issues.

Subcategory events in Manual Flying were dominated by Hand Flying Lateral (7.9 per cent) of errors followed by Hand Flying Vertical (4.6 per cent). Other errors included Failure to Hold Short (0.7 per cent), Low Altitude Flying (0.51 per cent) and Inadvertent Stalls (0.2 per cent). Stall results in Table 4 may suggest that not all stall events are reported to the CAANZ. Results from O'Hare and Chalmers (1999) show at least 11 per cent of pilots surveyed had experienced an inadvertent stall once. In addition, Hunter (1995) reports that about 5 per cent of all pilots by license category had experienced an inadvertent stall.

4.3.2 Procedural Errors



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Briefings	1	1	1	0	0	2	0	0	0	0
Callout	128	161	147	157	152	199	213	275	227	159
Checklist	8	0	1	1	2	4	6	8	3	1
Documentation	25	15	8	17	13	15	18	16	9	12
Pilot Flying / Pilot Not Flying	0	1	0	0	0	0	0	0	0	0
SOP Cross verification	1	0	1	0	0	0	0	0	0	0
Other Procedural	96	139	158	189	181	285	335	326	267	194

Year

Figure 12. Frequency of Procedural Errors

The majority of procedural errors were coded in the ‘Other Procedural’ subcategory, followed by Callout errors (see Figure 12). Both these error subcategories show an increase in the number of reported occurrences until 2005, where both subcategories start to reduce. Individual events that populated the Other Procedural subcategory included Deviations from SOPs, Other Deviations from Government Regulations and Flight Manual Requirements. Events classified in the Callout category included Entering Controlled Airspace without a Clearance and Omitted/ Incorrect Approach Callouts.

There were a total of 4,178 Procedural error classifications, constituting 31 per cent of total threats and errors (see Appendix 2). The most frequent errors reported were Deviations from SOPs (8.9 per cent) and Entering Controlled Airspace without Clearance (7.4 per cent) (see Table 5). There was also a noticeable lack of classifications in error categories: Briefings, SOP Cross-verification, Pilot Flying/Pilot Not Flying and Checklist.

The Other Procedural error category had the majority of reported errors, with 52 per cent, whereas the Callout category had 43 per cent (see Figure 12). The main subcategory events, including Deviations from SOPs, made up 8.9 per cent of total threat and error classifications, while Other Deviations from Government Regulations resulted in 1.1 per cent of total classifications. Even though SOPs Deviations made up the majority of Procedural errors, even more of these errors could have gone unreported. Due to the nature of SOPs and pilots' perception of reporting, these types of procedural errors may result in a form of sanction from either an aeroclub or the CAANZ.

Entering Controlled/Restricted/Military Airspace without Clearance consisted of the highest Procedural error, with 7.4 per cent of total classifications (see Figure 10). This was the most common procedural error in the Callout category. Other results included Omitted Take Off and Approach Callouts, both equalling 0.5 per cent.

Documentation category errors made up 3.5 per cent of all Procedural errors. The most frequent errors were Forgetting Maps/Important Flight Documents (0.22 per cent), followed by Failing to Check Notices To AirMen (NOTAM) (0.13 per cent); Misinterpreting Items on Paperwork was only 0.12 per cent. The occurrence brief in the CAANZ database indicated that pilots reported that they realised they had forgotten documentation only after they had tried to find a particular piece of paperwork/map. The occurrence brief also indicated that pilots reported misinterpreting items in paperwork when under high pressure and reading under poor light conditions.

4.3.3 Communication Error

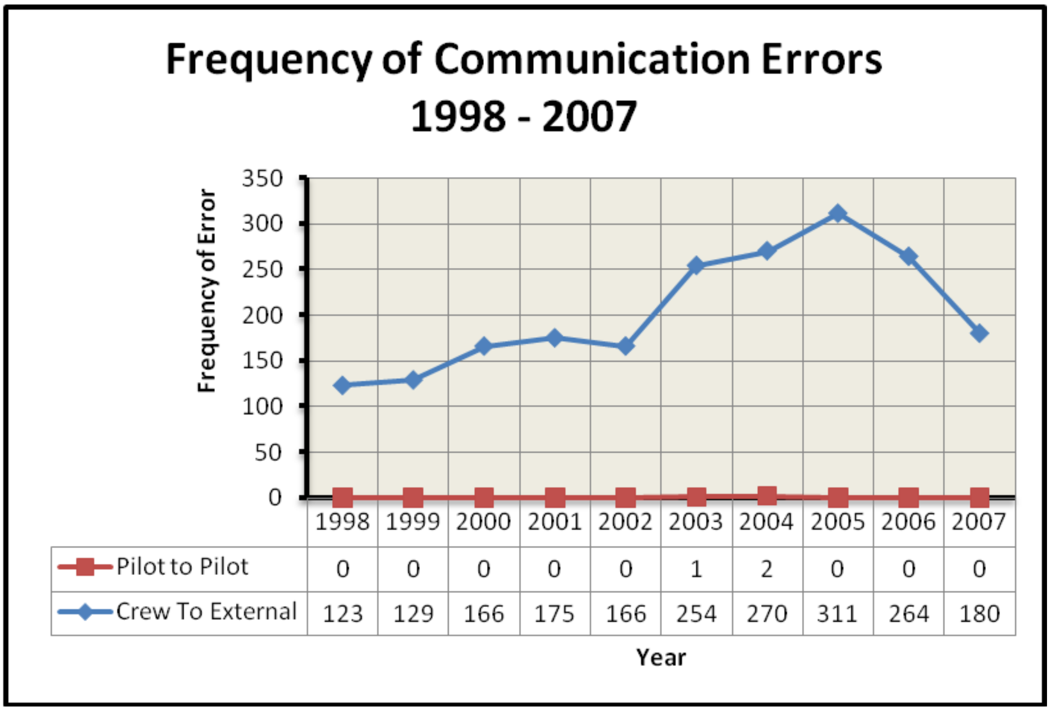
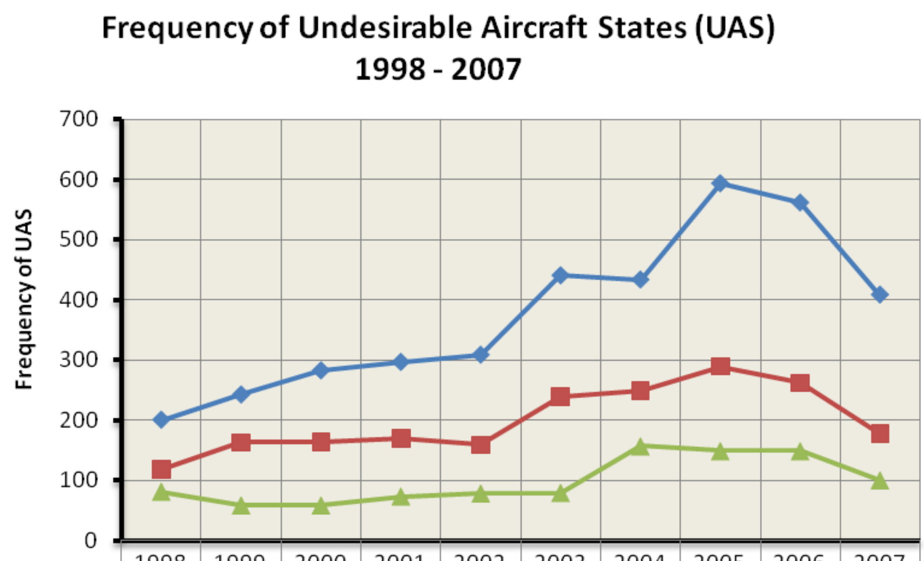


Figure 13. Frequency of Communication Errors

The majority of communication errors in Figure 13 are categorised as Crew to External. Events pilots experienced most often were Missed Calls (see Figure 10), followed by the Misinterpretation of Instructions. There were very few reported pilot to pilot miscommunications.

The most frequent communication error category was Crew to External (see Figure 12). The most prominent subcategory event was Missed Calls (8.16 per cent), then Misinterpretation of Instructions (0.8 per cent) and Failed to Report/Terminate Flight Plan SARWATCH (0.29 per cent) (see Table 6). The remainder of the subcategory errors were insignificant in frequency.

4.4 Undesirable Aircraft States



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Incorrect Aircraft Configuration	81	58	58	73	78	79	157	149	149	100
Ground Navigation	118	163	164	170	159	239	249	289	262	178
Aircraft Handling	200	242	282	296	308	440	433	593	561	408

Figure 14. Frequency of UASs

In Figure 14, the most commonly coded UAS categories was Aircraft Handling, followed by Ground Navigation. Both these subcategories show increasing frequencies until 2005, before dropping off to five-year lows. The most frequent Aircraft Handling events were Lateral Deviations, followed by Vertical Deviations. Subcategory events in Ground Handling were made up of Entering Military/Controlled or Restricted Airspace without Clearance, followed by Runway/Taxiway Incursions. Events that made the majority of Incorrect Aircraft Configuration subcategory were Flight Control, followed by Engine and Hydraulic Systems/Doors/Exterior/Undercarriage.

Figure 14 lists the results of the UAS categories where it clearly shows that Aircraft Handling UAS experiences the majority of events (56 per cent), Ground Navigation (30 per cent) and Incorrect Aircraft Configuration (15 per cent).

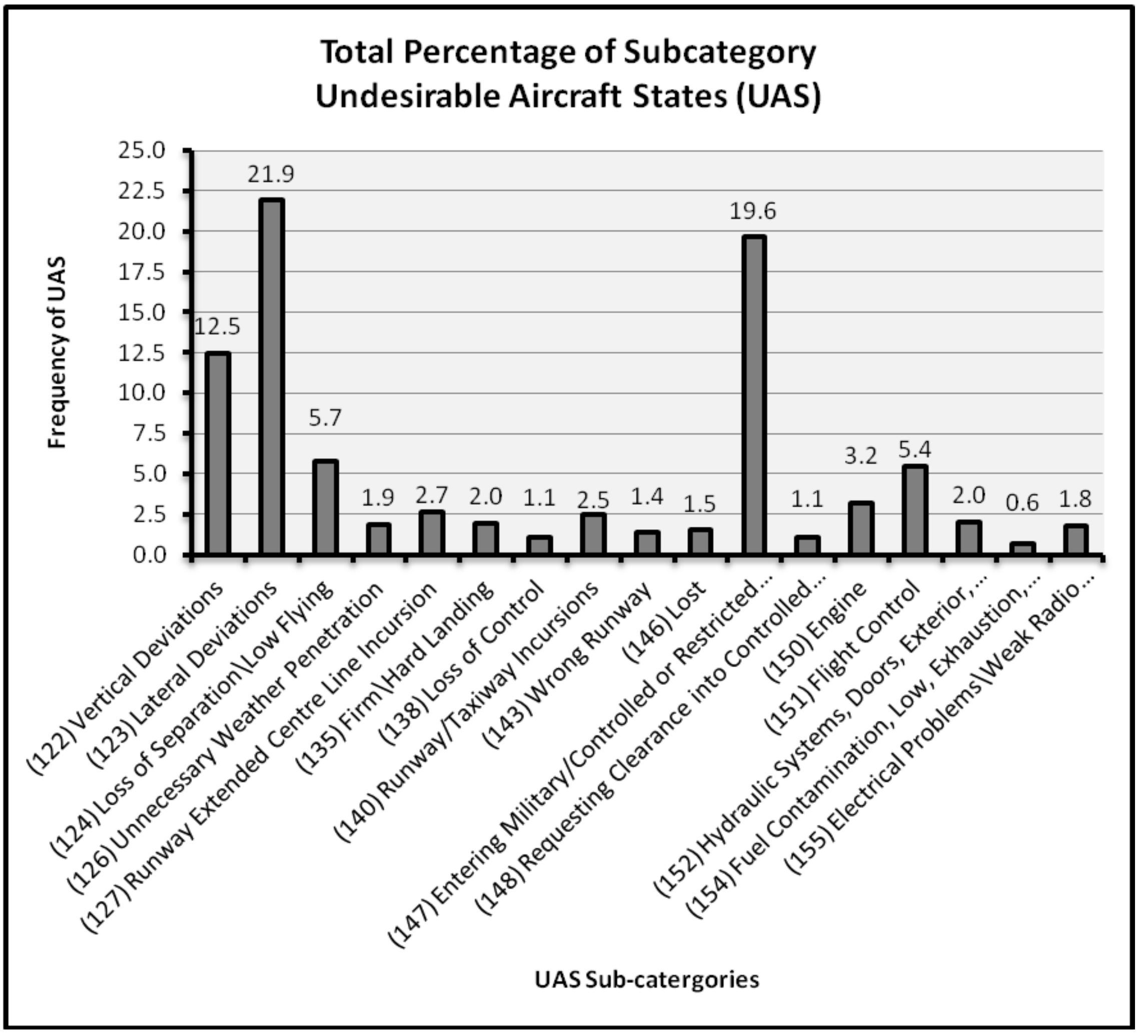
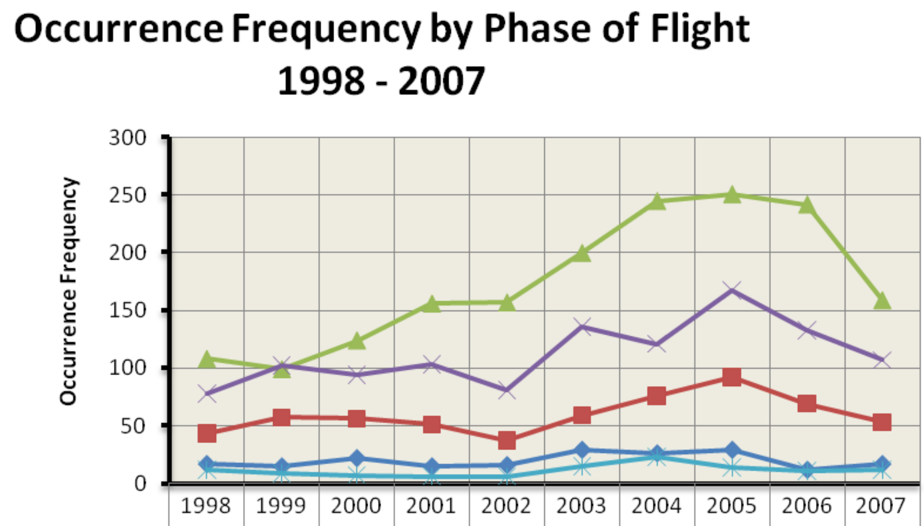


Figure 15. Total Percentage of Subcategory UAS

UAS subcategories clearly show that Lateral Deviations (22 per cent) was the most common UAS classified (see Figure 15), followed by Entering Controlled/Restricted or Military Airspace without Clearance (20 per cent) of all UAS classifications. The third most frequent UAS was Vertical Deviations (12.5 per cent). Due to the high numbers of lateral and vertical deviations, it could be argued that some of these UAS helped cause additional UAS events, when the pilot entered Controlled/Restricted or Military Airspace without Clearance. As the pilot would not have been aware of any infringement at the time, the real frequency of airspace violations could be greater.

4.5 Phase of Flight



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Preflight/Taxi	17	15	22	15	16	29	26	29	12	17
Take Off / Climb	43	57	56	51	37	59	76	92	69	53
Cruise	108	99	124	156	157	200	245	251	242	159
Descent/Approach/Land	78	102	94	103	81	136	121	167	133	107
Taxi/Park	12	9	7	6	6	15	23	14	11	12

Year

Figure 16. Phase of Flight by Occurrence Type

Note that the following data in the results below are not adjusted for time exposure and results do not total 3,326 occurrences. This is due to the way the phase of flight has been classified, to sometimes capture involvement of multiple aircraft in one occurrence.

The majority of airspace incidents are reported by pilots during the cruise phase of flight (see Figure 16). Incident frequencies peaked during the Descent/Approach/Land phase of flight. The number of reported incidents almost doubles in frequency as the flight progressed towards the landing phase. However, incidents show similar occurrence frequencies for the Pre-flight/Taxi and Taxi/Park phases.

Figure 16 also displays that the Descent/Approach/Landing phase of flight had 30 per cent of total occurrences. Previous research has shown that the landing phase is the most dangerous phase due to end-of-flight human error factors and sudden changes in atmospheric conditions within close proximity to the ground (Ha, 2010). O'Hare's (2006) results indicated that accidents were disproportionally associated with the Landing/Ground phase. As shown in Table 8, the majority of accidents (48 per cent) happened during the Descent/Approach/Landing phase, resulting in 50 per cent of occurrences if the Taxi/Park phase was included. In comparison, accidents in the Take Off/Climb phase accounted for 22 per cent of all occurrences, less than half the frequency of the Descent/Approach/Landing phase.

4.6 Frequency of Reported Occurrence by Type

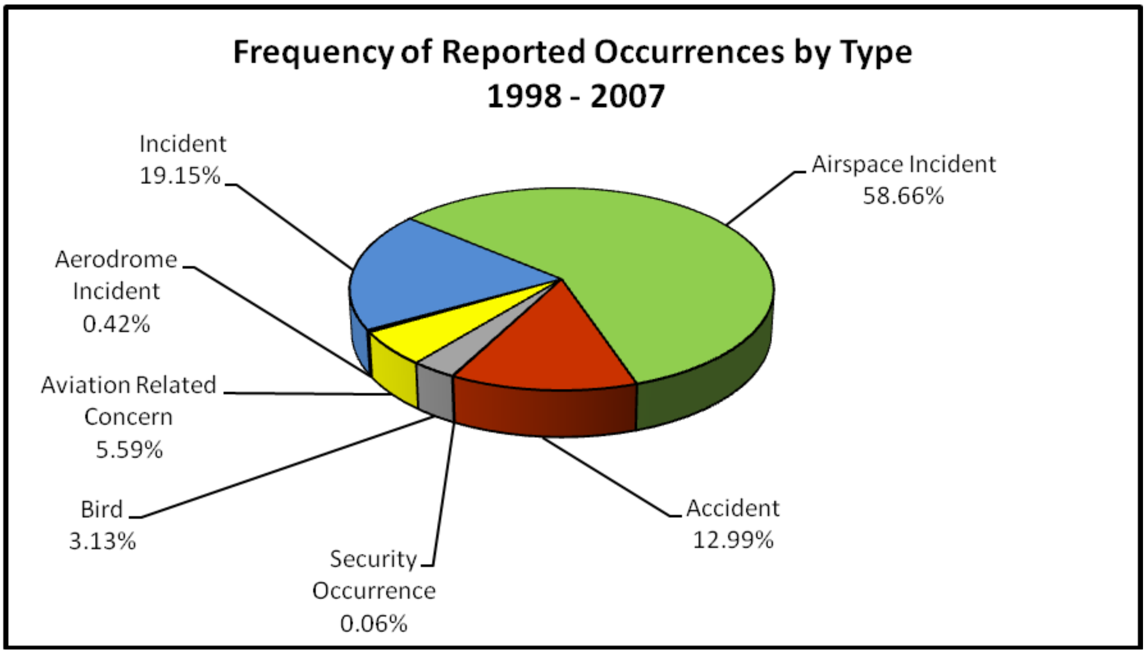
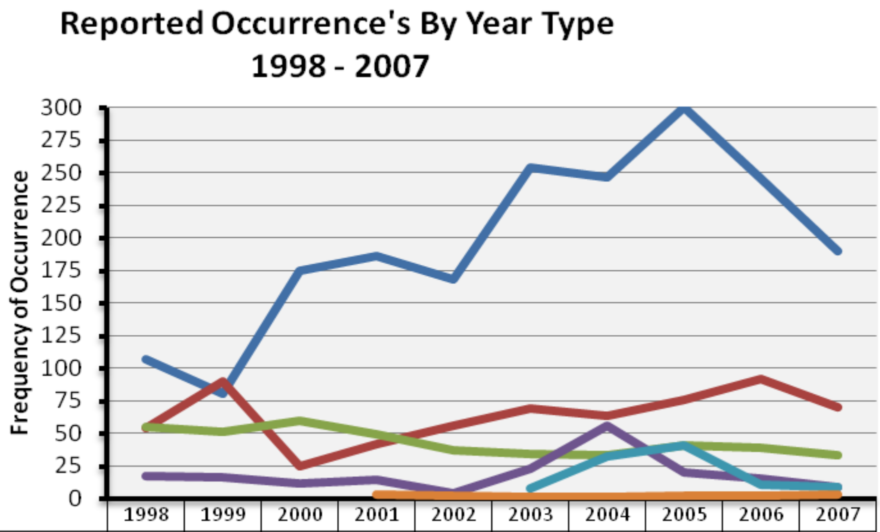


Figure 17. Frequency of Reported Occurrences by Type

Figure 17 depicts the frequencies of the different types of reported occurrences. The most common reported occurrences to CAANZ are airspace incidents (59 per cent). Accidents make up 13 per cent, while voluntary ARCs make up 6 per cent of occurrences. The least reported occurrence types are security occurrences with two events, followed by aerodrome incidents with fourteen events.

4.7 Reported Occurrence Type by Year



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Airspace Incident	107	80	175	186	168	254	246	300	245	190
Incident	54	90	25	42	56	69	63	76	92	70
Accident	55	51	60	49	37	34	33	41	39	33
Aviation Related Concern	17	16	12	14	4	23	56	20	15	9
Bird		1		2		8	32	41	11	9
Aerodrome Incident				3	2	1	1	2	2	3
Security Occurrence			1					1		

Year & Frequency

Figure 18. Reported Occurrence Type by Year

Figure 18 depicts the frequencies of reported safety occurrences by year. The number of reported airspace incidents tripled by 2005. The rest of the occurrence categories remained constant or decline in frequency until 2007.

4.8 Frequency of Threats and Errors

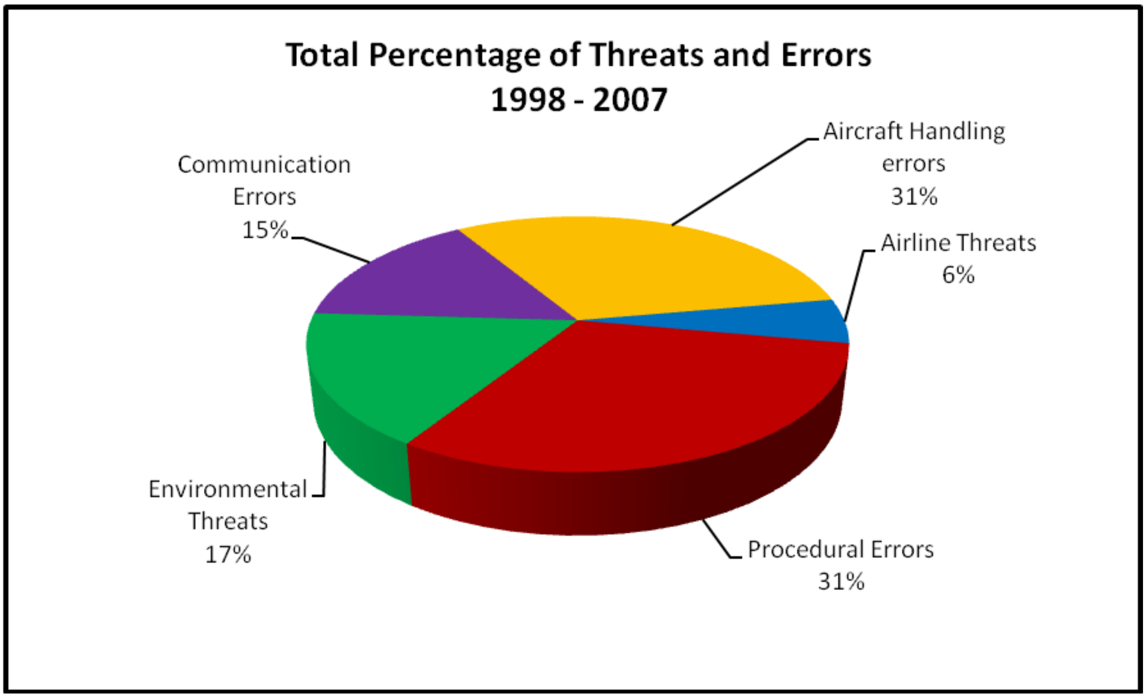


Figure 19. Total Percentage of Threats and Errors

Figure 19 is a breakdown of all reported occurrences by threats and errors. The majority of codings are classified as aircraft handling and procedural errors (31 per cent), followed by communication errors (15 per cent). There are more errors (77 per cent) experienced than threats (23 per cent). The most common type of threat were environmental threats (17 per cent).

