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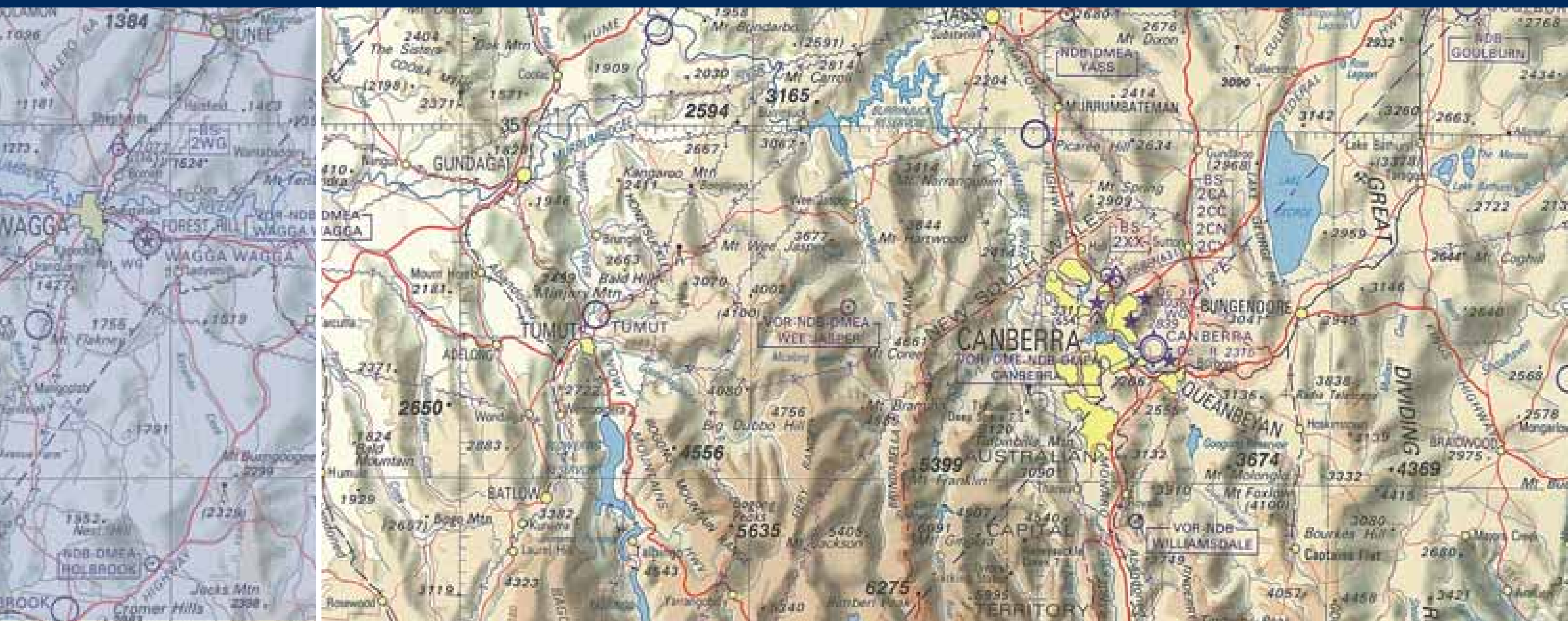

ATSB TRANSPORT SAFETY RESEARCH REPORT

Aviation Research and Analysis Report - B2006/0352

Final

CFIT: Australia in context 1996 to 2005

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Photo of the Ilyushin IL-76 TD, RDPL-34141, courtesy of Mr Greg Ranse.
Figure 3 'CFIT risk factors' sourced from the United States Federal Aviation Administration.

Abstract

Controlled flight into terrain (CFIT) has been identified as one of 'aviation's historic killers', claiming the lives of more than 35