4.9 Time of Reported Occurrences

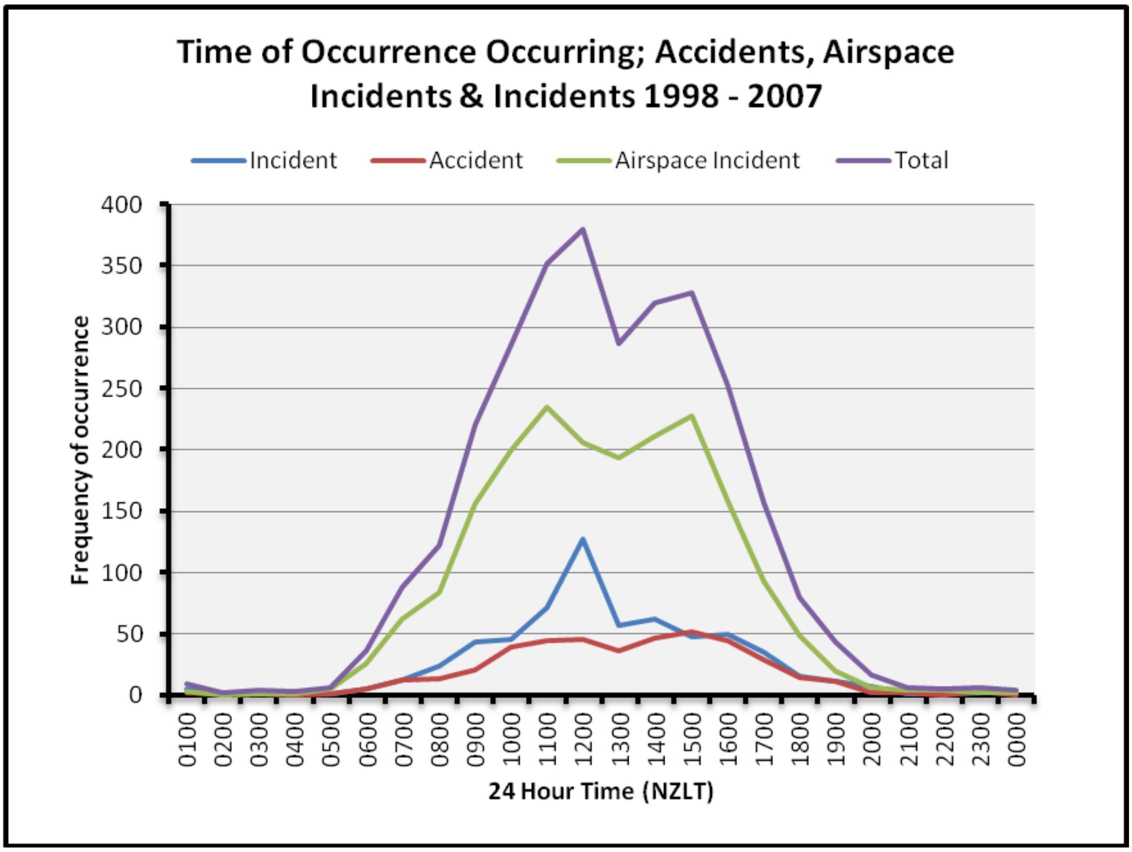
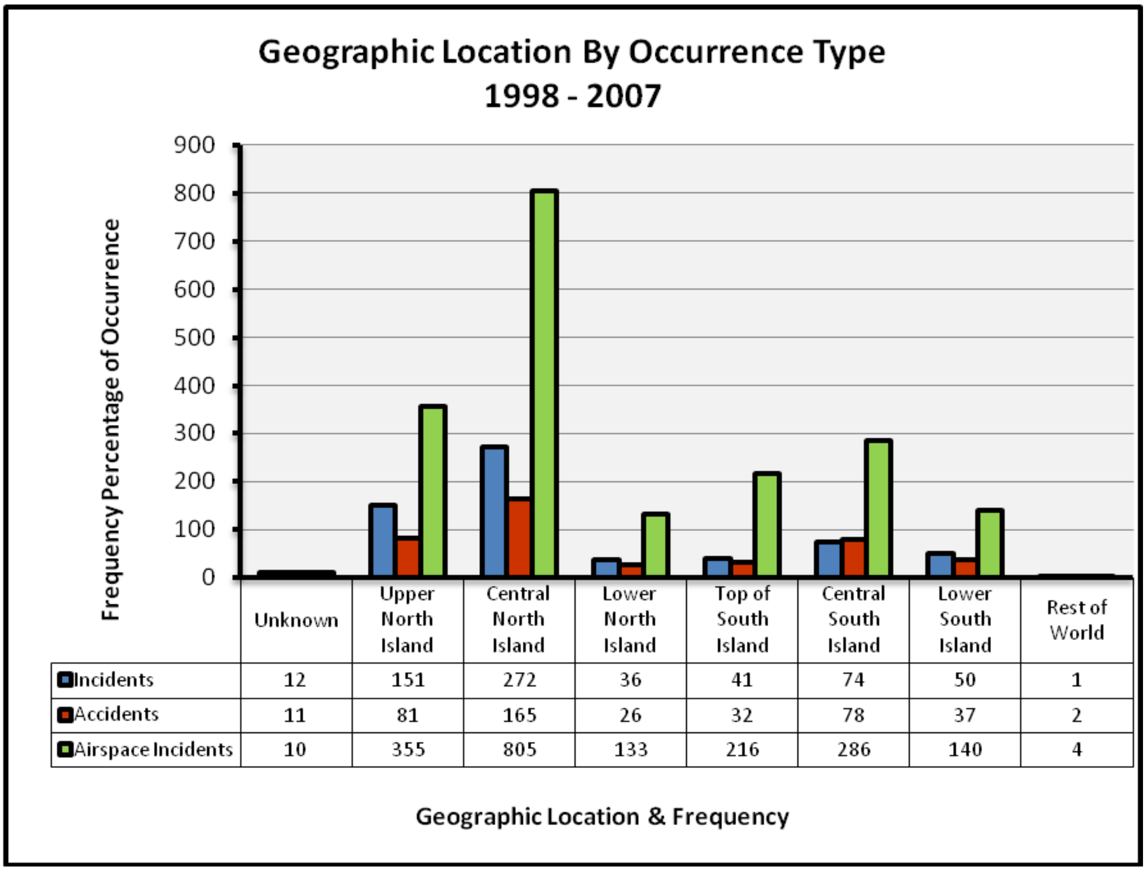


Figure 20. Time of Reported Occurrences: Accidents, Airspace Incidents & Incidents

According to Figure 20, the most frequent time for reported occurrence to happen is between 1,200 and 1,259 hours New Zealand Local Time (NZLT). The highest frequency of accidents occurs between 1500–1559 hours, incidents between 1200–1259 hours and airspace incidents between 1100–1159 hours. The majority of occurrences occur during hours of 1100 hours and 1559 hours NZLT.

Occurrence times in the CAANZ database are recorded in Coordinated Universal Time (UTC); these results have been adjusted to NZLT time to avoid frequency changes when daylight savings start and finish.

4.10 Geographic Location of Reported Occurrences



	Unknown	Upper North Island	Central North Island	Lower North Island	Top of South Island	Central South Island	Lower South Island	Rest of World
Incidents	12	151	272	36	41	74	50	1
Accidents	11	81	165	26	32	78	37	2
Airspace Incidents	10	355	805	133	216	286	140	4

*Figure 21*1. Geographic Location of Reported Occurrences

Note: Data were not adjusted for regional concentration of aircraft.

Figure 21 shows that the majority of accidents, incidents and airspace incidents are reported as occurring in the central North Island area. Airspace incidents in the upper North Island consisted almost entirely of occurrences around Auckland International airport and Ardmore aerodrome.

There were also concentrations of airspace incidents in the central South Island, involving aircraft around Christchurch International airport. The highest accident and incident occurrence rates in the South Island also happened in the central region. Refer to Figure 31 for a full location taxonomic.

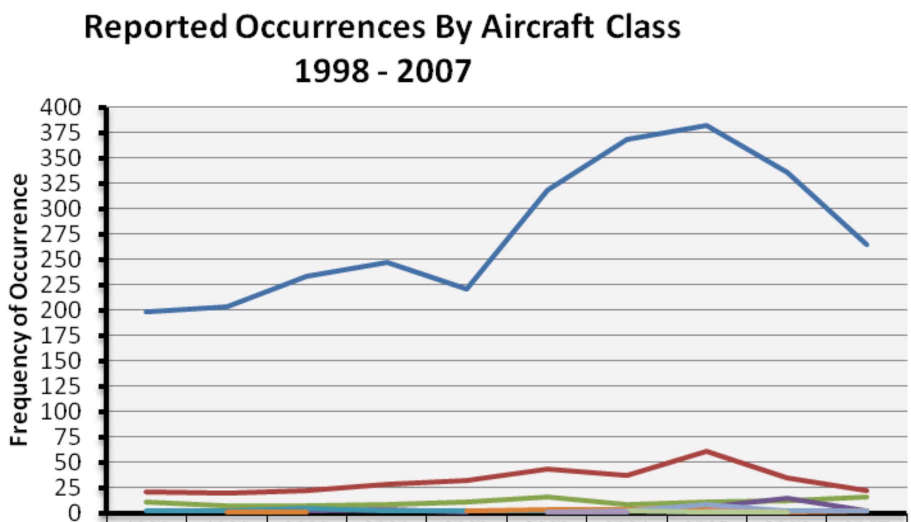
It is not surprising that the majority of airspace incidents are the areas in New Zealand with the largest population centres in the North and South Islands (Christchurch/Canterbury region with 14 per cent of incidents and the Auckland region with 11.4 per cent). Results were divided by regional boundaries rather than airspace boundaries. These were chosen because they change less frequently than airspace boundaries.

The region that experienced the most frequent accidents is the Christchurch/Canterbury area (13.6 per cent), followed by Hamilton (9.5 per cent). The Christchurch/Canterbury area is unique in its mix of natural geography and aviation traffic. It could be argued that the size and lack of easily distinguishable landmarks in the Canterbury plains may delay a pilot regaining situational awareness, especially during VFR navigation.

The highest frequency of aircraft incidents was found in the Ardmore area (13.8 per cent), Christchurch/Canterbury (9.9 per cent), Tauranga (9.1 per cent), Hamilton (8.9 per cent) and Auckland (2.7 per cent). The frequency of incidents reported from the Ardmore area could be due to the number of unique aircraft kept and flown there, along with its use by visiting pilots. Airways NZ (2009a) stated in its Aeronautical Information Publication (AIP) that Ardmore is New Zealand's busiest aerodrome, so extra warnings are provided to alert users to be extra vigilant when flying around this area. As this research shows, this area has the highest number of reported airspace incidents.

The Auckland region has the widest range between the frequency of airspace incidents (at 11.4 per cent) and accident/aircraft incidents (at 3.5 per cent/2.7 per cent). No other region in New Zealand has a difference of more than 5 per cent. This may suggest that even though Auckland has one of the highest rates of airspace incidents, it is also one of the safest airspaces in New Zealand in terms of number of accidents.

4.11 Occurrences by Aircraft Class



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Fixed wing aircraft	198	203	234	247	221	319	368	382	336	265
Helicopter	21	20	23	29	32	44	38	61	35	23
Gliders	11	8	8	9	11	16	9	11	12	16
Kites			2	4	1		3	6	15	2
Gyrocopter	3	3	5	3	2	2	4	1	2	3
Paraglider		1	1		3	4	4	6	1	3
Balloon		2		1		1	2	9	2	2
Model Aircraft								3	1	
Hangglider							2	1	1	
Microlight		1				1	1			

Year & Frequency

Figure 22. Classification Consistency Results

Note: These results are unadjusted for the number of aircraft class on register.

The majority of occurrences involved fixed wing aircraft, which peaked in 2005, then started to decline. Helicopters are the second most involved aircraft class, occurrence reporting peaks in 2005 before showing a decline. Reported glider occurrences tend to remain constant for the time period. However, events that include aviation activities, such as kites and paragliders, show a noticeable fluctuation towards 2007.

Figure 22 shows that fixed wing aircraft are involved in the majority of occurrences for the entire period under study, followed by helicopters, gliders and kites. The database does not split fixed wing aircraft by weight categories, nor by the CAR Part number under which they operate. Occurrence frequencies committed by fixed wing aircraft continue to rise until 2005 before starting to decline. The same trend is seen among helicopters, where occurrence involvement increases until 2005 before dropping off around the same time as fixed wing occurrences do. Occurrences that involve gliders remain steady throughout the study period. However, according to Figure 22 there are two peaks of sixteen occurrences, each in 2003 and 2007.

Kites involved in safety occurrences are usually reported by pilots or ATC as being flown in the approach area near the extended centreline of the runway. Occurrences involving kites have been increasing since 1998 and peaked in 2006. The frequency of safety occurrences involving gliders has increased only very minimally and has remained steady during the period studied.

The reported locations of occurrences involving kites are found to have been predominantly flown around airports located near beaches (such as Rotorua and Tauranga). Some of these occurrences include kite 'surfers' and fishing long lines. The police are normally called in to remove the offending kite user from the approach area.

Gyrocopters are the next most frequently reported safety occurrence class after kites, reported safety occurrences peak in 2000 with five safety occurrences. In the case of other aviation activities (Balloon, Parapente, Paraglider, Hang Glider and Parachute), frequency of reported safety occurrences does not seem to be significant, due to the relatively small number of people participating in these aviation activities.

4.12 Pilot Hours

4.12.1 Last 90 Days

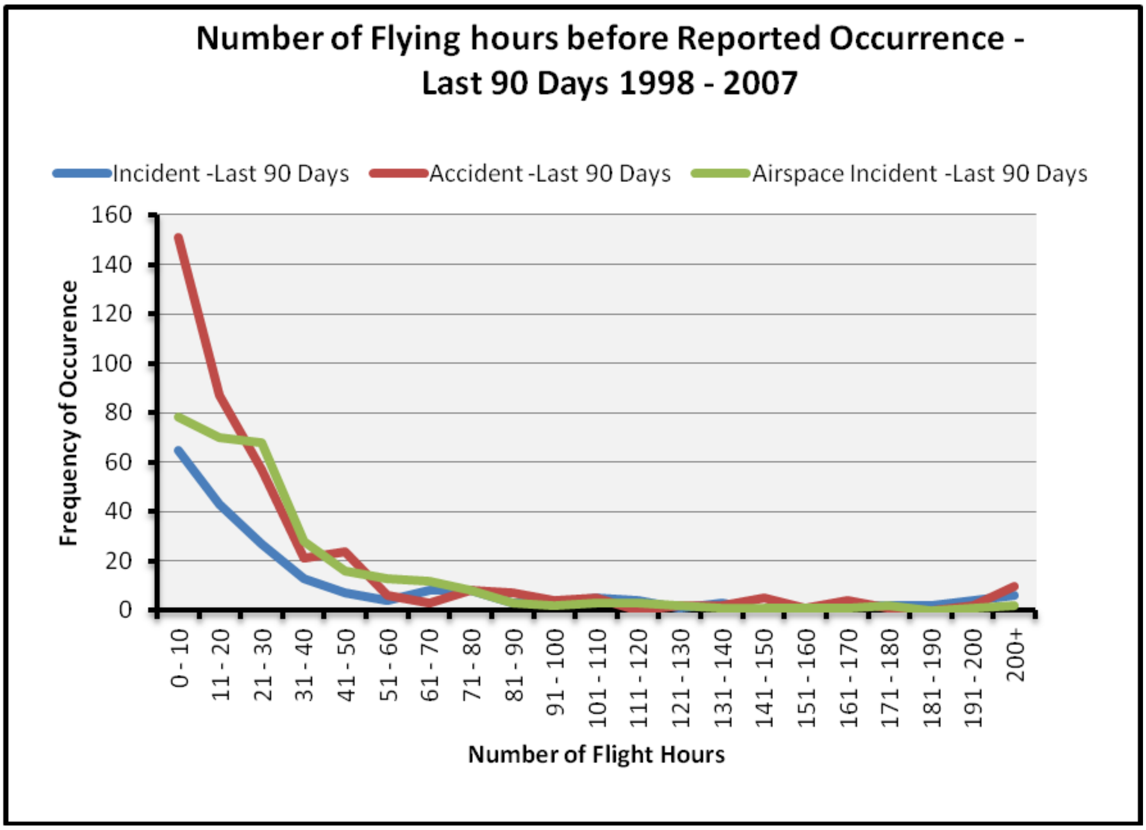


Figure 23. Pilot Hours—Last 90 Days

Figure 23 represents PIC flying hours for the last 90 days of flying across classes of aircraft. According to Figure 23, the majority of pilots who experience an occurrence will do so between zero and 50 hours flight time. Accidents record the highest frequency in the first zero to ten hours of flying, before dropping off significantly until 40 hours of flying is reached. The accident rate flattens out to almost zero at about the 100 hour mark. Both incidents and airspace incidents experience a similar decline in the number of reported occurrences as recent flying time builds up. However, the 200+ flight hour category reveals an increase in the number of reports towards the end of the time scale.

In Figure 23, the majority of occurrences drops off significantly after pilots have reached 40 hours of flying time before starting a gradual downwards trend. The number of accidents drops from 151 in the 0–10 hour category to three after 60 hours of flight time. Incidents drop from 65 in the 0–10 hour category to under ten after 40 hours of flight time and airspace incidents drop from 78 in the 0–10 hour category to under ten occurrences after 70 hours of flight time. All three occurrence types remain under ten occurrences per hour up until 200+ hours, where there are ten accidents experienced in the 200+ hour category.

4.12.2 Total Flying Hours

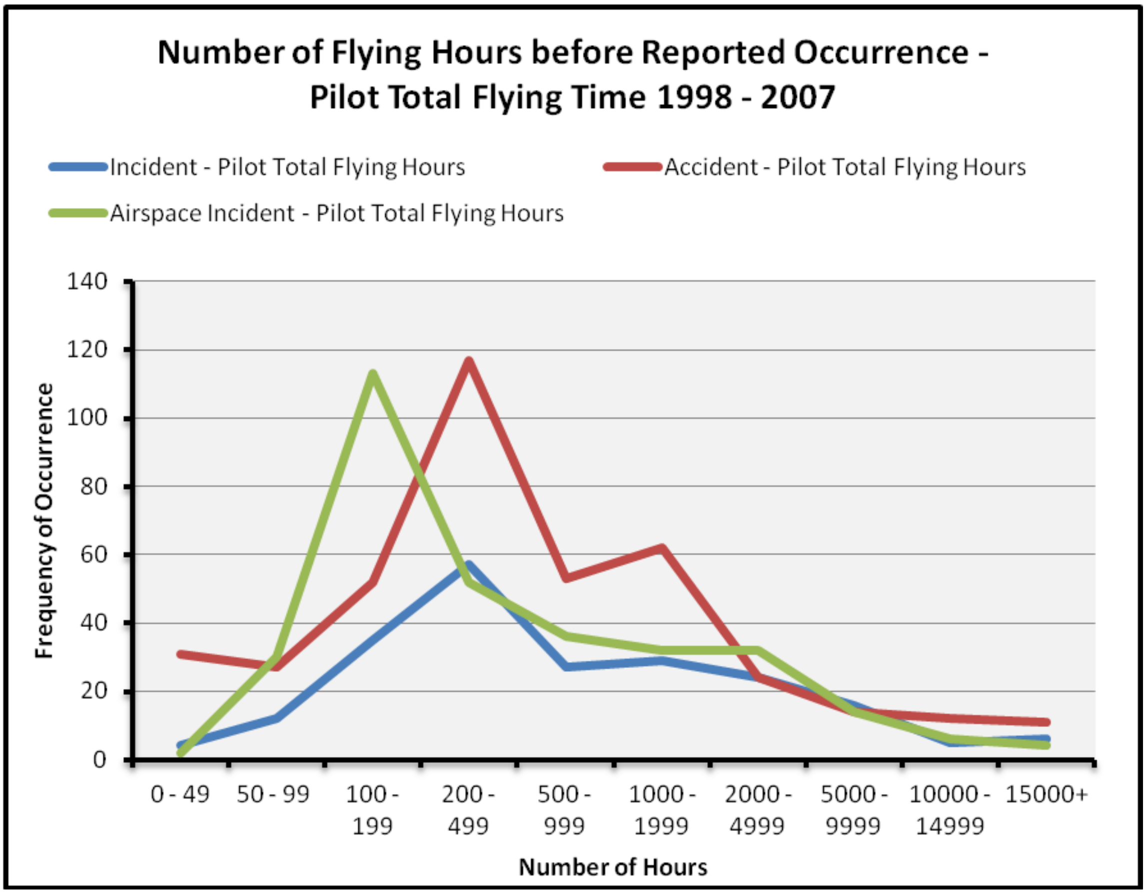


Figure 24. Pilot Hours—Total Flying Time

Figure 24 depicts the total flying time a pilot has before they are involved in a reported safety occurrence. The number of accidents and incidents peak at 117 and 57 occurrences respectively in the 200–499 hours range, whereas airspace incidents peak in the 100–199 hour bracket.

Both incidents and airspace incidents decline in the number of reported occurrences after their respective peaks and continue to decline. However, accidents have a secondary peak between 1000–1999 hours of flight time.

4.12.3 Hours on Type

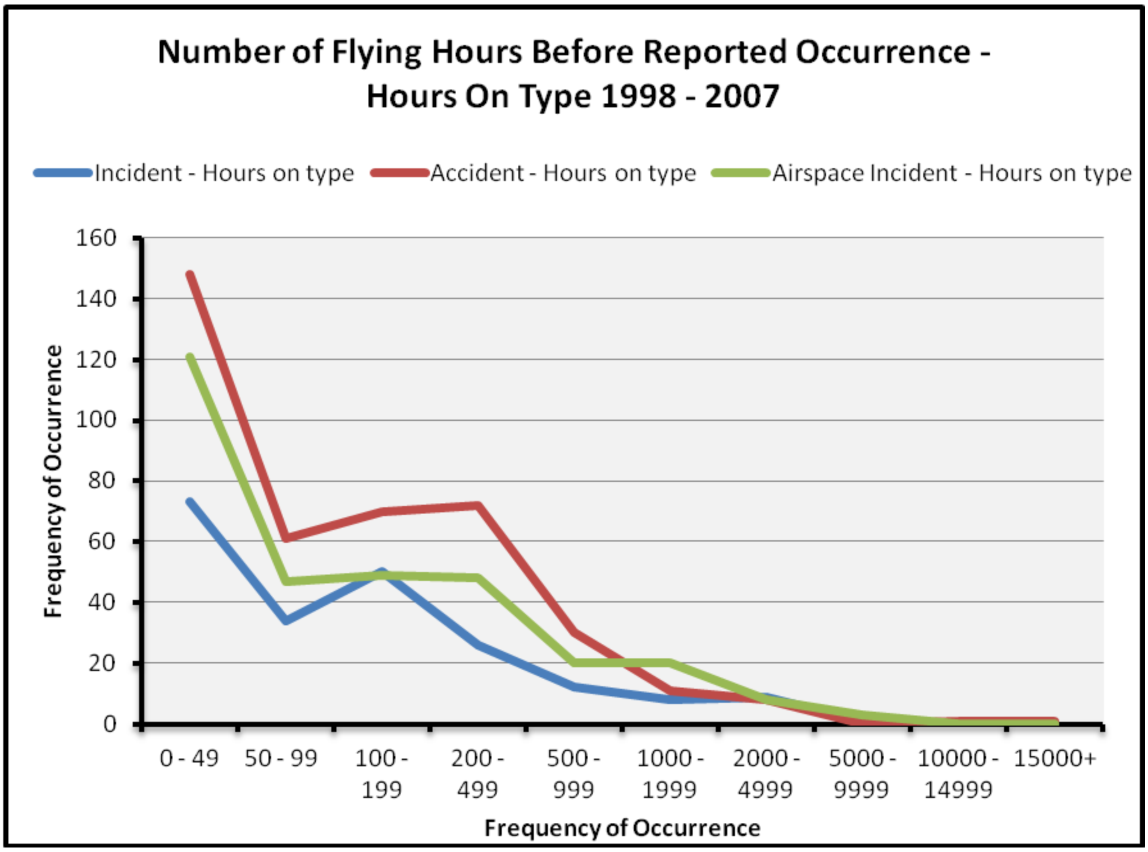
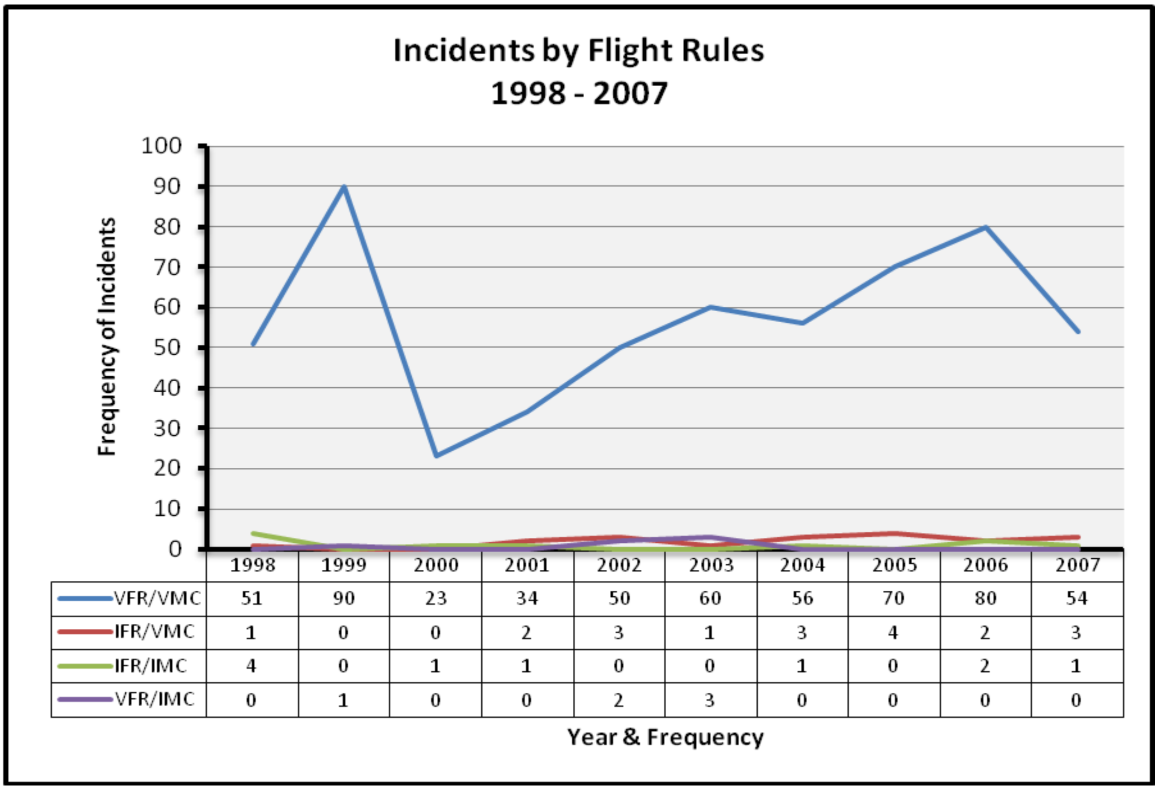


Figure 25. Pilot Hours—On Aircraft Type

In Figure 25, pilot flight time is recorded according to the type of aircraft (e.g. Cessna 172, Piper PA28); the pilot was flying at the time of occurrence. Figure 25 depicts all three types of occurrence experience a decline in the number of events in the first 99 hours of flying time. Only incidents and accidents see an increase in the number of events from 100 hours to 200 hours. Incidents in the 200–499 hour bracket start to decline, where accidents continue to rise until 499 hours. Here accident events reduce to zero at 5000 hours, whereas incidents and airspace incidents reduce to zero at 10,000 hour mark.

4.13 Incidents by Flight Rules

There are two sets of flight rules in New Zealand: VFR and IFR. VFR rules can only be used in VMC and pilots are expected to ‘see and avoid’ obstacles and other aircraft, with no ATC services provided in certain classes of airspace. The pilot must be appropriately rated and aircraft must be approved for IFR operations. In most cases, ATC provide separation for IFR traffic and flight plans must be filed prior to departure.



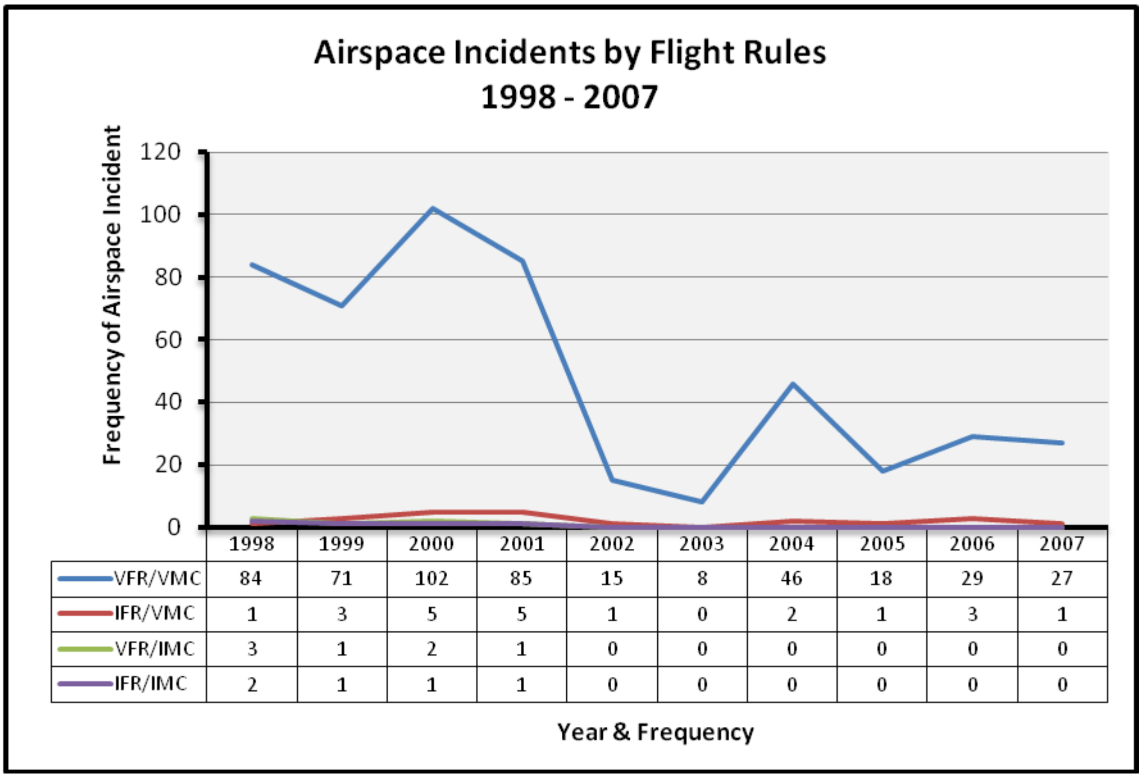
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
VFR/VMC	51	90	23	34	50	60	56	70	80	54
IFR/VMC	1	0	0	2	3	1	3	4	2	3
IFR/IMC	4	0	1	1	0	0	1	0	2	1
VFR/IMC	0	1	0	0	2	3	0	0	0	0

Figure 26. Incidents by Flight Rules

Note: Information not provided on 34 occurrences.

In Figure 26, the majority of safety occurrence incidents happen during VMC conditions under VFR flight rules. The highest reported incidents happened during 1999. VFR/IMC incidents peaked in 2003, IFR/VMC in 2005 and IFR/IMC in 1998.

4.14 Airspace Incidents by Flight Rules



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
VFR/VMC	84	71	102	85	15	8	46	18	29	27
IFR/VMC	1	3	5	5	1	0	2	1	3	1
VFR/IMC	3	1	2	1	0	0	0	0	0	0
IFR/IMC	2	1	1	1	0	0	0	0	0	0

Figure 27. Airspace Incidents by Flight Rules

Note: Information not provided on 1432 airspace incidents.

Figure 27 shows the majority of airspace incidents happened to VFR/VMC pilots between 1998 and 2001. The number of reported airspace incidents drops off significantly in 2002 and drops further to eight in 2003. However, from 2004 to 2007 the number of report airspace incident starts to increase again. The number of airspace incidents involving IFR operations in IMC was very low. A few more airspace incidents occurred when operating in IFR, but in VMC conditions.

4.15 Accidents by Flight Rules

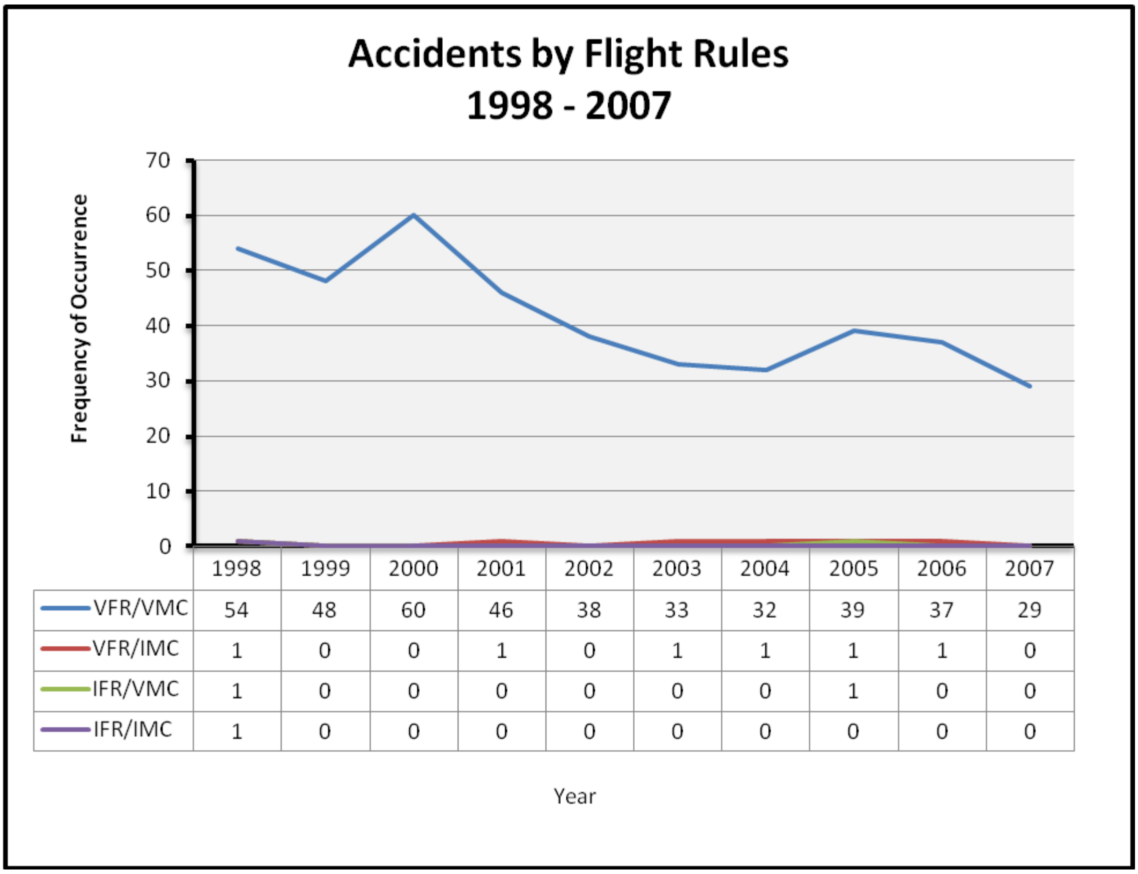


Figure 28. Accidents by Flight Rules

Note: Information not provided on Nine Accidents.

Figure 28 shows most accidents happen to pilots in VFR/VMC conditions. There are only a very few other accidents reported during IFR or in IMC. The number of accidents steadily rises until 2001, where it peaks at 60 accidents. After 2001, accident frequencies start to steadily decline. There were at least 29 VFR into IMC accidents every year from 2003 to 2006.

4.16 Seasonal Reporting

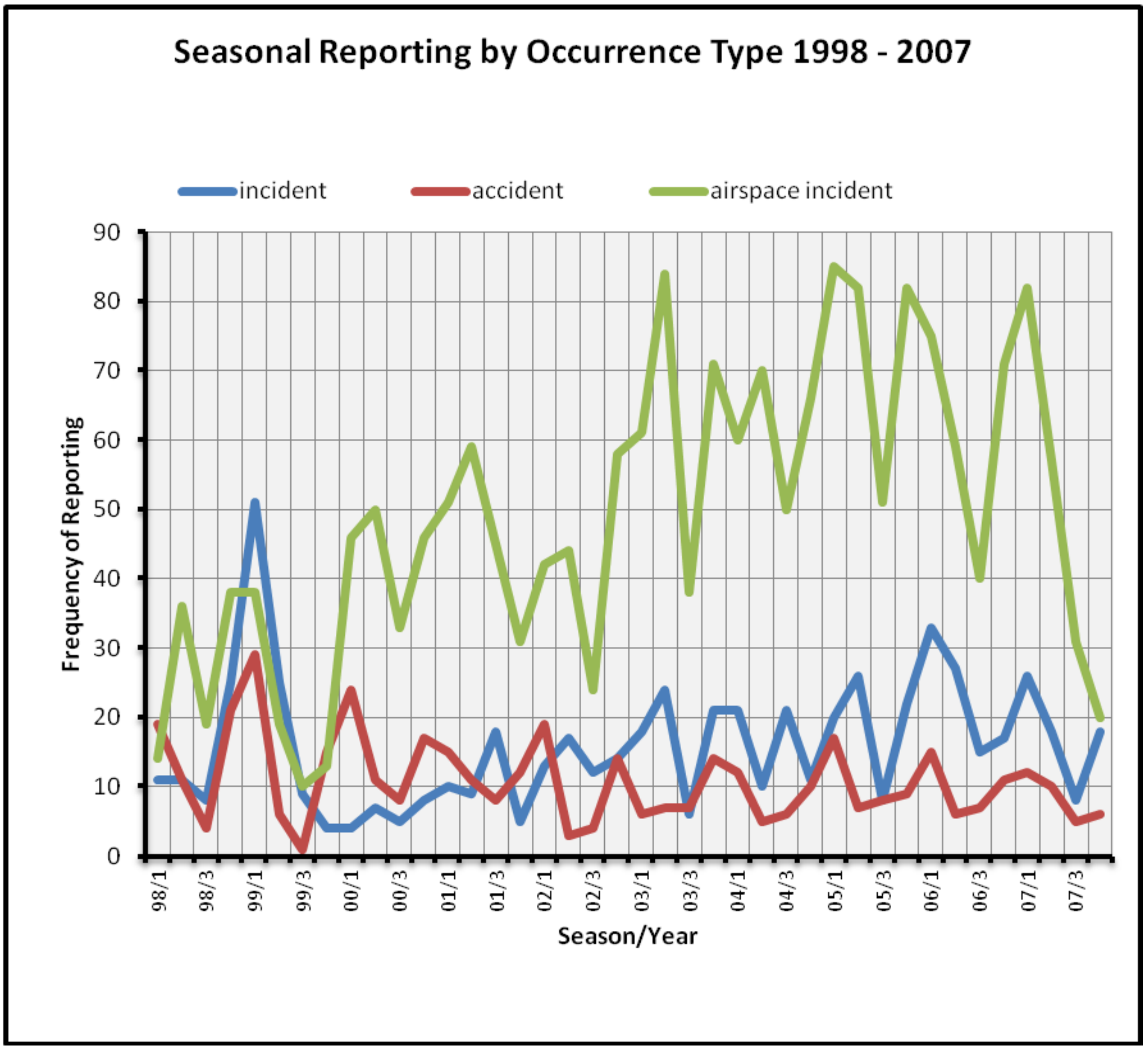


Figure 29. Seasonal Reporting

According to Figure 29, all occurrences experience seasonal peaks during any of the years. The reporting of all types of occurrences tend to peak in either the first or fourth quarter of each year.

Incidents and airspace incidents show a continuous increase in number of reported occurrences until peaking in 2005 and 2006. Both incidents and airspace incidents continue to plateau before trending downwards.

Both accidents and incidents peaked in the first quarter of 1999; however, all three categories reached their lowest occurrences during the third quarter of 1999.

Accidents peaked to their second highest occurrence count before the frequency rate decreased.

5.0 General Discussion

Merritt and Klinect (2006) describe TEM as a systems approach to aviation safety. The basic concept of TEM is to provide pilots with the skills necessary to manage and reduce the safety risks present in everyday flying. The analysis of safety-related occurrences identifies these threats, errors and UAS and breaks them down into smaller subsystems for easier identification and mitigation.

TEM breaks potential safety risks into smaller subsystem parts to help the aviation industry better understand and manage any emerging threats, errors and UAS. Understanding each threat, error and UAS aids the development of mitigation techniques to help flights remain inside the safety envelope (Soeters & Boer, 2000). A safety envelope describes an aircrafts safe performance limits in regard to such things as minimum and maximum operating speeds, and its operating structural strength (Pratt, 2000).

The safety envelope is the boundaries and limitations of a safe flight. It is combination of the pilot's abilities and the aircraft's performance limitations. Soeters and Boer (2000, p. 119) suggest that a trained pilot, knowledge of regulations and quality of flight preparation provide a 'safety envelope'.

With a wealth of aviation safety information flowing in from safety-related reporting systems, new investigation paths have been developed to help identify the precursors to a serious incident or accident. Programs such as Line Operation Safety Audits (LOSA) and CRM complement TEM to help target a pilot's training in breaking the next accident sequence.

TEM training helps pilots recognise potential threats, errors and UAS in order to mitigate the adverse effects and establish counter measures in a timely manner. TEM also helps equip pilots with the mental benchmarks needed to recognise these threats, errors and UAS. Each threat, error and UAS must have its own each unique mitigation strategy, to further avoid any deterioration in safety.

5.1 Why Incidents?

McFarland, (1946) describes incidents as near accidents. He argues that incidents are accidents that did not end with any loss of life or major damage to the aircraft or ground object, but could have resulted in more serious consequences. They are commonly experienced by pilots. A pilot's degree of exposure to incidents would indicate that specific TEM training would aid pilots in detecting incidents and avoiding potentially unsafe situations. Results from Figure 16 support McFarland's argument, where 'incidents' are reported to occur more frequently than accidents.

While aviation accidents have been described as rare events, they do not happen in isolation and show only the tip of the aviation safety iceberg (Haunschchild & Sullivan, 2002; Hunter, 1995; Reason, 1998). Figure 17 indicates only 13 per cent of occurrences are accidents; incidents constitute the majority of the remainder, with 81 per cent. By researching the more common incident, information about frequencies detailing common trends in threat, error and UAS can be used to develop countermeasures for particular events, without the impact of costly damage to equipment and, more importantly, loss of life.

5.2 Applying Threat and Error Management

TEM serves to advance safety in the aviation industry. In any aviation safety reporting system, due diligence is required by all participants in order to benefit from higher safety synergies.

With any safety reporting system, trust plays a key factor. Trust must be established with participants in order to provide rich, contextual information for the greater good of the aviation industry (Barach & Small, 2000). The system must acknowledge the participant's safety-related experience while reinforcing the importance of submitting a safety-related occurrence. Barach and Small (2000, p. 762) state ‘any cracks in the framework of trust among stakeholders in aviation has been associated with noticeable decreases in reporting’. Therefore, the fundamentals behind any reporting system must be robust enough to minimise mistrust issues.

Using information from Klinect et al., (1999) LOSA study found that threat and error are ubiquitous in the aviation environment. Results from this research indicate the presence of threat, error and UAS in every event subcategory with exception of a few subcategories with zero. Klinect et al. (1999) LOSA findings showed that an average of two threats and two errors were observed in each flight. These findings found that each reported occurrence observed on average 0.95 threats per occurrence, 3.09 errors per occurrence and 2.16 UAS per occurrence. These results are not surprising, as there are significantly more errors than threats (see Figure 19).

Processing the safety-related occurrence data reveals the most commonly experienced occurrences. This information helps the aviation industry to plan targeted safety campaigns (Shappell & Wiegmann, 2000). The majority of these dominant categories has one or two subcategory events, each of which makes up at least 50 per cent or more of each respective category. For example, Environmental threats have two dominate categories: Traffic and Terrain (see Figure 7). A safety campaign for Terrain and Traffic (see Appendix 2) subcategory events in EOP may focus on techniques to mitigate risk while flying in mountainous terrain or aircraft detection. A Missed Calls (see Appendix 2) focus (Crew to External) could target map reading skills or produce an evening to meet ATC controllers to help pilots overcome radio shyness.

TEM framework looks at an event using a ‘holistic’ approach, examining pilot intentions and actual occurrences so that a defence can be put in place to mitigate threat or error. By combining aircraft data and submitted safety occurrence reports, scenarios can be built to help pilots, mechanics, ATC and managers to develop risk mitigation strategies. The development of these skills will help prevent these safety-related occurrences from happening in the future, adding associated feedback loops to help maintain safety vigilance.

5.3 Motivation to Report

The motivation to report or lack of reporting a safety occurrence can depend on the type of organisational culture or the type of unsafe act (see Figure 4) that was committed or witnessed. At the same time, certain aviation activities must legally be reported as a safety-related occurrence (CAANZ, 2009). Research from van der Schaaf and Kanse (2004) identifies four mains reasons for not reporting a safety-related occurrence, including fear of disciplinary action, risk acceptance, belief that reporting is useless and practical reasons.

One reason why pilots may not report an occurrence is the fear of retribution (Johnson, 2002) or disciplinary action. This is a result of a 'blame culture', where those who commit an error are punished, suffer embarrassment or fear getting a colleague in trouble (van der Schaaf & Kanse, 2004). The creation of non-punitive reporting systems eases these fears of retribution and encourages more pilots to report (Klinect et al., 1999).

Risk acceptance occurs when a pilot considers an accident or incident an unpreventable part of the job. Van der Schaaf and Kanse (2004) see this as a macho perspective. A pilot may also perceive the act of reporting as useless, believing that management takes no notice or takes no action (van der Schaaf & Kanse, 2004).

Pilots may not report for practical reasons (doing so is too time-consuming and too difficult). The forms pilots are required to fill out for a single incident may be too long and complex, creating the perception of too much effort for too little return.

A pilot's professional culture may inhibit his or her willingness to report a safety-related occurrence. Reason (2000) states that pilots overwhelmingly like their work and are proud of their profession. However, the professional culture also contains a component of denying personal vulnerability (Reason, 2000). This fear of personal vulnerability may have future implications later in a pilot's career.

Creating an organisational culture that vales safety and the input of its participants helps encourage the reporting of all accidents and incidents. By valuing the information received by the participants with timely feedback, participants of the system are rewarded with the recognition of their contributions towards safety. Ultimately, the more information received about occurrences, the more the TEM framework can expose hidden threats, errors and UAS in the aviation system.

5.4 Line Operation Safety Audit and TEM

Line Operation Safety Audits (LOSA) is a cornerstone of TEM. Aviation safety has benefited from LOSA audits in helping to identify situations during normal flight hours where safety levels have wavered outside the safety envelope. During a LOSA debrief, flight crews are told which threats and errors were missed and how their safety performance be improved. The trained observer during a LOSA audit uses the TEM framework to assess the flight crew's ability to identify threats and errors and to assess whether correct mitigation techniques were used to avoid a UAS (Reason, 2000).

LOSA grew from the need to better understand the threats, errors and UAS that flight crews come across during normal operations (Klinect & Wilhelm, 1999). The need grew for a new safety paradigm in accident investigation, aiming for a new proactive approach in actively seeking and estimating from the source of a future accident. Using a TEM framework to map threats, errors and UAS recorded using a LOSA audit in a structured way. By dividing threats, error and UAS into subgroups, the TEM framework helps pilots better understand how they can improve their safety performance.

The reactive approach to accident investigation is often too late. A more proactive approach to safety will help guide aviation safety strategies using data-driven methodologies to target areas needing attention. TEM helps apply the findings from LOSA audits to help pilots recognise these threats and errors and develop countermeasures against inevitable UAS situations.

5.5 Crew Resource Management and Threat and Error Management

CRM is meant to reduce errors by creating a work environment where synergy is created between crew members that increase the level of safety to more than the sum total of their parts (Klinect & Wilhelm, 1999). CRM has become an integral part of modern aviation and, with the dynamic evolution of TEM, is a safety tools that is continually re-sharpened to meet the future safety needs of the aviation industry.

To achieve a level of synergy, the total performance of a crew should be greater than the sum of its parts, in which United Airlines has with desirable results from CRM targets (Croucher, 2005). It could be argued that TEM is an important tool of CRM and that further mandatory training is needed. The future benefits of such training include helping pilots improve their chances over time of successful resolution actions or the avoidance of potential UAS.

CRM is now said to be in its fifth phase of evolution. According to Helmreich et al. (1999), over the last three generations of CRM the overaching rationale of reducing the frequency and severity of errors has been lost, replaced by the notion of 'training that makes us work together better'(Helmreich, et al., 1999, p. 25). They argue that a lack of management support, broadening of training to include flight attendtants and failure of line check airmen to reinforce CRM practies compounded this effect.

CRM, in its fifth generation, has been refocused on the normalisation of error and the development of strategies for managing error (Helmreich, 1997 as cited in Helmreich, et al. 1999). This suggests that CRM is focusing on its founding purposes, which are more aligned to TEM than previous generations. CRM takes on the perspective that threat and error will always be present. Helmreich et al. (n.d.) argues that CRM has evolved and become more sophisticated. It can now be viewed as a set of error countermeasures that lead to recognition of threat or risk and effective management of inevitable error. If the replication of the United Airlines CRM result can be achieved elsewhere, accidents and incidents could potentially decline.

This TEM taxonomic tool is cause-oriented rather than event-originated, to ensure that events are classified by their underlying causes.

5.6 Threats

Threats are potential situations stemming from external influences that pilots must address when a threat is present. Threats are different from errors, which can be managed to some extent. Merritt and Klinect's (2006) definition of threats are events or errors that occur outside the influence of the flight crew, increase the complexity of the flight and require crew attention and management if safety margins are to be maintained.

Though threats can be avoided, they still have the possibility to remain undetected. Aviation personnel must be vigilant against unique, surprise situations. For example, a pilot reporting the wrong position may lead another pilot to misestimate the second pilot's location. This communication error is in fact an environmental threat to other pilots in the surrounding area. This environmental threat could maintain undetected until a mid-air collision is imminent. In this situation, an active search outside the aircraft is one threat mitigation technique that could be used to defend against this unexpected threat.

Threats in this TEM taxonomic can be classified as errors in some situations. When applying this TEM taxonomic from the view of the flightcrew or pilot, errors made by other people are considered threats to the flightcrew/pilot. For example a maintenance engineer using the wrong fasteners is a maintenance error. However, it is considered a threat because the TEM taxonomic is taken from the view of the flight/pilot. The left windscreen of a British Aircraft Corporation (BAC) One-Eleven, which had been replaced prior to the flight, was blown out under the effects of cabin pressure when it overcame the retention of securing bolts. It was found that 84 of the 90 bolts used to secure the windscreen were of a smaller than specified diameter (Air

Accident Investigation Branch, 1992). Errors from the Shift Maintenance Manager produced a major threat, which affected the flightcrew and the safety of the flight.

5.6.1 Environmental Threats

Environmental threats originate from the outside environment. Pilots do not have any control over them, except to avoid them or to minimise the impact they have on the safety of the flight. Environmental threats accounted for 17 per cent of threat and error totals (see Figure 19), where the majority of Environmental threats (see Figure 7) are EOP, which further break down into Terrain, Traffic, TCAS TA/RA, Radio Congestion and Bird Strikes.

Traffic threats in this TEM taxonomic are caused from a wide range of flying activities and classes of aircraft, including kites, model aircraft, gliders and helicopters. Some occurrences are caused by aircraft infringing on the operations and airspace that other aircraft have been cleared to use. Traffic threats can be caused by pilot navigation errors, ATC errors, pilot misinterpretation of ATC instructions and cutting corners of controlled airspace. Navigation errors can be minimised by adequate flight planning by the pilot, vigilant scanning of the external environment and remaining in VMC conditions. In order to minimise ATC and misinterpretation errors, pilots must speak up and challenge the controller's instructions if they feel something is not quite right. Where there is any doubt on instructions, pilots should ask the controller to repeat or reword an instruction.

Traffic threats also include aircraft that do not maintain the required separation distance between each other. Radio calls at the appropriate times and scanning of the outside environment can help pilots alert others of their current positions and thus avoid possible traffic conflicts. Pilots misinterpreting ATC instructions need to ask ATC to make their calls easier to understand for the pilots, without the fear of embarrassment.

Kites flown inside controlled airspace near the airports are an unusual traffic threat classified in the TEM taxonomic. These create a flying threat to aircraft either on approach or taking off from airports near beaches. Here, fishing kites and kite boarding activities pose threats to an aircraft, usually requiring police intervention to remove the threat.

An example of a traffic threat from the CAANZ occurrence database is 01/2503:

> *An unknown aircraft, later deduced to be ZK-***, caused at least one technical loss of separation while carrying out an unauthorised transit of controlled airspace from approximately 6 nm south of the Blenheim NDB tracking towards Waverley. The pilot of E***** sighted the aircraft and stated that it was a C172 or similar type of aircraft. In the initial stages of the transit, the aircraft was transponding but when a general call was made on the Christchurch Flight Information frequencies, the transponder was switched off near Mt Robertson. It was seen again briefly, indicating 9500 ft and thereafter remained a primary return only. The pilot had misinterpreted the controlled airspace boundaries in the vicinity of Blenheim and believed he was in uncontrolled airspace.*

Threats in the example above have to do with the unauthorised transit of controlled airspace by an aircraft, which failed to gain clearance, lost separation and incorrectly operated their transponder. This pilot has placed other the aircraft and its passengers at risk by entering airspace for which it is not cleared and losing the required separation between the two aircraft.

Terrain in New Zealand is very mountainous in most places (see Appendix 3). The mountainous terrain is an unforgiving landscape, offering a higher level of risk to a flight if something goes wrong. Not only can mountainous terrain be hostile, it also has an effect on local weather phenomena and VFR navigation.

Threats from changing meteorological conditions can pose a significant risk for pilots flying in New Zealand. It is well documented that local New Zealand weather patterns can unexpectedly change while en route. This creates a weather threat for the pilot, who must therefore decide on a mitigation strategy to keep the flight within its safety envelope.

An example of a terrain threat from the CAANZ occurrence database is 01/4335:

> *An Australian pilot was flying locally and experienced "sink" near top of a mountain. The pilot was unable to maintain terrain clearance and the glider struck a downslope.*

The threat in this occurrence was the surrounding mountainous terrain in which the pilot was flying. Local air currents around the top of the mountain can be unpredictable and can change without notice. Local knowledge of the surrounding geography in gliding situations can be invaluable when weather conditions change.

Previous research on the study of incidents found that 29 per cent of pilots that responded, had unintentionally entered IMC at least once (O'Hare & Chalmers, 1999). These action can be potentially fatal as Wackrow's (2005) results show that five CFIT accidents from VFR into IMC conditions, totalling fourteen fatalities. Pilots that have experienced four plus or more times VFR into IMC incidents may indicate repeat offending from the same pilots. Hunter's (1995) results indicated similar levels, in that 23 per cent of private pilots have at least flown once VFR into IMC, while 22 per cent of commercial pilots have. Only 5 per cent of both pilot groups experienced a second VFR into IMC entry, and just under 2 per cent of pilots reported involvement in four or more identical incidents, where O'Hare and Chalmers (1999) found that there was a 4 per cent involvement in as many incidents. One could argue that a high frequency of incidents comes with the nature of operation or that it was absolutely necessary due to the situation and location of the aircraft. However, a pilot's high level of involvement in incidents or accidents should be questioned, because the pilot's action after the threat is experienced determines whether any of the five hazardous attitudes was displayed (Murray, 1999).

5.6.2 Airline Threats

Airline threats are predominantly organisational in nature. They stem from the aircraft itself, the organisation, its management, or latent errors made by maintenance engineers and aircraft designers. These threats may come in the form of an aircraft overloading or maintenance errors and can be caused directly by a pilot's actions or a latent error that has not yet been exploited.

Airline threats prominently stem from the aircraft itself or the people that work on, in and around them. These threats can include errors made from maintenance work, ground handling and loading errors and flight crew distractions from the cabin. The identification and elimination of these threats will help the flight crew maintain a sterile cockpit and reduce their workload. Even though aircraft mechanics conduct their own sign-offs before releasing an aircraft back into service, and even if the previous flight returns without any reported problems, a pre-flight check must be carried out every time.

To eliminate these airline threats, pilots must sure they check their aircraft and its subsystems every time. Pilots must perform their pre-flight checks before they take off, to ensure that any latent errors are eliminated. The failure to check all aircraft systems before take off may lead to a surprise during a flight. This situation is undesirable, as the pilot may not have enough time to make a landing before the situation gets worse and the safety envelope of a flight is breached.

The following are examples of an airline threat:

02/3415

> *The pilot of ZK-*** reported to RO TWR that the flight was returning from Mt Tarawera with a chip warning light for a precautionary landing. The flight landed safely at 0236.*

A mechanical warning light prompts the pilot to land as soon as possible.

07/718

> *After the aircraft took off from Motueka the cockpit filled with smoke. The pilot made a 180 degree turnback and carried out a safe precautionary landing. The cockpit windscreen ended up covered with oil from a lose oil filter.*

In the above occurrence, a mechanical threat identified by smoke in the cockpit is the result of an aircraft mechanic's error.

5.7 Error

O'Leary (2002) describes error as resistance to management. He states that 'despite the great advances in aviation technology over the past decade or so we do not see any real improvement in the global accident rate' (2002, p. 245). This study endeavours to understand where errors are occurring and what consequences follow. O'Leary (2002, p. 246) suggests that 'managing error requires its understanding' and it is necessary to have information on the day-to-day operational difficulties, stresses and human failures that all aviation personnel face.

TEM uses the systems approach, which is based on the premise that humans are fallible and errors are to be expected (Merritt & Klinect, 2006; Reason, 2000). In TEM, errors cover three different categories: Aircraft Handling, Procedural and Communication. By dividing them into three different categories, errors can be investigated according to their origin. As each type of error has different origins (Wiegmann & Shappell, 2003), splitting errors into three types works to either bring the flight back into the safety envelope or maintain the safety envelope.

Errors are classified according to Wiegmann and Shappell's (1997) HFACS (see Figure 4) as unsafe acts. Unsafe acts can be further divided into violations or errors. Violations are intentional and errors are not; this research is only interested in errors. Error types are further split into skill-based, decision and perceptual. Each error type requires different mitigation strategies to keep a flight within its safety envelope. Skill-based errors are the stick and rudder skills a pilot gains while training. Decision errors are deviations from procedures and perceptual errors are missed visual or aural cues.

5.7.1 Aircraft Handling Errors

An Aircraft Handling Error generally refers to the mishandling of the aircraft and its systems. These skill-based errors generally refer to a pilot's stick and rudder skills and are usually made by low time pilots (Helmreich, 1997). Correct actions made in a timely manner help a flight stay within its safety envelope. Pilots in high-stress situations may make errors in the handling of the aircraft. For example, a pilot landing at an aerodrome for the first time may land to the side of the runway, because they were focusing on conducting the landing rather than where they were going to land.

Aircraft Handling Errors also include automation errors, including pushing the wrong button, entering incorrect information and selecting the wrong mode. There were very few automation errors classified from the CAANZ occurrence database. This could be due to the relatively few aircraft in New Zealand with full glass cockpits (especially in general aviation), the number of pilots with licence-type ratings on advanced avionic aircraft or the fact that these automation errors were viewed as relatively unimportant errors and were corrected in a timely manner. Therefore, filing an occurrence report might be viewed as a waste of time.

Some Aircraft Handling Errors can be avoided by maintaining situational awareness (focusing on what is going on outside the cockpit and where the aircraft is heading). For pilots to maintain situation awareness, they need to remain ahead of the aircraft at all times. By doing this, a pilot can be sure to avoid obstacles that could possibly comprise safety. Ground navigation errors in this study mostly consisted of hitting ground-based objects and landing on places other than the runway, both which had 1.4 per cent of total classifications (see Appendix 2). Hitting Ground-Based Object errors included aircraft hitting poles, trees, fences, vehicles and buildings. Fences and trees were the objects hit the most frequently. These objects were mainly hit by aircraft on the approach and overrun the runway or experienced an outlanding. Landed Not on Runway errors were mostly experienced by aircraft that landed right beside the runway itself, due to the pilot floating the landing or not compensating for crosswind vectors. If the pilot maintained their situational awareness and thought ahead of the aircraft, obstacles on the ground could have been avoided.

An example of Aircraft Handling Errors is 04/3401:

> *Airways reported that ZK-*** was an IFR flight from NZTG to NZGS. The flight was cleared to carry out the GS RWY14 VOR/DME Approach. The pilot turned the aircraft the wrong way onto the arc. When the error was detected, the pilot cancelled IFR and proceeded VFR.*

The pilot in this occurrence turned onto the arc the wrong way. The pilot quickly realised the error and minimised the impact on other airspace users by changing the flight to VFR.

01/2431

> *The aircraft suffered a total loss of communications just prior to re-joining from the south of NZPM. 7600 was squawked and an overhead re-join was carried out. Inadvertent radio switching was the cause of the communications failure.*

In this occurrence, the pilot's inadvertent radio switching error lead to a communication failure. The pilot realised the communication failure and correctly squawked 7600 to alert ATC.

5.7.2 Procedural Errors

Procedural errors are decision errors where the pilot has either did not complete an action, the action was conducted at the wrong time or an inappropriate action was done. According to Figure 10, deviations from Standard Operational Procedures (SOP) ranked as the highest error type in this study. Refer to Appendix 1 for procedural error subcategories.

In potentially high-loss activities such as airline operations and flying in general, Degani and Wiener (1997) argue that it is essential to have a detailed set of procedures in order to successfully operate complex human-machine systems. As the majority of operational decisions by pilots in airline environment are predetermined in standard operating procedures, failure to comply with such procedures may result in a disciplinary action and the potential of failure to report such errors. Refer to Appendix 2 for frequency counts involving deviations from SOP. The majority of these could maintain unreported due to the fear of retribution (Johnson, 2002). Such views can inhibit safety; however, it may be necessary to force the few noncompliant pilots to report.

Examples of procedural errors are 02/333:

> *ZK-*** was observed to enter the Ohakea Terminal Control Area at 3000' north of Fielding without first having obtained an ATC clearance to do so. The pilot reported that he was navigating by means of a 262 chart rather than the OH VTC and so missed the detailed airspace structure.*

The above occurrence describes a possible situation where a pilot does not carry the correct documents. The pilot entered controlled airspace without first gaining clearance.

98/1993

> *There is serious concern about a RAANZ(Recreational Aircraft Association of New Zealand Incorporated) Flight Instructor, Mr ********* of ******* Beach, not meeting the standards for this industry sector, in relation to safety.*

In this occurrence, the flight instructor was conducting flights without first meeting the correct flight instructor standards, which places both the student and instructor at unnecessary risk, as the instructor is not updated with current practises.

5.7.3 Communication Errors

Communication errors refer to the breakdown in communication between pilots and the outside environment. Communication is a critical element that helps keep the aviation environment safe. The transfer of information to others further down the aviation chain need to know a pilot's intentions, so they can react, plan and organise tasks that are critical to maintain an acceptable level of safety. Pilots need to communicate with ATC so they can let other pilots and area controllers know what they are doing and where they are going. Pilots need to broadcast their intentions at uncontrolled aerodromes to let other pilots know what their intentions are and prompt other pilots to call out if there is a possible conflict.

This study investigates types of error, including failure to report position, failure to request entry into controlled airspace, mispronunciation or miscommunication of intentions to either the other pilot or ATC. Communication errors found in this study can be a precursor to more errors, while creating a new threat to other aviation users at the time. For example, the pilot in the occurrence below fails to obtain clearance into the Whenuapai CTR, which creates a threat to an aircraft wanting to take off or land on runway 23. If the pilot had of been on the correct radio frequency and made the appropriate radio calls at the correct time, ATC could have given clearance to the aircraft to enter the CTR.

An example of a communication error is 98/3059:

> *A VFR target entered the Whenuapai CTR at 1300 feet near the Auckland Harbour Bridge and tracked through the extended centreline for runway 23 at 3.5 nm. The target was identified by the controller listening out on North Shore traffic frequency. The pilot could not recall the incident or why he missed requesting a clearance.*

Missed Call error events in this study were reported when pilots entered controlled/restricted or military airspace without clearance. Pilots who have missed radio calls create uncertainty in the surrounding airspace, as other users are unaware of the intentions of pilot. Both procedural errors and UAS show a high-frequency rate of entering controlled/restricted or military airspace without clearance (see Appendix 2). Particularly dangerous situations are created by pilots who fly into military airspace without clearance and while live-firing exercises are being conducted. The pilot places him- or herself at great risk, as the aircraft could be mistaken for an actual target. Pilots flying around these areas need to ensure they have either received a clearance to enter or need to accurately navigate around them.

The misinterpretation of instructions can happen for a number of reasons: lack of understanding, pronunciation or knowledge; distraction while receiving instructions and poor radio clarity. Radio transmissions may distort words because of local weather, terrain or poorly maintained equipment. The pilot must try their best to understand any instructions given to them by ATC; if not, the pilot must ask for them to be repeated until they are understood. One research study has found that Maori place names can negatively affect aviation safety (Colmar & Brunton, 2004), showing that in such situations, the pilot has had difficulty in both pronouncing and interpreting New Zealand place names. This could cause problems, such as the ATC's failure to identify a particular aircraft in order to receive the correct instructions.

Communication errors are can be made between pilots and the rest of the flight crew. Pilots failing to communicate with each may cause errors, such as data entry or procedural errors. In one example of miscommunication, a less experienced first officer may not inform a more experienced captain of an error due to professional culture reasons (Brown & Moren, 2003). The crash of Air Ontario, Flight 1363 in Dryden could have been prevented if the cabin crew passed on the passengers concerns for de-icing to the flight crew before take off (Baron, n.d). These examples show the importance of communication and how its lack could lead to disastrous results.

5.8 Undesirable Aircraft States

Marusic, Alfirevic and Radisic (2009) described a UAS as a *flight-crew-induced* aircraft state that clearly reduces safety margins, that is, a safety-compromising situation that results from ineffective threat/error management. A UAS is recoverable. It is important to identify UAS because pilots in these situations will have to act in order to mitigate the risk posed to the aircraft.

The Model of Flight Crew Error (see Figure 6) shows that once the aircraft has reached the UAS point, there are three possible outcomes: recovery, additional error and incident/accident. The safety of the flight is still in jeopardy if the pilot makes an additional error, but does not cause an incident/accident straight away. Incident/accident path is when the flight enters an incident/accident and recovery means that the flight returns to within the safety envelope.

Examples of UAS are detailed below:

00/2445

> *Once airborne at NZNS, ZK-*** suffered a power loss and the pilot landed the aircraft back on the runway.*

The pilot's UAS is the loss of power. Unable to continue flight, the pilot was able to recover from the UAS and land safely on the runway.

98/3799

> *ZK-*** on short finals when ZK-*** (or ***) taxied across grass without calling. ZK-*** went around.*

The pilot's UAS is the other aircraft entering an active runway while on short finals. The pilot was able to go around and avoid a collision with the other aircraft while attempting to land.

98/2144

> *ZK-*** did several circuits at Ardmore without making any radio calls. There were several other aircraft in the circuit at the time that were cut off by ZK-***. The aircraft also used grass 21 which was NOTAM closed.*

The first aircraft created a UAS by failing to use the radio and cut in front of other aircraft waiting to land. The situation was made worse when the first aircraft landed on an unserviceable runway.

It was discovered that 1.5 per cent of all UAS were coded as 'lost' (see Appendix 2). Lost is defined as a temporary loss of current geographic location, loss of situational awareness and disorientation from a lack of visual cues. Comparing incident results with O'Hare's and Chalmers' 1999 study shows that pilots surveyed have become 'lost' at least once (10 per cent), whereas Hunter's (1995) study show private (17 per cent) and commercial (15 per cent) pilots becoming 'lost' at least once. The comparisons may point to under-reporting to the CAANZ by pilots who have experienced being lost.

Fuel and its associated subsystems are critical for safe flight. Just over half a percent of UAS involved some sort of fuel problem. O'Hare's and Chalmers' (1999) results indicated 34 per cent of pilots have experienced fuel problems (21 per cent of low-fuel situations and 13 per cent of fuel starvation). Results from Hunter (1995) show that pilots at all levels have experienced at least one low-fuel incident: nineteen per cent of private, 34 per cent of commercial, 36 per cent of Air Transport Pilot (ATP). Again, pilot groups may under-report these events. To avoid undesirable fuel problems, pilots must make sure that correct fuel reserves are maintained, engine fuel burn figures are within tolerances, unexpected weather conditions are anticipated and acceptable alternate aerodromes (with the correct available fuel) are within reach in case of an unexpected problem. Results from O'Hare and Chalmers (1999) and Hunter (1995) indicate that the likelihood of a pilot having a fuel-related UAS is quite high, and therefore every pilot should remain vigilant.

5.9 Phase of Flight

When controlled for time exposure, landings, not take offs, are the most hazardous phases of flight, according to Croucher (2005) and Marusic, Alfirevic and Radisic (2009). As a result, pilots have a small operating window in which there is the potential of intense exposure to threat and error. By comparing landing and cruise flight phases, pilots in the cruise phase have more time to adequately detect and mitigate potential adverse situations as demanded. Timing becomes more critical in the Descent/Approach/Landing phase, when pilots are trying to mitigate threats or errors and trying to land an aircraft simultaneously.

If the results from Phase of Flight (see Figure 16) were controlled for exposure, the Descent/Approach/Landing category would likely be the most common phase of flight to have a reportable occurrence. The landing, approach and take off phases of flight comprise only a short time compared to the amount of time an aircraft spends in cruise (Croucher, 2005). Wackrow (2005) shows similar results, showing that the majority of accidents occurred during the cruise phase of flight (38 per cent). Wackrow (2005) expands on Craig's (2001) notion of the 'killing zone' and suggests a wider range of hours (between 200 and 2000) in which pilots are subject to a higher risk. Wackrow's results show just under 20 accidents occurred between 1000 and 1999 hours of flight time.

Occurrences have the potential to develop anytime during flight or ground operations. Without controlling for time exposure, the primary finding in relation to the phase of flight shows the cruise phase as experiencing the majority of the airspace incidents (45 per cent) (see Figure 16). Results are supported by research from O'Hare and Chalmers (1999) and O'Hare (2006) that incidents are strongly associated with the cruise and descent phases.

Wackrow's (2005) other results indicate that pilots are likely to experience an accident during the cruise phase. Wackrow (2005) also reported less involvement of accidents during the Descent/Approach/Landing phases. In comparison, Wackrows (2005) results had similar involvement in the Take Off/Climb phases in this study.

Further similarities are found with O'Hare's and Chalmers' (1999) second study, which displayed similar results as those found in Figure 16. The highest frequency of incidents occurred during the Cruise phase (39.4 per cent), followed by the Approach phase (16.5 per cent). Similar to Figure 16 accident results, accidents peak during the Landing phase.

According to Figure 16, there were 128 accidents during the cruise phase. Follow-up research into cruise phase accidents revealed a wide variety of involvement from different aircraft classes, ranging from gliders, helicopter, microlights and fixed wing aircraft. The following extracts detail sample accident synopses.

05/1

> *The glider was reported as being caught in heavy sink created from a wave effect set up from wind across the Kaimai Ranges. A forced landing was carried out 3km west of Tauranga and the on the approach the glider clipped a power pole.*

05/2733

> *The helicopter was seen to yaw uncontrollably to the right before descending and striking the ground in an almost inverted position on its right side. The pilot was killed, and the passenger was seriously injured.*

06/4477

The aircraft was observed by witnesses to spin before crashing into the ground and bursting into flames. Both the pilot and passenger were killed.

5.10 Time of Reported Occurrence

Investigations into the time that occurrences are reported could reveal the time future occurrences are likely to occur. For example, a spike in occurrences is reported between the hours of 0600 and 1259hrs (see Figure 20).

Wackrows (2005) occurrence result has a very similar resemblance to Figure 20. Both tables show a sharp rise in the frequency of occurrences between 0600hrs and 1259hrs NZLT and show a gradual decline from 1300hrs to 2000hrs. Both airspace incidents and accidents in both Figure 18 and Wackrow (2005) experience a dip in frequency between 1300 and 1359hrs NZLT.

In O'Hare and Chalmers (1999), the Take Off/Climb phase resulted in the highest level of accidents (23 per cent); Wackrow (2005) put the figure at 21 per cent, where the total percentage for Figure 16, excluding incidents, was 22 per cent. Figure 16 shows the Descent/Approach/Landing phase to have the highest involvement in accidents (48 per cent), followed by O'Hare and Chalmers (1999) with 44 per cent; Wackrow (2005) indicates only 16 per cent involvement.

5.11 Geographic Locations

The use of TEM differs depending on the geographical location. A pilot flying in mountainous terrain or a pilot taxiing on a major airport require the use of different risk mitigation techniques to keep the aircraft inside its safety envelope. The mountain-flying pilot must keep an eye out on the weather and altitude and keep a possible escape route, whereas the pilot taxiing must stay vigilant about where the aircraft is and communicate when required.

Analysing geographic locations results reveals clusters of safety-related occurrences. TEM can further probe these occurrences to identify which threats, errors and UAS are most common in this particular area. The aviation industry has a chance to target a safety campaign to mitigate specific risks. For example, if unauthorised airspace incursions were a regular occurrence, the authority in charge of airspace design may rearrange airspace boundaries to help reduce the number of incursions.

However, airspace classifications and the nature of operations also influence results. For example, the Canterbury region is flat and includes a major international airport.

According to the CAANZ (2008), aircraft movements at airports with a control tower have recorded an increasing number of aircraft movements, while the number of hours flown is also rising. Any increase in aviation activity also increases the chance that a pilot may experience a UAS, where additional traffic is involved and external threats from both the other pilots and ATC are potentially greater.

5.12 Class of Aircraft

The types of aircraft included in this study vary widely from high capacity regular public transport aircraft to kites, microlights and gliders. Although this study does not take into consideration the class of aircraft involved in each safety-related occurrence, TEM can still be used to investigate safety-related occurrences. Common denominators across all classes of aircraft are human interaction and the chance of coming across a threat, making an error and placing the aircraft into a UAS.

Each class of aircraft has different safety procedures, depending on the risk and the complexity of the operation. For example, regular public transport aircraft have more stringent safety regulations and are required to report occurrences under CAR Part 12 (CAANZ, 2008), where classes of smaller aircraft fall outside this requirement and any submitted reports are voluntarily. To ensure that the TEM analysis covers all classes of aircraft, these voluntary reports are included.

The majority of Merritt and Klinect's (2006) TEM taxonomic events are applicable to most of the aircraft classes, listed in Figure 22. Taking into account that some classes of aircraft are not required to report under current CAR Part 12 and non-reporting CAR Part 12 operators, the true frequency of incidents and airspace may be triple the amount that this study has coded over the research time period. Therefore, it would be time-consuming but worthwhile to continue research into incident frequencies and the threat and error they involve.

As this study does not control for exposure, including the voluntary reports will skew the class of aircraft results to aircraft for which aviation regulations require reporting. The inclusion of these different types of aircraft into this study highlights the fact all classes of aircraft are susceptible to a reportable offence, no matter how simple the aircraft may be. A few examples from the CAANZ database show that even kites near approach paths can cause a safety risk to other aircraft, requiring the operator to stay conscious of safety.

5.13 Pilot Hours—Expertise and Judgement

'Exposure to hazardous events had the likelihood of having made both good and bad decisions increases as a function of experience rather than age' (Merritt & Klinect, 2006, p. 17). Merritt and Klinect argue that pilot exposure to hazardous events can be determined by the intensity and finesse they demonstrate while flying.

While the student pilot is learning to fly, additional flying skills such as judgement and TEM should be learned. This would help student pilots identify threat, error and UAS, using judgement to help maintain safety levels, as Jensen and Benel (1977) suggest. Jensen and Benel's (1977) definition of pilot judgement is presented consisting of an intellectual element (how well can you think) and a motivating part (your level of caution or risk). Evidence was found from research in other fields, such as medicine and business, indicating that both aspects of judgement can be taught (Olsen & Rasmussen, 1989). Other research also indicates that judgement can be evaluated. In view of the accident statistics and the favourable findings concerning judgement training in other fields, it is suggested that judgement training could be highly beneficial to civil aviation safety.

Results from O'Hare's and Chalmers' (1999) study of incidents and accidents were similar to Hunter's (1995) results, who suggests that pilot experience is determined more by the inherent demands of aviation than by the idiosyncratic factors of national geography or society. Both O'Hare and Chalmers (1999) and Hunter (1995) argue that the stressors of flying shape a pilot experience rather their personal background.

5.13.1 Last 90 Days

Wackrow's (2005) 'Number of Fixed Wing Pilots Involved in Accidents Sorted by Flight Time within Last 90 days 1995–2004' displays a similar trend, where pilot groups between 0 and 20 hours on aircraft type experience the most accidents. In the 200+ hour category, all three occurrences begin to increase. This is due to the large range of flight hours beyond the graph's range. It could be argued that pilots that report occurrences in the 200+ hour category may induce occurrences due to low personal fatigue levels from the intensity of flying required in this category.

Studies have been completed on total flying time, time on type and flight time during the last 90 days. Wackrow's 2005 study argues that the best indicator on accident risk is the 90 Last Days. Pilots with high last-90-day hours are less likely to have an accident than pilots with less than 40 hours (Wackrow, 2005). Wackrow (2005) shows that over 120 pilots between 1995 and 2004 have been involved in an accident in the last 90 days, before clocking up over 20 flying hours. After 20 hours, the frequency of accidents starts to drop off significantly and remains constant.

5.13.2 Total Hours

Figure 24 shows the number of safety occurrences sorted by total flying hours. The first column of 0–49 hours total flying time is relatively low compared to the rest of the results. Pilots in this column are usually student pilots who are accompanied by their flight instructor. This is essentially a multi-crew environment where the flight instructor supervises the student pilot and manages the threats and errors that are present during the flight. Therefore, having the flight instructor on board increases the safety in the system. After pilots reach about 50 hours, they are eligible to earn their Private Pilots Licence (PPL) to fly solo and carry passengers. Figure 24 shows an increase in the number of occurrence statistics; between 50 and 499 hours, safety occurrence rates increase dramatically before dropping off after 500 hours. O'Hare and Chalmers (1999) tested a hypothesis that a pilot has a higher vulnerability of having an accident between flight hours of 100 and 200 or between 100 and 300 hours. Results concluded that there was no evidence of any increased of accident involvement, rather suggesting that the trend was in the opposite direction. Craig (2001) labelled the time of total flying hours between 50 and 300 hours a 'killing zone' (see Figure 30). He suggests that in this 'killing zone', pilots are more susceptible to experiencing an occurrence. Results from this study align with this statement. Research from other studies described the 'killing zone' as occurring between 100 and 200 hours (Jensen, 1995, as cited in O'Hare and Chalmers, 1999).

O'Hare's and Chalmers' (1999) results found that 24 per cent of accident pilots experience an accident in the 100–300 hour range of total flight time and that between 100 and 200 hours flight time, only 14 per cent of pilots experience an accident. In contrast, Craig's (2001) results show that 57 per cent of all accidents happen to pilots between 50 and 300 hours. These results tend to indicate that accident rates start to decline between the 200 and 300 hour marks of total flying time. O'Hare's and Chalmers' (1999) study showed that 11.3 per cent of accident pilots between 100 and 200 hours only represent 15.1 per cent of the total pilot population in New Zealand. In contrast, the 100 to 300 group increases the percentage of accident pilots to 21.1 per cent, where only 25.8 per cent of the total pilot population are in this bracket.

Wackrow (2005) stated the pilot group with the least amount of occurrences has between 50 and 99 hours of flight time. There is a comparative increase in the frequency of pilots experiencing incidents and airspace incidents against accidents between 2,000 and 4,999 hours. This could be due to new Commercial Pilots License (CPL) pilots experiencing unfamiliar threats and errors that are more specific and common to commercial operations.

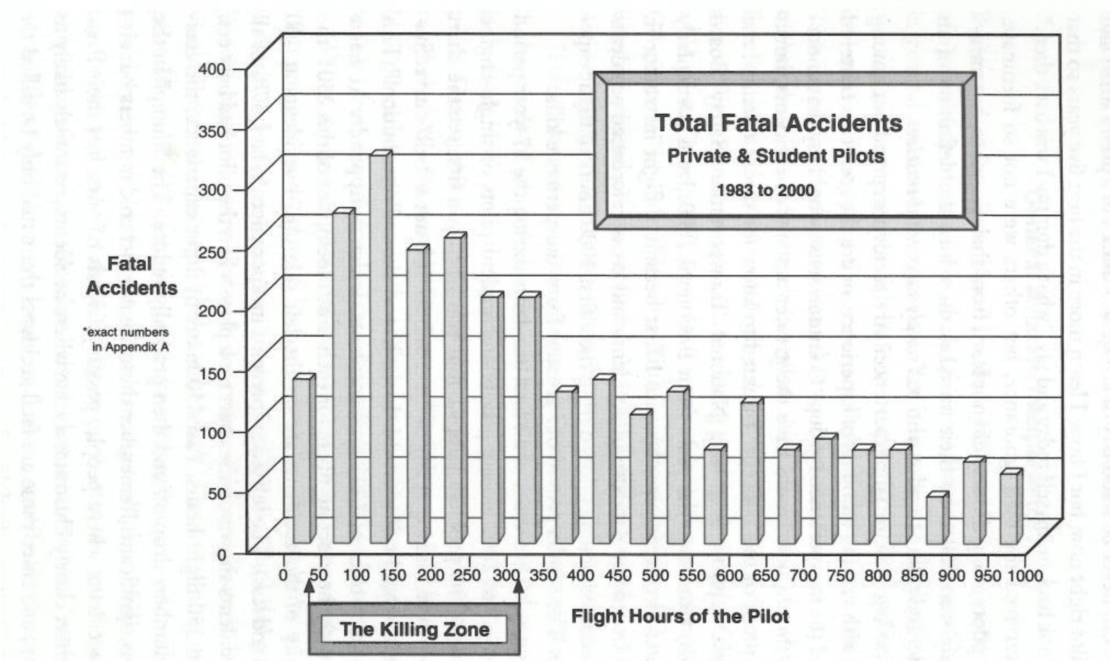


Figure 30. Killing Zone—Fatal Accidents
Source: Craig, 2001

After about 350 flight hours, the number of pilots significantly reduces as pilots gain more flight time (see Figure 30). The effects of having a flight instructor on board between the hours of 0 and 49 are shown in the graph above. The number of pilot fatalities doubles when student pilots first gain their private pilot licence and begin flying solo.

5.13.3 Hours on Type

PIC Hours on Type (see Figure 25) provides data on pilots who have multiple aircraft type ratings involved in a reported occurrence. Results are displayed as total flying time by aircraft type flown, not total flying time.

Figure 25 clearly shows the majority of occurrences are reported within the first 0–49 hours on aircraft type. Reported occurrence hours are determined by which type of aircraft the pilot flies (e.g. Cessna 172, Beech 1900D). All three occurrence types trend down thereafter to about a third of previous levels. They plateau until 500 hours, where only half as much reporting is experienced until the 2,000 hour mark is reached, where occurrences reduce to zero by 5,000–9,999.

Wackrow's (2005) fixed wing accidents, sorted by pilot flight time on type of aircraft, resulted in similar results to Figure 25. The first 50 hours have the highest frequency of accidents; the frequency decreases as flight hours increase. However, similar behaviours occur around the 500 hour mark, where the frequency of accidents increases a little before dropping back down, eventually nearing zero past the 10,000 hour mark.

5.14 Visual Flight Rule and Instrument Flight Rule Occurrences

Threats and errors are continually present during any aviation activity. The pilots are the last line of defence in what is often a flawed and complex sociotechnical system within which aircraft operates (Reason, 1997). One such system is the VFR and IFR and the conflicts that can arise between aircraft using different rules. The VFR and IFR are the two most commonly used flight rules in New Zealand. Fundamentals of VFR include exclusive VMC use, pilots who are expected to 'see and avoid' obstacles and other aircraft with or without ATC separation. Whereas IFR flights are used both in IMC and VMC, ATC normally provides separation and requires more advanced training and rating requirements.

Generally, most general aviation pilots will operate under VFR most of the time. Commercial and scheduled flights are almost entirely flown under IFR. IFR flights require pilots to be appropriately rated and the aircraft certified accordingly. IFR pilots must go through additional flight training, including simulator and 'under the hood' time.

Each set of flight rules also comes with its own set of specific threats, errors and UAS. Problems can arise when conflicting IFR and VFR flights fail to maintain minimum separation distances. IFR flights do not have the freedom to 'roam' like VFR flights can; therefore, when one aircraft falls fowl of the flight rules, it may place aircraft on a conflicting heading. VFR pilots do not have the necessary training and flight experience to safely fly into IMC conditions, increasing their chances of experiencing a CFIT accident when flying in IMC (Goh & Wiegmann, 2002).

The results from Figure 26 illustrate that the most frequent incidents are reported under VFR/VMC flight rules. IFR/VMC incidents peak in 2005, IFR/IMC incidents in 1998 and VFR/IMC in 2003. VFR/VMC incidents peaked in 1999 before dropping in 2000 to their lowest rate and trending upwards until 2006. These trend frequencies follow those depicted in Figure 29. VFR into IMC incidents are more common than what is reported to CAANZ. According to O'Hare and Chalmers (1999), around 28 per cent of surveyed pilots said they had experienced VFR flight into IMC.

The majority of airspace incidents (see Figure 27) are reported under VFR/VMC flight rules. VFR/VMC occurrences display a downward trend for the majority of the study period before levelling out during 2006 and 2007. VFR/VMC occurrences recorded their lowest involvement statistics in 2003 before returning to a moderate reporting level. Additionally, airspace incidents reported the highest level of unclassifiable occurrences.

This study and others indicate that pilots flying VFR are more likely to be involved in an occurrence than an IFR pilot. O'Hare's and Chalmer's (1999) results show that fewer than 30 per cent of all pilots have experienced VFR flight into IMC where Hunter's (1995) results indicate 23 per cent of private pilots have at least flown VFR into IMC. In both cases, around a quarter of the pilots surveyed had been involved in a flight that has strayed outside the operating flight rules. This particular situation can be dangerous, as Wackrow (2005) argues that CFIT is one of the major contributors to the causes of accidents in New Zealand.

5.15 Seasonal Trends in Occurrences

Seasonal trends (see Figure 29) show that during the summer months, there is an increase in the number of reported occurrences. While during the middle months of the year, reporting usually experiences a decline in the number of reports. This fluctuation in frequencies is influenced by higher number of flying hours, perhaps due to more favourable flying weather and longer daylight hours during the summer months of the year.

From the data (see Figure 29) found that the reporting of airspace incidents have been trending up until the first quarter of 2006, whereas reporting has remained constant until the end of 2007.

According to Figure 29, incident frequencies show that there is an overall increase in the number of reported occurrences. Incidents peaked in the first quarter of 1999 before dropping to record lows during the fourth quarter of 1999 and first quarter of 2000. Incidents from 2000 until 2007 trend up slightly, reaching an average of 25 incidents per quarter towards 2007. The CAANZ (2008) indicates that both helicopter and fixed wing aircraft incidents are trending upwards.

Accident frequencies, according to Figure 29, show a downwards trend from 1999. According to the New Zealand data, accidents peak in the first quarter of 1999 and have since marginally declined in frequency for the next eight years. The CAANZ Aviation Industry Safety Update Revision 21 (2008) also depicts a downwards trend in accidents for both fixed wing and rotary wing aircraft.

The downwards trend in accidents does not necessarily mean that safety levels in aviation are increasing; it merely indicates that fewer accidents are happening. Both the incident and airspace incident occurrence categories are increasing in frequency, which means that either more pilots are reporting their occurrences or that incident occurrences are increasing in frequency. This may be due to efforts from the CAANZ to create a safety culture; Reason (2000, p. 769) stated that 'engeering a just culture is an essential early step in creating a safe culture'.

5.16 Safety Culture and Occurrence Reporting

The development of a safety culture in the aviation industry is also an important keystone in the development to incident reporting systems. Culture can be used to influence the values, beliefs and behaviours of individuals and organisations to suit the requirements of safety. By manipulating the different levels of culture (national, organisational and professional), a safety culture can be established and maintained to meet the safety requirements of the organisation and those affected.

Helmreich (1999) argues that all three cultures are needed in the cockpit because each influences critial behaviours in different ways and encourage TEM and safety reporting.

National culture is influenced by aviation authorities and by the government. In New Zealand, the CAANZ and its government influence national culture by using such vehicles as policy implementation, regualtion, enforcement and aduiting. The introduction of aviation TEM protocols at national level gives the industry a benchmark for measurement.

Organisational culture stems from the aeroclub, flight school and airline levels. It is influenced by its members and their combined personal values (Helmreich, 1999). Here, the value of safety and TEM is passed onto new or junior pilots. Flight instructors, examiners and check pilots consistently apply TEM fundamentals, limiting the number of weak links in a pilot's safety chain.

Hunter (1995, as cited in O'Hare, 1999) states that virtually every pilot has at one time or another been a general aviation pilot, and that attitudes and behaviours developed at this stage are likely to influence performance down the road. Here, the flight school has a responsibility to seed and nurture a safety culture in each student pilot. This learned safety culture will be carried on through the pilot's flying career.

Incident reporting is voluntary, and one cannot know the true base rate of occurrences, which is necessary for validation (Helmreich et al., 1999). There will always be some non-reporting of occurrences. It could be argued that making reporting mandatory to certain aircraft operators has increased safety in some areas of the aviation system (see Figure 18). However, the question is how much non-reporting occurs and whether these events contribute any significant changes to safety culture. Compared to earlier research (O'Hare & Chalmers, 1999; Wackrow, 2005), this study shows a gap in the reporting to levels to the CAANZ. The continual promotion and encouragement of reporting can only go so far; thus, it is up to pilots and their fellow flyers to encourage one another to foster a reporting culture.

Helmreich et al. (1999) suggests that the basic steps that every organisation needs to follow to establish a proactive safety culture are establishing trust, adopting a credible non-punitive policy towards error, committing to reduce error-inducting conditions, collecting on-going data on nature and types of error, providing TEM training for crews, providing training in evaluation and reinforcing TEM for instructors and evaluators.

5.16.1 Incident Reporting Systems

There are a variety of incident reporting systems around the world operating under different names, all with the same goal of increasing the level of safety in aviation. Incident reporting systems are used as a mean to collect details of events where the operation of an aircraft and its effects have affected safety margins in some way. Without such a program, event information would otherwise remain unknown to researchers and authorities. In New Zealand, the CAANZ collects form CA005 submissions. Other examples of reporting systems include Immediate Reportable Matters (IRM), the results of which are reported to the Australasian Transport Safety Bureau (ATSB) in Australia, and ASAP reports, collected by NASA in the US.

Since accidents occur so infrequently, an examination of threat and error under routine conditions can yield rich data for improving safety margins (Helmreich, 2000). McFarland (1946) argues that incident reporting systems are necessary tools to maintain a feedback loop between the aviation user and the controlling authority. Without this feedback, threat and error information would only be investigated in serious incidents or accidents. In contrast, Helmreich and Merritt (1998) argue that incident reports are touted as a more useful diagnostic source of system information than accident investigations, since they occur more frequently than accidents. Therefore, reports provide two important functions of information feedback and a source of diagnostic information.

Establishing trust and the implementation of non-jeopardy incident reporting has lessened the fear of punishment or blame placed on pilots for reporting incidents. Some pilots perceive this as a ‘get out of jail free card’, as reporting incidents means consequences will be waived (Wiegmann & Shappell, 2001). This has increased the reporting participation rates of pilots and the ability to investigate threat, error and UAS as the amount of information grows. However, aviation authorities can only do so much to encourage pilots to report. Thus, it is up to the pilot themselves and others around them to continue to report and encourage others to do the same.

5.17 Preventing Incidents Turning into Accidents

Accidents are rare events, and pilots can increase their chances of avoiding them by engaging in good airmanship at all times (Hunter, 1995). One intended outcome of this research is to increase a pilot's awareness of the ambiguity that threats, errors and UAS present in everyday flying. Therefore, pilots can use this information to address threats and errors before they develop into a more serious UAS. If the situation has already developed into a serious UAS, a pilot using TEM training could employ suitable countermeasures that prevent the flight from progressing towards an accident.

It has been found that errors experienced by pilots differ according to the number of flight crew members (O'Hare & Chalmers, 1999; Wackrow, 2005). Therefore, pilots need to adjust expectations based on the type of errors they are likely to come across. This can be due to a number of factors, including type of operation, aircraft type, professional culture, total flight hours and flight time on aircraft type. Helmreich (2000) states that single pilot crews are more likely to experience skill-based errors, whereas multi-pilot crews are prone to more decision-based errors. This study did not investigate threat and error comparing multi-crew versus single pilot operations, as this data is not controlled for. Therefore, no conclusions can be drawn about which specific threats, errors or UAS affect single or multi-pilot crews the most.

Pilots flying in multi-crew environments trap threats and manage errors more successfully than a single pilot. O'Hare and Chalmers (1999) and Wackrow (2005) argue that fewer incidents turn into accidents when there is more than one flight crew member present, and that just over a third of incidents involve a flight crew of two or more. This indicates that two pilots are safer than one; however, multi-crew aircraft are prone to different errors than those of single pilot crews and pilots need to be aware of these differences. Therefore, no conclusions on this question can be drawn from the present study.

Using Reason's (1990) Swiss-cheese model (see Figure 2), a pilot who can close or make the holes in the cheese smaller would reduce the risk of an event completing the accident trajectory. Using threat recognition and error avoidance behaviours, external threats from expected and unexpected events can be avoided and the risks consequently mitigated. Error detection and response behaviours can be used to stop crew-based errors and external error (Helmreich et al., 1999).

By recognising the origins of external and internal threats, pilots can prepare themselves by using detection and avoidance behaviours to combat risks. Drawing from Helmreich et al. (1999) (see Figure 1), threat recognition and error avoidance behaviours would help reduce the risk from external threats from expected and unexpected sources. Helmreich et al. (1999) lists expected threats, including terrain, predicted weather and airport condition. Unexpected threats include ATC commands, system malfunctions and operational pressures. Error detection and response behaviours, if used successfully, will prevent the pilot from becoming involved in an incident or accident.

O'Hare (2006) argues that incidents were more often associated with events beyond the pilot's control; these events may be due to a lack of awareness of information signalling a problem or a failure to understand or correctly interpret the significance of this information. Figures 8 and 9 depict the external threat frequency that reported occurrences contain. However, accidents are more likely to be attributed to failure to select an appropriate goal, procedure or strategy (O'Hare, 2006).

As threats are ubiquitous, pilots have to keep in mind the possibility of threats originating from maintenance (see Figure 9), management (see Figure 9) and ATC (see Figure 8). They also have to contend with changes in advance of new technologies. These advancements are creating fundamental change in the etiology of both accidents and incidents. Changing etiology also forces change in explanatory mechanisms so that the mechanisms can adequately perform when incidents and accidents events occur (Leveson, 2004). Such changes mean that any TEM taxonomic needs updating once new individual threats become known. Also, TEM training needs to be modified as a pilot gains more experience or changes his/her flying environment or type of operation.

6.0 Research Limitations

The amount of information available in the occurrence database is limited to the information provided by the person who reported the occurrence. More information about the details of each occurrence would be useful to ensure clarity and that all threat, error and UAS events can be identified.

Classification reliability is an issue in studies like these, especially in gaining an acceptable percentage of agreement. To gain a higher percentage of agreement, the researcher suggests providing training on TEM concepts. Ideally, all participants would be given the same amount of pre-training, before using pre-testing to ensure uniform agreement using sample occurrences. After the completion of the reliability analysis, the participants would be able to review a sample of occurrences and review peer classifications before the final analysis.

An ICAO audit found that the CAANZ occurrence database is not comparable with other international aviation authorities (ICAO, 2006). The report AIG/18 recommends changes be made for aircraft accident and incident investigations. It also finds that coding used by the member state is not compatible with the Accident/Incident Data Reporting (ADREP)/European Co-ordination Centre for Aviation Incident Reporting Systems (ECCAIRS). The report stated that only 90 per cent of the database is compatible with the ADREP/ECCAIRS (ICAO, 2006). Research designed to investigate accident/incident reporting may not be comparable to New Zealand data without modification of the research method, and some data comparability may be difficult due to categories differing from taxonomy to taxonomy.

7.0 Further Research

Merritt and Klinect (2006) TEM taxonomic could be developed one step further to be used as a guide to develop an intervention/prevention strategies. As with the Haddon Matrix, Shappell and Wiegmann (2007) and Wiegmann et al. (2005) HFIX (Human Factors Intervention matrix) model, has been adapted to include threats as well as errors. Such a matrix would help pilots develop strategies to mitigate any experienced threat, error or UAS.

Incident reports should also include the actions taken by the pilot that returned the aircraft to within its safety margins. Reporting these mitigating actions would help other pilots develop their safety procedures and complete the Haddon Matrix (Shappell & Wiegmann, 2007), focused on aviation safety.

Additional research could be carried out into the involvement of pilots in incidents that are not required to be reported under the current CAR Part 12 rules. Expansion of TEM into other aviation activities, such as microlights, paragliders and hang gliders, would benefit such users of these crafts. According to O'Hare and Chalmers (1999), the accident rate for microlight pilots is eight times greater than that of small fixed wing aircraft. Introducing TEM concepts to more recreational users may benefit these pilots in the same way, as doing so is believed to assist fixed and rotary wing pilots by increasing the level of safety, using knowledge of past incidents.

8.0 Conclusion

TEM is another tool used to improve safety. This research identified predominant threats, errors and UAS in a New Zealand context based on reported occurrences. Threats included Traffic and Terrain. Errors included Deviating from SOPs, Missed Calls and Hand Flying Lateral Deviation Errors. UAS included Lateral Deviations and Entering Controlled/Restricted or Military Airspace without Clearance.

The benefit of using a TEM taxonomic is that individual activities are singled out and analysed within a dynamic aviation environment. Threats, errors and UAS are everyday aviation events that all pilots experience and that have an immediate effect on the levels of safety during a flight. If the pilot is unable to manage these events accordingly, a further error or accident may occur. Therefore, all such incidents should be reported so that other pilots may benefit without inducing risk.

The study represents a picture of the frequencies from reported threats, errors and UAS present in New Zealand airspace 1998–2007. This study is meant to be a guide for pilots, CAANZ and air operators in the identification of threats, errors and UAS. Analysis of reported occurrences, filtered through threat and error taxonomies, enables identification of threats, errors and UAS that are trending up and those that are reducing. As more pilots become active in reporting occurrences, these databases will continue to grow in content richness.

From the New Zealand data analysed in this study, it is clear that pilots should be on the lookout for threats and errors that appear mostly during the cruise phase of their flight. These were Environmental Threats (Terrain, Traffic), Airline Threats (Systems, Engines and Flight Controls), Aircraft Handling Errors (Hand Flying Lateral and Vertical), Procedural Errors (Deviations from SOPs, Entering Controlled/Restricted or Military Airspace without Clearance and Communication errors), Missed Calls and Misinterpretation of Instructors.

The reporting from Airways NZ Corporation (2009) makes traffic threats the most frequent threat in the CAANZ database. Managing movements can prove a challenge when aircraft of different performances, different airspace, flight rules and pilot skill levels mix. The majority of occurrences were reported from the Christchurch/ Canterbury region. However, statistical results from the Ardmore area suggest that the surrounding airspace is safer, as the area has a lower frequency of accidents and airspace incidents, although it is known to be one of the busiest aerodromes in New Zealand.

It is no surprise that Terrain is the second most common environmental threat. The unpredictable nature of weather patterns and ruggedness of terrain can make flying in these regions very risky. Due to the inherent risks of mountain flying, the CAANZ (2009b) now requires pilots at the CPL level to undertake additional ground instruction and flight training to ensure they are equipped to undertake such risky flying activities.

Threats can be minimised or avoided, errors can be managed and countermeasure be developed against UAS. By using these techniques, a pilot can prevent the aircraft from slipping out of its safety envelope. It is up to pilots to use the resources and training they have received to help them develop countermeasures against threats, errors and UAS. By applying the results from this TEM taxonomic, pilots may benefit in the form of better understanding of the importance in TEM and how frequent incidents can occur. It is also intended to help pilots determine their own hierarchy of threat and error for each flight they undertake. When applying a threat and error management framework is ‘when an adverse event occurs, the important issue is not who blundered, but how and why the defences failed’ (Reason, 2000, p. 768).

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10.0 Appendix 1: Threat and Error Management Taxonomic Categories.

Table 3. Environmental Threat Categories

Environmental Threats	
Adverse Weather	**Air Traffic Control**
Thunderstorms	Tough to meet clearances
Turbulence	Reroutes
Wake Turbulence	Language Difficulties
Poor Visibility	Controller Error
Wind Shear	**Environmental Operational Pressure**
Icing Conditions	Terrain
IMC	Traffic
Airport	TCAS TA/RA
Poor Signage (8)	Radio Congestion
Faint Markings (9)	Bird Strike
Runway/Taxiway Closures (10)	
INOP Nav Aids (11)	
Poor Braking Action (12)	
Contaminated Runways/Taxiways (13)	

Table 4. Aircraft Threat Categories

Aircraft Threats	
Aircraft	**Dispatch/Paperwork**
Systems	Load Sheet Errors
Engines	Crew Scheduling Events
Flight Controls	Late Paperwork
Automation Anomalies or Malfunctions	Changes or Errors
Other Aircraft Threats Requiring Flight Crew Attention	**Ground/Ramp**
	Aircraft Loading Events
Airline Operational Pressure	Fuelling Errors
On-time Performance Pressure	Agent Interruptions
Delays	Improper Ground Support
Late Arriving Aircraft or Flight Crew	De-Icing
Cabin	**Ground Maintenance**
Cabin Events	Aircraft Repairs on Ground
Flight Attendant Errors	Maintenance Log Problems
Distractions	Maintenance Errors
Interruptions	**Manuals/Charts**
	Missing Information
	Documentation Errors

Table 5. Aircraft Handling Error Categories

Aircraft Handling Errors	
Automation	**Manual Flying**
Incorrect Altitude	Hand flying Vertical
Incorrect Speed	Hand flying Lateral
Incorrect Heading	Speed Deviations
Incorrect Autothrottle Settings	Stall
Incorrect Mode Executed	Failure to Hold Short
Incorrect Entries	Low Altitude Flying
Flight Control	Taxi above Speed Limit
Incorrect Flaps	Low Altitude Aerobatics
Speed Brake	Turn Wrong Direction
Autobrake	**Systems/Radio/Instruments**
Thrust Reverser	Incorrect Pack
Power Settings	Altimeter
Lower Landing Gear	Fuel Switch
Ground Navigation	Radio/Transponder Frequency
Attempting to Turn Down Wrong Runway/Taxiway	Transponder Activation
Turned Down Wrong Runway/Taxiway	
Hit Ground-Based Object	
Landed Not on Runway	
Missed Runway/Taxiway/Gate	

Table 6. Procedural Error Categories

Procedural Errors	
Briefings	**Documentation**
Missed Items in the Brief	Wrong Weight and Balance
Omitted Departure and Take Off Brief	Failed to Check Notams
Handover Briefing	Forgot Maps/Important Flight Documents
Callout	Fuel Information
Omitted/ Incorrect Take Off	ATIS
Omitted/Incorrect Descent	Clearance Recorded
Omitted/ Incorrect Approach	Misinterpreted Items on Paperwork
Non-Standard Language	Pilot not Rated/Current Medical
Entering Controlled Airspace without Clearance	**Pilot Flying (PF) / Pilot Not Flying (PNF)**
	PF Makes Own Automation Changes
Checklist	PNF doing PF duties
Pre-flight Inspection	PF doing PNF duties
Preformed Checklist from Memory	**SOP Cross-verification**
Omitted Checklist	Intentional and Unintentional Failure to Cross-Verify Automation Inputs
Missed Items	
Wrong Challenge and Response	**Other Procedural**
Performed Late or Wrong Time	Other Deviations from the Government Regulations
	Flight Manual Requirements
	SOP Adherence

Table 7. Communication Error Categories

Communication Errors	
Crew To External	**Pilot to Pilot**
Missed Calls	Within Crew Miscommunication
Misinterpretation of Instructions	Within Crew Misinterpretation
Incorrect Read-backs to ATC	
Wrong Clearance Communicated	
Wrong Taxiway Communicated	
Wrong Gate Communicated	
Wrong Runway Communicated	
Failed to Maintain Separation	
Failed to Report/Terminate Flight Plan/SARWATCH	
Callout Wrong Position	
No Transponder\ELT Present in Mandatory Transponder Airspace	

Table 8. Undesirable Aircraft State Categories

Undesirable Aircraft States (UAS)	
Aircraft Handling	**Ground Navigation**
Vertical Deviations	Runway/Taxiway Incursions
Lateral Deviations	Wrong Taxiway/Ramp
Loss of Separation\Low Flying	Wrong Gate/Hold Spot
VFR on Top	Wrong Runway
Unnecessary Weather Penetration	SARWATCH/Failed to Amend/Terminate
	Taxi Above Speed Limit
Runway Extended Centre Line Incursion	Lost
Short Landings	Entering Military/Controlled or Restricted Airspace without Clearance
Overrun	
Unstable Approach	Requesting Clearance into Controlled Airspace After Infringing
Bounced on Landing	
Long Landings	**Incorrect Aircraft Configuration**
Floated Landing	Automation, GPS
Braking - Ground	Engine
Firm\Hard Landing	Flight Control
Off-Centre Landing	Hydraulic Systems, Doors, Exterior, Undercarriage
Loss of Lift	
Loss of Control (	Weight/balance events
Entering Wake Turbulence	
	Fuel Contamination, Exhaustion, Loading, Leak
	Electrical Problems\Weak Radio Transmission
	Gyro/Instrument/ELT Malfunctions

11.0 Appendix 2: Threat, Error and UAS Frequency

Table 9. Subcategory Event Table of Environmental Threats

Environmental Threats					
Threat Categories	Category Total	Environmental Subcategories	Subcategory event Total	Percentage within threat category	Percentage of total threat and error
Adverse Weather	415	Thunderstorms	6	0.25	0.04
		Turbulence	28	1.19	0.13
		Wake Turbulence	17	0.72	0.08
		Poor Visibility	96	4.07	0.45
		Wind Shear	97	4.11	0.46
		Icing Conditions	24	1.02	0.11
		IMC	147	6.23	0.70
Airport	146	Poor Signage	2	0.08	0.01
		Faint Markings	0	0.00	0.00
		Runway/Taxiway Closures	20	0.85	0.09
		Inoperative Navigation Aids	6	0.25	0.03
		Poor Braking Action	17	0.72	0.08
		Contaminated Runways/Taxiways	101	4.28	0.48
ATC	112	Tough to Meet Clearances	0	0.00	0.00
		Reroutes	1	0.04	0.00
		Language Difficulties	8	0.34	0.04
		Controller Error	103	4.37	0.49
Environmental Operational Pressure	1685	Terrain	737	31.26	3.48
		Traffic	783	33.21	3.70
		TCAS TA/RA	42	1.78	0.20
		Radio Congestion	19	0.81	0.09
		Bird Strike	104	4.41	0.49

Table 10. Subcategory Event Table of Airline Threats

Airline Threats					
Threat Categories	**Category Total**	**Airline Subcategories**	**Subcategory event Total**	**Percentage within threat category**	**Percentage of total threat and error**
Aircraft	714	**Systems**	231	29.24	1.09
		Engines	206	26.08	0.97
		Flight Controls	57	7.22	0.27
		Automation Anomalies or Malfunctions	0	0.00	0.00
		Other Aircraft Threats Requiring Flightcrew Attention	220	27.85	1.04
Airline Operational Pressure	1	**On-Time Performance Pressure**	1	0.13	0.00
		Delays	0	0.00	0.00
		Late Arriving Aircraft or Flight Crew	0	0.00	0.00
Cabin	7	**Cabin Events**	1	0.13	0.00
		Flight Attendant Errors	0	0.00	0.00
		Distractions	4	0.51	0.02
		Interruptions	2	0.25	0.01
Dispatch/ Paperwork	2	**Load Sheet Errors**	1	0.13	0.00
		Crew Scheduling Events	0	0.00	0.00
		Late Paperwork	0	0.00	0.00
		Changes or Errors	1	0.13	0.00
Ground/ Ramp	26	**Aircraft Loading Events**	6	0.76	0.03
		Fuelling Errors	20	2.53	0.09
		Agent Interruptions	0	0.00	0.00
		Improper Ground Support	0	0.00	0.00
		De-Icing	0	0.00	0.00
Ground Maintenance	35	**Aircraft Repairs on Ground**	16	2.03	0.08
		Maintenance Log Problems	3	0.38	0.01
		Maintenance Errors	16	2.03	0.08
Manuals/ Charts	5	**Missing Information**	2	0.25	0.01
		Documentation Errors	3	0.38	0.01

Table 11. Subcategory Event Table of Aircraft Handling Errors

Aircraft Handling Errors					
Error Categories	**Category Total**	**Aircraft Handling Subcategories**	**Subcategory event Total**	**Percentage within Error Category**	**Percentage of total threat and error**
Automation	3	**Incorrect Altitude**	1	0.02	0.00
		Incorrect Speed	1	0.02	0.00
		Incorrect Heading	0	0.00	0.00
		Incorrect Autothrottle Settings	0	0.00	0.00
		Incorrect Mode Executed	0	0.00	0.00
		Incorrect Entries	1	0.02	0.00
Flight Control	109	**Incorrect Flaps**	7	0.17	0.03
		Speed Brake	26	0.64	0.12
		Autobrake	1	0.02	0.00
		Thrust Reverser	0	0.00	0.00
		Power Settings	60	1.48	0.28
		Landing Gear	15	0.37	0.07
Ground Navigation	656	**Attempting to Turn Down Wrong Runway/Taxiway**	21	0.52	0.10
		Turned Down Wrong Runway/Taxiway	21	0.52	0.10
		Hit Ground-Based Object	300	7.38	1.42
		Landed Not on Runway	301	7.40	1.42
		Missed Runway/Taxiway/Gate	13	0.32	0.06
Manual Flying	3104	**Hand Flying Vertical**	982	24.15	4.64
		Hand Flying Lateral	1670	41.07	7.90
		Speed Deviations	58	1.43	0.27
		Stall	33	0.81	0.16
		Failure to Hold Short	148	3.64	0.70
		Low Altitude Flying	108	2.66	0.51
		Taxi above Speed Limit	4	0.10	0.02
		Low Altitude Aerobatics	11	0.27	0.05
		Turn Wrong Direction	90	2.21	0.43
Systems/ Radio/ Instruments	194	**Incorrect Pack**	0	0.00	0.00
		Altimeter	0	0.00	0.00
		Fuel Switch	4	0.10	0.02
		Radio/Transponder Frequency	137	3.37	0.65
		Transponder Activation	53	1.30	0.25

Table 12. Subcategory Event Table of Procedural Error

Procedural Errors					
Error Categories	**Category Total**	**Procedural Subcategories**	**Subcategory event Total**	**Percentage within Error Category**	**Percentage of total threat and error**
Briefings	5	**Missed Items in the Briefing**	4	0.10	0.02
		Omitted Departure Briefing	1	0.02	0.00
		Handover Briefing	0	0.00	0.00
Callout	1818	**Omitted Take Off**	99	2.37	0.47
		Descent Callouts	37	0.89	0.17
		Approach Callouts	100	2.39	0.47
		Non-Standard Language	15	0.36	0.07
		Entering Controlled/ Restricted/ Military Airspace without Clearance	1567	37.51	7.41
Checklist	34	**Pre-flight Inspection**	29	0.69	0.14
		Preformed Checklist from Memory	0	0.00	0.00
		Omitted Checklist	1	0.02	0.00
		Missed Items	3	0.07	0.01
		Wrong Challenge and Response	1	0.02	0.00
		Performed Late or Wrong Time	0	0.00	0.00
Documentation	148	**Wrong Weight and Balance**	1	0.02	0.00
		Failed to Check NOTAMS	27	0.65	0.13
		Forgot Maps/Important flight Documents	46	1.10	0.22
		Fuel Information	20	0.48	0.09
		ATIS	13	0.31	0.06
		Clearance Recorded	0	0.00	0.00
		Misinterpreted Items on Paperwork	25	0.60	0.12
		Pilot Not Rated/Current Medical	16	0.38	0.08
Pilot Flying / Pilot Not Flying	1	**PF Makes Own Automation Changes**	1	0.02	0.00
		PNF Doing PF Duties	0	0.00	0.00
		PF Doing PNF Duties	0	0.00	0.00
SOP Cross-verification	2	**Intentional and Unintentional Failure to Cross-verify Automation Inputs**	2	0.05	0.01
Other Procedural	2170	**Other Deviations from Government Regulations**	230	5.51	1.09
		Flight Manual requirements	60	1.44	0.28
		Deviations from SOPs	1880	45.00	8.89

Table 13. Subcategory Event Table of Communication Errors

Communication Errors					
Error Categories	Category Total	Communication Subcategories	Subcategory event Total	Percentage within Error Category	Percentage of total threat and error
Crew To External	2038	Missed Calls	1725	84.52	8.16
		Misinterpretation of Instructions	169	8.28	0.80
		Incorrect Read-backs to ATC	3	0.15	0.01
		Wrong Clearance Communicated	3	0.15	0.01
		Wrong Taxiway Communicated	1	0.05	0.00
		Wrong Gate Communicated	0	0.00	0.00
		Wrong Runway Communicated	4	0.20	0.02
		Failed to Maintain Separation	8	0.39	0.04
		Failed to Report/Terminate Flight Plan/SARWATCH	62	3.04	0.29
		Callout Wrong Position	38	1.86	0.18
		Non-Transponder\ELT Present in Mandatory Transponder Airspace	25	1.22	0.12
Pilot to Pilot	3	Within Crew Miscommunication	3	0.15	0.01
		Within Crew Misinterpretation	0	0.00	0.00

Table 14. Subcategory Event Table of UASs

Undesirable Aircraft States				
Error Categories	**Category Total**	**Aircraft Handling Subcategories**	**Subcategory event Total**	**Percentage within Error Category**
Aircraft Handling	3763	**Vertical Deviations**	896	12.48
		Lateral Deviations	1573	21.92
		Loss of Separation\Low Flying	412	5.74
		VFR on Top	21	0.29
		Unnecessary Weather Penetration	133	1.85
		Runway Extended Centre Line Incursion	192	2.68
		Short Landings	19	0.26
		Overrun	33	0.46
		Unstable Approach	42	0.59
		Bounced on Landing	19	0.26
		Long Landings	26	0.36
		Floated Landing	24	0.33
		Braking - Ground	38	0.53
		Firm\Hard Landing	141	1.96
		Off-centre Landing	46	0.64
		Loss of Lift	57	0.79
		Loss of Control	79	1.10
		Entering Wake Turbulence	12	0.17
Ground Navigation	1991	**Runway/Taxiway Incursions**	178	2.48
		Wrong Taxiway/Ramp	5	0.07
		Wrong Gate/Hold Spot	57	0.79
		Wrong Runway	97	1.35
		SARWATCH/Failed to amend/terminate	61	0.85
		Taxi above Speed Limit	0	0.00
		Lost	108	1.50
		Entering Military/Controlled or Restricted Airspace without Clearance	1409	19.63
		Requesting Clearance into Controlled Airspace After Infringing	76	1.06
Incorrect Aircraft Configuration	982	**Automation, GPS**	4	0.06
		Engine	230	3.20
		Flight Control	391	5.45
		Hydraulic Systems, Doors, Exterior, Undercarriage	144	2.01
		Weight/Balance Events	9	0.13
		Fuel Contamination, Low, Exhaustion, Loading, Leak	46	0.64
		Electrical Problems/Weak Radio Transmission	129	1.80
		Gyro/Instrument/ELT Malfunctions	29	0.40

Table 15. Totals for Phase of Flight

		Pre-flight/ Taxi	**Takeoff / Climb**	**Cruise**	**Descent/ Approach/ Land**	**Taxi/ Park**
Percentage	Total	4.90	14.88	48.08	29.70	2.44
	Airspace Incident	2.79	9.06	38.31	15.77	0.65
	Accident	0.36	2.29	3.80	6.30	0.30
	Incident	1.75	3.53	5.97	7.63	1.49
Tally	Incident	59	119	201	257	50
	Accident	12	77	128	212	10
	Airspace Incident	94	305	1290	531	22
	Total	165	501	1619	1000	82

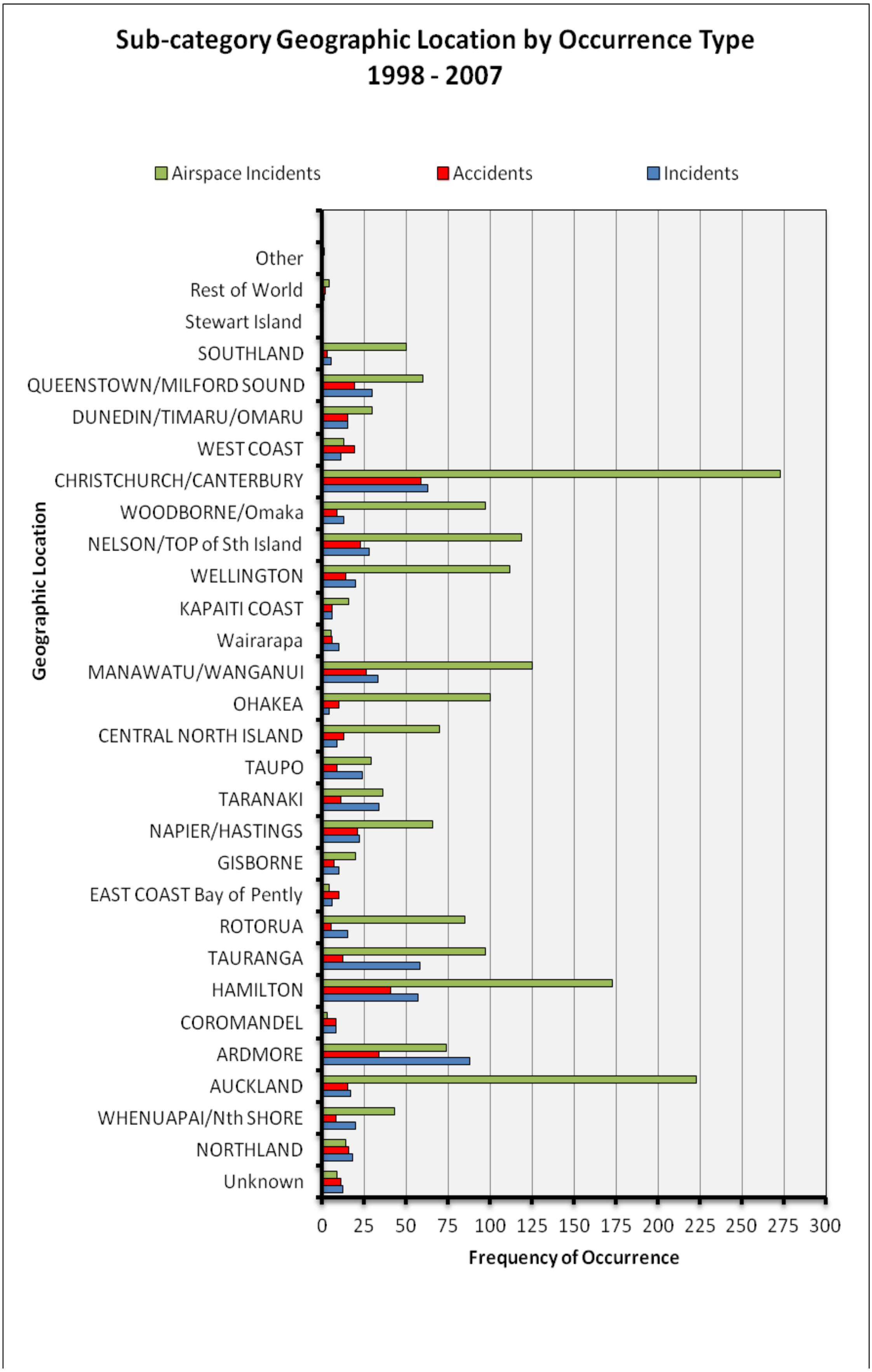

Figure 31. Subcategory Geographic Location of Safety Occurrences

Table 16. Totals for Geographic Location

Region	Percentage of Results: Incidents	Percentage of Results: Accidents	Percentage of Results: Airspace Incidents	Location	Tally of Results: Incidents	Tally of Results: Accidents	Tally of Results: Airspace Incidents
Unknown	12	11	10	**Unknown**	12	11	9
Upper North Island	151	81	355	**Northland**	18	16	14
				Whenuapai/North Shore	20	8	43
				Auckland	17	15	223
				Ardmore	88	34	74
				Coromandel	8	8	3
Central North Island	272	165	805	**Hamilton**	57	41	173
				Tauranga	58	12	97
				Rotorua	15	5	85
				EAST COAST Bay of Pently	6	10	4
				Gisborne	10	7	20
				Napier/Hastings	22	21	66
				Taranaki	34	11	36
				Taupo	24	9	29
				CENTRAL NORTH ISLAND	9	13	70
				Ohakea	4	10	100
				Manawatu/Wanganui	33	26	125
Lower North Island	36	26	133	**Wairarapa**	10	6	5
				Kapaiti Coast	6	6	16
				Wellington	20	14	112
Top of South Island	41	32	216	**Nelson/TOP of South Island**	28	23	119
				Woodborne/Omaka	13	9	97
Central South Island	74	78	286	**Christchurch/Canterbury**	63	59	273
				West Coast	11	19	13
Lower South Island	50	37	140	**Dunedin/Timaru/Omaru**	15	15	30
				Queenstown/Milford Sound	30	19	60
				Southland	5	3	50
				Stewart Island	0	0	0
Rest of World	1	2	4	**Rest of World**	1	2	4
				Other	0	0	1

12.0 Appendix 3: New Zealand Mountainous Zones

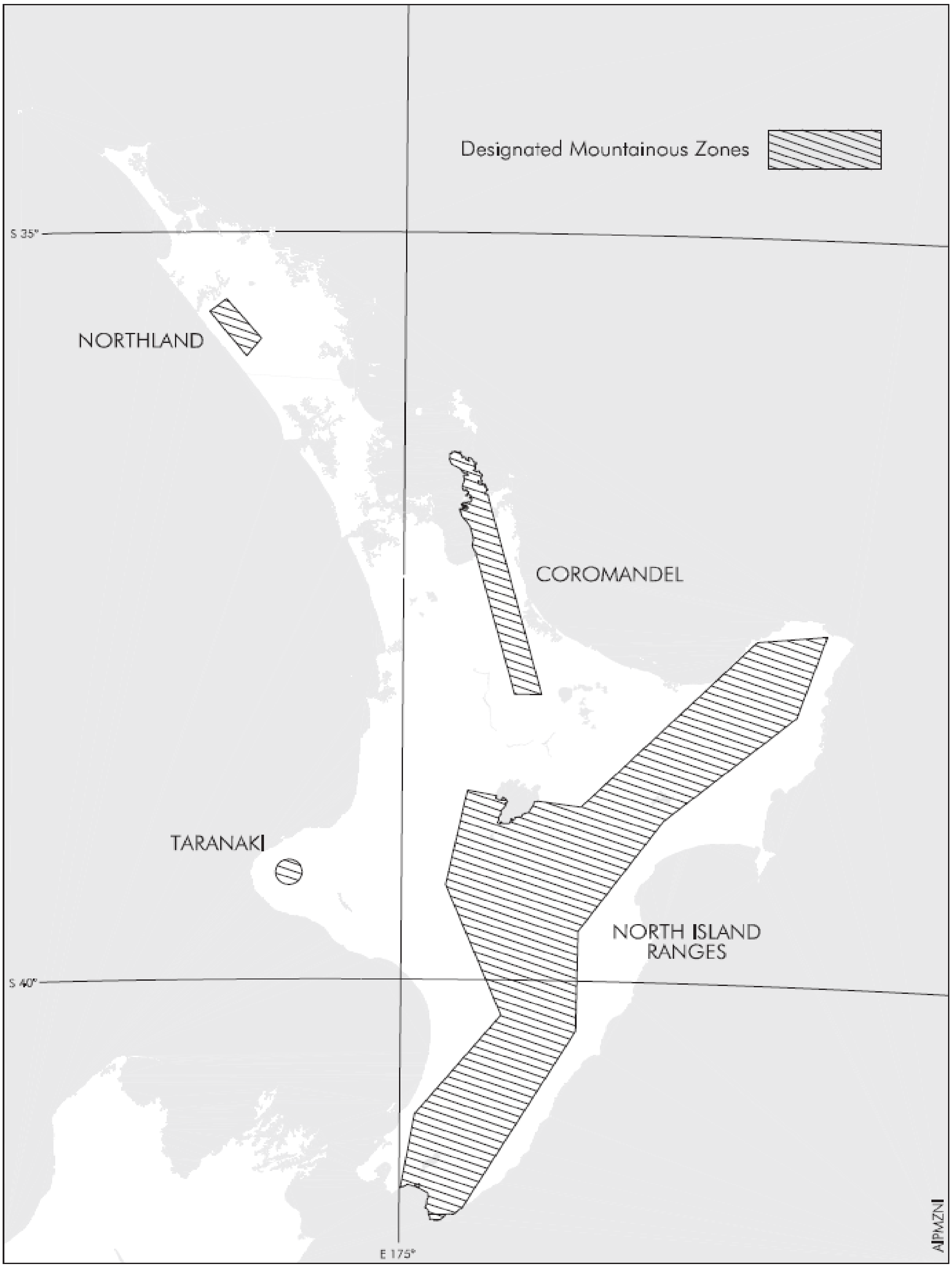

Figure 32. Mountainous Zones–North Island

Source: AIP New Zealand (2010)

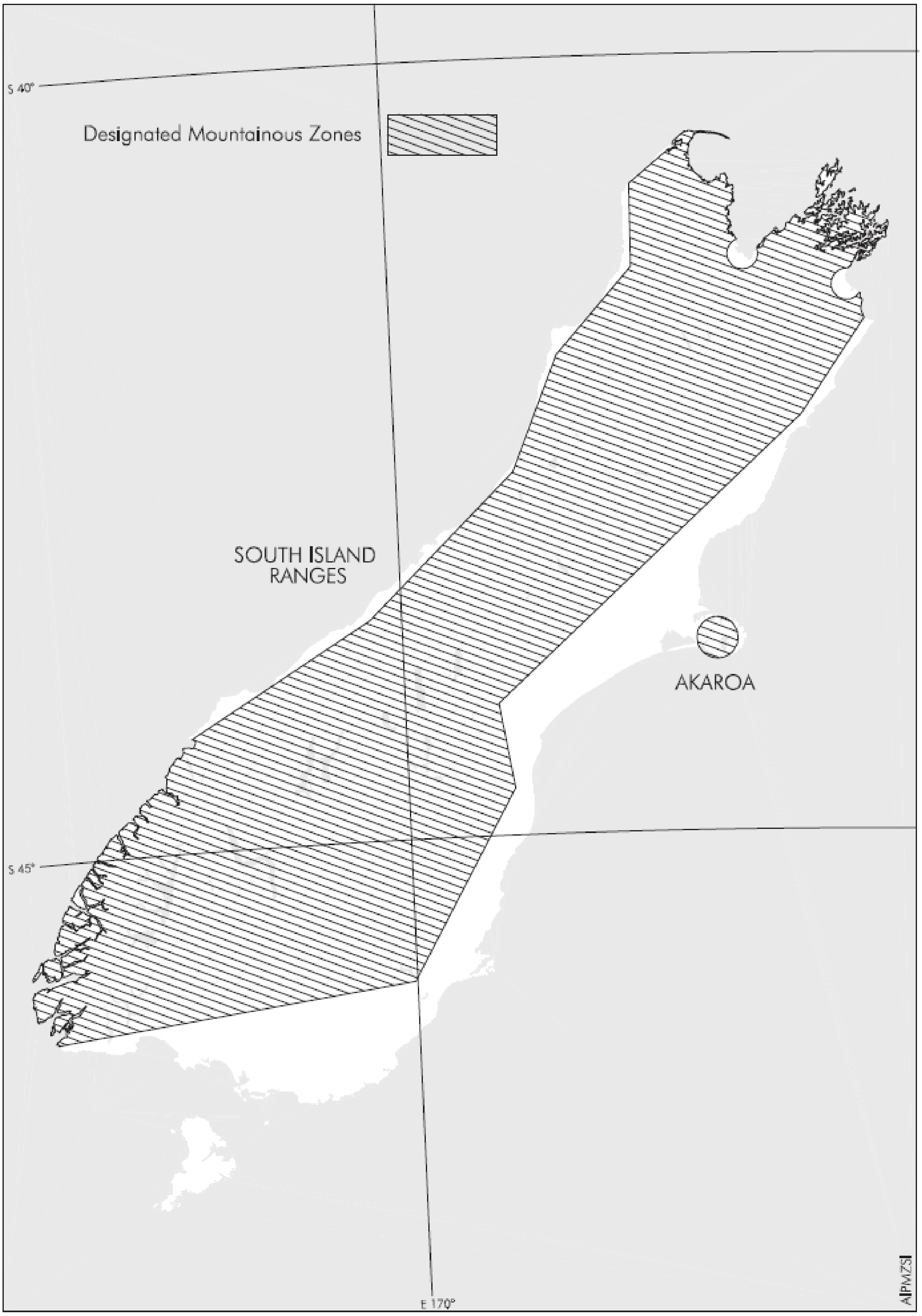

Figure 33. Mountainous Zones–South Island

Source: AIP New Zealand (2010)

13.0 Appendix 4: Threat and Error Management Taxonomic Occurrence Examples

The occurrence number that follows the threat, error and UAS are examples of such present in that occurrence.

Table 17. Environmental Threat Occurrence Examples

Category	Environmental Threat Subcategories	Example Occurrence
Adverse Weather	Thunderstorms	00/3122
	Turbulence	02/2809
	Wake Turbulence	05/1798
	Poor Visibility	01/2715
	Wind Shear	98/65
	Icing Conditions	06/3772
	IMC	05/125
Airport	Poor Signage	98/843
	Faint Markings	None Reported
	Runway/Taxiway Closures	01/3756
	INOP Navigation Aids	07/50
	Poor Braking Action	03/735
	Contaminated Runways/Taxiways	03/3734
ATC	Tough to Meet Clearances	None reported
	Reroutes	05/4197
	Language Difficulties	99/1479
	Controller Error	06/2414
Environmental Operational Pressure	Terrain	01/4335
	Traffic	01/2503
	TCAS TA/RA	02/1501
	Radio Congestion	99/214
	Bird Strike	07/795

Table 18. Airline Threat Occurrence Examples

Category	Airline Threat Subcategories	Example Occurrence
Aircraft	Systems	02/3415
	Engines	99/727
	Flight Controls	98/7
	Automation Anomalies or Malfunctions	None Reported
	Other Aircraft Threats Requiring Flightcrew Attention	07/4089
Airline Operational Pressure	On-Time Performance Pressure	98/1492
	Delays	None Reported
	Late Arriving Aircraft or Flightcrew	None Reported
Cabin	Cabin Events	99/442
	Flight Attendant Errors	None Reported
	Distractions	03/59
	Interruptions	00/3164
Dispatch/ Paperwork	Load Sheet Errors	02/704
	Crew Scheduling Events	None Reported
	Late Paperwork	None Reported
	Changes or Errors	03/3154
Ground/ Ramp	Aircraft Loading Events	01/451
	Fuelling Errors	98/3194
	Agent Interruptions	None Reported
	Improper Ground Support	None Reported
	De-Icing	None Reported
Ground Maintenance	Aircraft Repairs on Ground	07/718
	Maintenance Log Problems	04/4019
	Maintenance Errors	98/356
Manuals/ Charts	Missing Information	98/2972
	Documentation Errors	04/901

Table 19. Aircraft Handling Error Occurrence Examples

Category	Aircraft Handling Subcategories	Example Occurrence
Automation	**Incorrect Altitude**	06/332
	Incorrect Speed	00/1382
	Incorrect Heading	None Reported
	Incorrect Autothrottle Settings	None Reported
	Incorrect Mode Executed	None Reported
	Incorrect Entries	00/1382
Flight Control	**Incorrect Flaps**	05/820
	Speed Brake	07/492
	Autobrake	03/865
	Thrust Reverser	None Reported
	Power Settings	00/1
	Lower Landing Gear	99/1320
Ground Navigation	**Attempting to Turn Down Wrong Runway/Taxiway**	99/1854
	Turned Down Wrong Runway/Taxiway	00/1041
	Hit Ground-Based Object	04/97
	Landed Not on Runway	06/1330
	Missed Runway/Taxiway/Gate	02/26
Manual Flying	**Hand Flying Vertical**	01/2431
	Hand flying Lateral	04/3401
	Speed Deviations	04/3624
	Stall	99/3783
	Failure to Hold Short	00/37
	Low Altitude Flying	98/4
	Taxi Above Speed Limit	01/2839
	Low Altitude Aerobatics	01/2351
	Turn Wrong Direction	03/1956
Systems/ Radio/ Instruments	**Incorrect Pack**	None Reported
	Altimeter	None Reported
	Fuel Switch	07/4027
	Radio/Transponder Frequency	01/2431
	Transponder Activation	06/4521

Table 20. Procedural Error Occurrence Examples

Category	Procedural Error Subcategories	Example Occurrence
Briefings	**Missed Items in The Brief**	98/602
	Omitted Departure Briefing	03/459
	Handover Briefing	None Reported
Callout	**Omitted Take Off**	98/1016
	Descent Callouts	99/779
	Approach Callouts	04/3653
	Non-Standard Language	04/47
	Entering Controlled/ Restricted/ Military Airspace without Clearance	05/1862
Checklist	**Pre-flight Inspection**	07/441
	Preformed Checklist from Memory	None Reported
	Omitted Checklist	98/1536
	Missed Items	01/744
	Wrong Challenge and Response	06/2729
	Performed Late or Wrong Time	None Reported
Documentation	**Wrong Weight and Balance**	98/2972
	Failed to Check NOTAMS	99/3043
	Forgot Maps/ Important Flight Documents	02/333
	Fuel Information	07/1189
	ATIS	07/411
	Clearance Recorded	None Reported
	Misinterpreted items on paperwork	01/3907
	Pilot not Rated/Current Medical	04/245
Pilot Flying / Pilot Not Flying	**PF Makes Own Automation Changes**	99/79
	PNF Doing PF Duties	None Reported
	PF Doing PNF Duties	None Reported
SOP Cross-verification	**Intentional and Unintentional Failure to Cross-verify Automation Inputs**	00/1382
Other Procedural	**Other Deviations from The Government Regulations**	98/1993
	Flight Manual Requirements	01/2946
	Deviations from SOPs	03/3279

Table 21. Communication Error Occurrence Examples

Category	Communication Error Subcategories	Example Occurrence
Crew To External	**Missed Calls**	98/3059
	Misinterpretation of Instructions	99/2302
	Incorrect Read-backs to ATC	00/1217
	Wrong Clearance Communicated	02/822
	Wrong Taxiway Communicated	01/1399
	Wrong Gate Communicated	None Reported
	Wrong Runway Communicated	06/4275
	Failed to Maintain Separation	98/63
	Failed to Report/Terminate Flight Plan/SARWATCH	06/1457
	Callout Wrong Position	98/984
	No Transponder\ELT Present in Mandatory Transponder Airspace	03/2281
Pilot to Pilot	**Within Crew Miscommunication**	04/952
	Within Crew Misinterpretation	None Reported

Table 22. UAS Occurrence Examples

Category	UAS Subcategories	Example Occurrence
Aircraft Handling	**Vertical Deviations**	98/1532
	Lateral Deviations	04/236
	Loss of Separation/Low Flying	05/2744
	VFR on Top	99/80
	Unnecessary Weather Penetration	03/3384
	Runway Extended Centre Line Incursion	06/2647
	Short Landings	07/475
	Overrun	04/3553
	Unstable Approach	03/2996
	Bounced on Landing	02/2400
	Long Landings	05/4214
	Floated Landing	03/3739
	Braking Ground	98/1422
	Firm/Hard Landing	00/483
	Off-centre Landing	02/541
	Loss of Lift	05/2916
	Loss of Control	01/4204
	Entering Wake Turbulence	03/3154
Ground Navigation	**Runway/Taxiway Incursions**	98/3799
	Wrong Taxiway/Ramp	03/3072
	Wrong Gate/Hold Spot	00/37
	Wrong Runway	98/671
	SARWATCH/Failed to Amend/Terminate	04/1856
	Taxi above Speed Limit	01/2839
	Lost	05/57
	Entering Military/Controlled or Restricted Airspace without Clearance	99/35
	Requesting Clearance into Controlled Airspace after Infringing	07/1391
Incorrect Aircraft Configuration	**Automation, GPS**	07/4151
	Engine	03/3557
	Flight Control	00/673
	Hydraulic Systems, Doors, Exterior, Undercarriage	01/814
	Weight/balance events	04/220
	Fuel Contamination, Low, Exhaustion, Loading, Leak	00/1313
	Electrical Problems/Weak Radio Transmission	99/2855
	Gyro/Instrument/ELT Malfunctions	04/2780

14.0 Appendix 5: Occurrence Database Fields

List of the CAANZ occurrence database data fields:

occurrence number, date and time, local UTC, occurrence type & code, location, flight rules, altitude ASL (Above Sea Level), altitude AGL (Above Ground Level), altitude flight level, departure point, destination point, aircraft ID, aircraft registration, latitude, longitude, NRP, distance from NRP, bearing from NRP, wind bearing, wind velocity, total cloud, cloud height, precipitation, pilot total hours, pilot hours on type, pilot last 90 days, intruder relative altitude, intruder relative position, bird species, bird size, bird number, aircraft IAS, aircraft lights on, TTIS (Total Time in Service) hours, TTIS cycles, TSO (Time Since Overhaul) hours, TSO cycles, TSI (Time Since Inspection) cycles, aircraft damage level, description of damage, aircraft disposal, TAIC advised, TAIC date time, TAIC investigating, TAIC reference, brief description, brief description ext., injuries fatal crew, injuries serious crew, injuries minor crew, injuries fatal PAX, injuries serious PAX and injuries minor PAX.

15.0 Appendix 6; Reliability Survey Handout

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COLLEGE OF BUSINESS
Kaupapa Whai Pakihi

SCHOOL OF AVIATION
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New Zealand
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Hello Aviator,

I am conducting a study of aviation safety occurrences reported to the NZ CAA for the period 1992 to 2008.

A safety occurrence may include accidents, incidents, airspace incidents, bird strikes, security occurrences and aviation related concerns.

Using threat and error (TEM) methodology, I have classified each safety occurrence into various threats, errors and undesirable aircraft states.

To assess the validity, accuracy and consistency of my TEM classification analysis, I would like you to read the following ten safety occurrences (they have been randomly selected from the NZ CAA database) and analyse each event. Please tick in each appropriate box the corresponding threat, error and undesirable aircraft state you think happened or was present in each safety occurrence.

You can identify as many different threats, errors or undesirable aircraft states as necessary if you think they were present in that safety occurrence (they are not necessarily mutually exclusive).

This is an opportunity for you to help me in my research on threat and error management (TEM) in NZ Aviation.

The last part of the survey is voluntary. These details will be used to gain a rough idea of the overall level of experience of the survey respondents. If you would like to include your flight experience and a brief description of your level of involvement in the aviation industry and your current job position, please do so at the end of this survey.

The ten randomly selected incidents are listed below. The tables provide background information on each occurrence.

Thank you for your participation.

Timothy Graham

MAv Thesis Candidate

Safety Occurrence Descriptions

#1 01/3050

An aircraft believed to be ZK-JER was observed on Ohakea radar to enter the Ohakea TMA without a clearance, passing in the opposite direction to ZK-EWD on final approach for the PM VOR/DME approach. The pilot of ZK-JER had believed that he heard and read back 2500 feet, when the original clearance was to be not above 1500 feet or similar.

#2 05/3429

Airways A2. Significant event. QFA035 was an IFR flight from Melbourne to Christchurch. PDL1 was a VFR flight from NZCH to Wigram in the right hand circuit pattern for RWY02 but en route for NZWG. While QFA35 was established on final for RWY02 at NZCH, PD L1 was tracking west to east . PDL1 passed close to QFA35 and QFA35 was instructed to carry out a go-around.

#3 00/1201

Airways A2. ZK-DIW departed off grass runway 20 from Christchurch with a clearance to the southwest, under visual flight conditions (VFR). A short time later an Ansett operated aircraft ZQA694 departed off runway 20. The pilot of ZQA694 reported traffic on the nose and carried out a left turn to pass around ZK-DIW that was, at that time, 2 nautical miles south of Christchurch.

#4 01/2714

An unknown radar target was observed to enter the AA CTR at Panmure and tracked via Otara and then through the 5 NM final approach for RWY23L, without a clearance. The aircraft was then observed to track on to NZAR and was subsequently identified as ZK-SMS by listening to the NZAR radio frequency 118.1 MHz. NZM76 was held up on left base and kept in on a short approach to avoid ZK-SMS and EAG526 was vectored clear of ZK-SMS by radar.

Investigation Summary: No Airways involvement.

#5 97/830

ZK-NDA observed approximately 15nm se of the WU-AY track and tracking towards Wellington at approximately 25nm from WU. The Taranaki radar gave vectors to regain track. The aircraft subsequently appeared to have difficulty maintaining track and was taken under vectors again. When closer to Nelson the aircraft was given a NZ VOR radial to fly to commence the approach. Mr Fredericsen advised me that this was a training flight (although this was not mentioned in the flight plan) and, also, that the aircraft was experiencing difficulties with the DI.

#6 98/356

Cessna 152 ZK-FGW was on a touch and go landing on Runway 03. While on the runway the pilot heard ZK-SNM call at Clevedon joining on final for Runway 21. The pilot of FGW informed SNM that 03 was the duty runway. No response or any further radio calls came from SNM. Another aircraft ZK-FCO also called SNM and advised him runway 03 was in use. Again no response. The pilot of SNM continued with an approach and landing on Runway 21. After landing, he saw another aircraft in the circuit and, increasing the volume on both radios, made a check call. Both other aircraft responded to this call. Subsequent examination of the radio volume control knob showed it was misaligned.

#7 02/1019

Significant event On Wednesday 10 April 2002 at about 1435 hours, Cessna 210N ZK-TWA departed from Dunedin, bound for Masterton. The aircraft did not arrive at Masterton, but was not reported overdue until the next day. After a search, the aircraft was found on the Friday morning near Conical Peak, 34 km southwest of Oamaru. The aircraft was destroyed and the pilot did not survive. The aircraft had struck the side of a ridge in an upright attitude, having descended as it approached the ridge, due either to pilot inattention or incapacitation.

#8 96/3014

Glider was trying to recover to launch point, but later decided this was unattainable and commenced an outlanding. First option unsuitable on closer inspection, second option required turn back and height loss incurred caused glider to strike tree tops, glider then stalled and impacted the ground. Pilot received back injuries, aircraft destroyed.

#9 99/3455

The helicopter was on short final for a paddock landing site, when the engine began running rough. One witness, who was familiar with engines, said that it sounded as if the engine had dropped a valve. The pilot attempted to flare the machine, which landed heavily on its right skid in a tail-low attitude, striking the ground with the tail rotor at the same instant. The skid collapsed and the helicopter rolled onto its right side. The right-seat occupant was trapped momentarily until assisted by bystanders. He received minor injuries, but the pilot was uninjured.

#10 07/191

ZK-HRE was a VFR flight that reported at the west shore of the Lake for landing at NZRO. The flight was cleared to enter the CTR via the BLUE LAKE due to traffic vacating to the east comprising ZK-EFI and ZK-FEO. ZK-HRE subsequently turned north and called at the BLUE LAKE when, in fact the flight was over LAKE OKATAINA and passed in front of and close to the two float planes. The pilot was apparently geographically confused.

Table. 1	Occurrence No									
	01/3050	05/3429	00/1201	01/2714	97/830	98/356	02/1019	96/3014	99/3455	07/191
Occurrence Date	06-Sep-01	25-Oct-05	08-May-00	24-Jul-01	05-Mar-97	03-Feb-98	10-Apr-02	10-Nov-96	04-Dec-99	20-Jan-07
Occurrence Time (24 hr)	04:15:00	01:30:00	01:30:00	05:48:00	00:20:00	07:50:00	02:51:00	01:50:00	22:40:00	02:40:00
Local UTC	UTC	UTC	UTC	UTC	UTC	DT	ST	UTC	UTC	UTC
Occurrence Type	Airspace Incident	Airspace Incident	Airspace Incident	Airspace Incident	Airspace Incident	Incident	Accident	Accident	Accident	Airspace Incident
Location	Ohakea TMA	Christchurch	Christchurch	AA	25NM SW WANGANUI	ARDMORE	18 SW Oamaru	New Plymouth	Wainuiomata	Lake Okatainao
VMC-IMC	VMC			VMC	IMC	VMC	VMC	VMC	VMC	VMC
Flight Rules	VFR	IFR	IFR	VFR	IFR	VFR	VFR	VFR	VFR	VFR
Altitude ASL	2500			1300			3000			3500
Altitude AGL								0		
Altitude FL										
Departure Point	Palmerston North	CH	Christchurch	NORTH SHORE	WANGANUI	GREAT BARRIER	Dunedin Airport	NORFOLK RD	Wainuiomata	Whakatane
Destination Point	GISBORNE	WG		ARDMORE	NESLON	ARDMORE	Masterton Aerodrome	NORFOLK RD	Wainuiomata	Rotorua
Registration Mark	JER			SMS	NDA	SNM	TWA	GFJ	HIM	HRE
Latitude	S40 1939.6	S43 3200.0	S43 2915.0	S37 0337.8	S39 3957.0		S44 5418.6	S38 5446.2	S41 2612.6	S38 0600.0
Longitude	E175 3028.8	E172 3200.0	E172 3201.8	E174 4237.8	E175 2432.4		E171 3529.4	E174 0330.0	E174 4007.8	E176 2521.0
NRP	PM	CH	CH	AA	WU	AR	OU	NP	WN	RO
Distance From NRP	5	3	0	5	25	0	22	8	9	5
Bearing From NRP	85	180	0	51	225	0	260	135	43	90
Wind Bearing										
Wind Velocity										
Total Cloud										
Cloud Height										
Precipitation										
Pilot Total Flying Hrs	200			450		1941	3525	433	87	
Pilot Hours On Type	175			300		37	2115	29	87	
Pilot Last 90 Days	9			10		4.9	171	5	10	

Table. 1 (cont)	Occurrence No									
	01/3050	05/3429	00/1201	01/2714	97/830	98/356	02/1019	96/3014	99/3455	07/191
Intruder Relative Altitude										
Intruder Relative Position										
Bird Species										
Bird Size										
Bird Number Seen										
Bird Number Hit										
Aircraft IAS										
Aircraft Lights On										
TTIS Hours										
TTIS Cycles										
TSO Hours										
TSO Cycles										
TSI Hours										
TSI Cycles										
Aircraft Damage Level							Destroyed	Substantial	Substantial	
Description Of Damage										
Aircraft Disposal							Writeoff	Unknown	Writeoff	
TAIC Advised				0	0	0	-1	-1	-1	0
TAIC Date Time							11-Apr-02		04-Dec-99	
TAIC Investigating				0	0	0	-1	0	0	0
TAIC Reference							02-004			
Injuries Fatal Crew		0			0	0	1	0	0	0
Injuries Serious Crew		0			0	0	0	1	0	0
Injuries Minor Crew		0			0	0	0	0	1	0
Injuries Fatal PAX		0			0	0	0	0	0	0
Injuries Serious PAX		0			0	0	0	0	0	0
Injuries Minor PAX		0			0	0	0	0	0	0

Classification of Safety Occurrences into Threats, Errors and Undesirable Aircraft States

Threats are defined as events or errors that occur outside the influence of the flight crew; increase the operational complexity of a flight; and require crew attention and management if safety margins are to be maintained.

Environmental Threats		01/3050	05/3429	00/1201	01/2714	97/830	98/356	02/1019	96/3014	99/3455	07/191
Adverse Weather	Thunderstorms										
	Turbulence										
	Wake Turbulence										
	Poor Visibility										
	Wind Shear										
	Icing Conditions										
	IMC										
Airport	Poor Signage										
	Faint Markings										
	Runway/taxiway closures										
	INOP nav aids										
	Poor braking Action										
	Contaminated Runways/Taxiways										
ATC	Tough to Meet Clearances										
	Reroutes										
	Language Difficulties										
	Controller Error										
Environmental Operational Pressure	Terrain										
	Traffic										
	TCAS TA/RA										
	Radio Congestion										
	Bird Strike										

Airline Threats		01/3050	05/3429	00/1201	01/2714	97/830	98/356	02/1019	96/3014	99/3455	07/191
Aircraft	Systems										
	Engines										
	Flight Controls										
	Automation Anomalies or Malfunctions										
	Other Aircraft Threats Requiring Flight Crew Attention										
Airline Operational Pressure	On-time Performance Pressure										
	Delays										
	Late Arriving Aircraft or Flight Crew										
Cabin	Cabin Events										
	Flight Attendant Errors										
	Distractions										
	Interruptions										
Dispatch/ Paperwork	Load Sheet Errors										
	Crew Scheduling Events										
	Late Paperwork										
	Changes or Errors										
Ground/ Ramp	Aircraft Loading Events										
	Fuelling Errors										
	Agent Interruptions										
	Improper Ground Support										
	De-Icing										
Ground Maintenance	Aircraft Repairs on Ground										
	Maintenance Log Problems										
	Maintenance Errors										
Manuals/ Charts	Missing Information										
	Documentation Errors										

Errors are defined as flight crew actions or inactions that lead to a deviation from the crew or organisational intentions or expectations; reduce safety margins; and increase the probability of adverse operational events on the ground during flight.

Aircraft Handling Errors		01/3050	05/3429	00/1201	01/2714	97/830	98/356	02/1019	96/3014	99/3455	07/191
Automation	Incorrect Speed										
	Incorrect Heading										
	Incorrect Autothrottle Settings										
	Incorrect Mode Executed										
	Incorrect Entries										
Flight Control	Incorrect Flaps										
	Speed Brake										
	Autobrake										
	Thrust Reverser										
	Power Settings										
	Lower Landing Gear										
Ground Navigation	Attempting to Turn Down Wrong Runway/Taxiway										
	Turned Down Wrong Runway/Taxiway										
	Hit Ground-Based Object										
	Landed not on Runway										
	Missed Runway/Taxiway/gate										
Manual Flying	Hand Flying Vertical										
	Lateral										
	Speed Deviations										
	Stall										
	Failure to Hold Short										
	Low Altitude Flying										
	Taxi above Speed Limit										
	Low Altitude Aerobatics										
	Turn Wrong Direction										
Systems/ Radio/ Instruments	Incorrect Pack										
	Altimeter										
	Fuel Switch										
	Radio/Transponder Frequency										
	Transponder Activation										

Procedural Errors		01/3050	05/3429	00/1201	01/2714	97/830	98/356	02/1019	96/3014	99/3455	07/191
Briefings	Missed Items in the brief										
	Omitted Departure										
	Handover Briefing										
Callout	Omitted Take Off										
	Descent Callouts										
	Approach Callouts										
	Non-Standard Language										
	Entering Controlled Airspace without Clearance										
Checklist	Pre-flight Inspection										
	Preformed Checklist from Memory										
	Omitted Checklist										
	Missed Items										
	Wrong Challenge and Response										
	Performed Late or Wrong Time										
Documentation	Wrong Weight and Balance										
	Failed to Check Notams										
	Forgot Maps/Important flight Documents										
	Fuel Information										
	ATIS										
	Clearance Recorded										
	Misinterpreted Items on Paperwork										
	Pilot not Rated/Current Medical										
Pilot Flying / Pilot Not Flying	PF Makes Own Automation Changes										
	PNF Doing PF Duties										
	PF Doing PNF Duties										
SOP Cross-verification	Intentional and Unintentional Failure To Cross-Verify Automation Inputs										
Other Procedural	Other Deviations from the Government Regulations										
	Flight Manual Requirements										
	SOP										

Communication Errors		01/3050	05/3429	00/1201	01/2714	97/830	98/356	02/1019	96/3014	99/3455	07/191
Crew To External	Missed Calls										
	Misinterpretation of Instructions										
	Incorrect Read-backs to ATC										
	Wrong Clearance Communicated										
	Wrong Taxiway Communicated										
	Wrong Gate Communicated										
	Wrong Runway Communicated										
	Failed to Maintain Separation										
	Failed to Report/Terminate Flight Plan/SARWATCH										
	Callout Wrong Position										
	Non-Transponder/ELT Present in Mandatory Transponder Airspace										
Pilot to Pilot	Within Crew Miscommunication										
	Within Crew Misinterpretation										

Please indicate what phase of the flight you think the safety occurrence happened.

Phase of Flight		01/3050	05/3429	00/1201	01/2714	97/830	98/356	02/1019	96/3014	99/3455	07/191
	Pre-flight/Taxi										
	Takeoff/Climb										
	Cruise										
	Descent/Approach/Land										
	Taxi/Park										

An **Undesirable Aircraft State (UAS)** is defined as a position, speed, attitude, or configuration of an aircraft that results from flight crew error, actions, or inaction and clearly reduces safety margins.

Undesirable Aircraft States		**01/3050**	**05/3429**	**00/1201**	**01/2714**	**97/830**	**98/356**	**02/1019**	**96/3014**	**99/3455**	**07/191**
Aircraft Handling	**Vertical Deviations**										
	Lateral Deviations										
	Loss of Separation/Low Flying										
	VFR on Top										
	Unnecessary Weather Penetration										
	Runway Extended Centre Line Incursion										
	Short Landings										
	Overrun										
	Unstable Approach										
	Bounced on Landing										
	Long Landings										
	Floated Landing										
	Braking Ground										
	Firm/Hard Landing										
	Off-Centre Landing										
	Loss of Lift										
	Loss of Control										
	Entering Wake Turbulence										
Ground Navigation	**Runway/Taxiway Incursions**										
	Wrong Taxiway/Ramp										
	Wrong Gate/Hold Spot										
	Wrong Runway										
	SARWATCH/Failed to Amend/Terminate										
	Taxi above Speed Limit										
	Lost										
	Entering Military/Controlled or Restricted Airspace without Clearance										
	Requesting Clearance into Controlled Airspace after Infringing										
Incorrect Aircraft Configuration	**Automation, GPS**										
	Engine										
	Flight Control										
	Hydraulic Systems, Doors, Exterior, Undercarriage										
	Weight/Balance Events										
	Fuel Contamination, Low, Exhaustion, Loading, Leak										
	Electrical Problems/Weak Radio Transmission										
	Gyro/Instrument/ELT Malfunctions										

Additional Details

Flying experience (type of aircraft usually flown, total flying hours):

Current job position:

Brief description of involvement in the aviation industry:

16.0 Appendix 7: Abbreviations

AAIB	Air Accidents Investigation Branch
ADREP	Accident/Incident Data Reporting
ADM	Aeronautical Decision Making
AGL	Above Ground Level
AIP	Aeronautical Information Publication
AQP	Advance Qualification Program
ARC	Aviation Related Concerns
ASAP	Aviation Safety Action Program
ASL	Above Sea Level
ASRS	Aviation Safety Reporting System
ATC	Air Traffic Control
ATP	Airline Transport Pilot
AVO	Air Transportation Safety Oversight Service
ATSB	Australian Transport Safety Bureau
BAC	British Aircraft Corporation
BOAC	British Overseas Airways Corporation
BTU	Bureau of Transportation Statistics
CAANZ	Civil Aviation Authority of New Zealand
CAR	Civil Aviation Rules
CASA	Civil Aviation Safety Authority (Australia)
CATS	Crew Action Tracking System
CFIT	Controlled Flight into Terrain
CHIRP	Confidential Human Factors Reporting Program
CRM	Crew Resource Management

CTR	Control Zone
CTR/D	Control Zone Class D Airspace
CPL	Commercial Pilots License
ECCAIRS	European Co-ordination Centre for Aviation Incident Reporting Systems
EOP	Environmental Operational Pressure
FAA	Federal Aviation Administration
FIR	Flight Information Region
FOD	Foreign Object Damage
FOQA	Flight Operation Quality Assurance
FMS	Flight Management System
GPS	Global Positioning System
HFACS	Human Factors Analysis and Classification System
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IR	Instrument Rating
IRM	Immediate Reportable Matters
LOSA	Line Operations Safety Audits
MRO	Maintenance, Repair & Overhaul
MTOW	Maximum Take Off Weight
NASA	National Aeronautics and Space Administration
NASDAC	National Aviation Safety Data Analysis Centre
NDB	Non-Directional Beacon
NOTAM	Notices to AirMen
NTS	Non-Technical Skills

NTSB	National transportation Safety Board
NZHGPA	New Zealand Hang Glider and Paraglider Association
NZLT	New Zealand Local Time
PIC	Pilot in Command
PPL	Private Pilots Licence
ROO	Regional Operations Officer
SARWATCH	Search and Rescue Watch
SOP	Standard Operating Procedure
STAMP	Systems Theoretic Accident Model and Process
TAIC	Transport Accident Investigation Commission
TCAS TA/RA	Traffic Alert and Collision Avoidance System Traffic Advisory/Resolution Advisory
TEM	Threat and Error Management
TWR	Tower
UAS	Undesirable Aircraft States
UTC	Coordinated Universal Time
VFR	Visual Flight Rules
VTC	Terminal Area Chart
VMC	Visual Meteorological Conditions
VOR/DME	VHF omnidirectional radio range/Distance Measuring Equipment
ZK	New Zealand Registered Aircraft

17.0 Appendix 8: Location Abbreviations

GS	Gisborne
NZGS	Gisborne Aerodrome
NZNS	Nelson Aerodrome
NZOM	Omaka Aerodrome
NZPM	Palmerston North Aerodrome
NZTG	Tauranga Aerodrome
OH	Ohakea
RO	Rotorua
US	United States of America
WB	Woodbourne Aerodrome
WN	Wellington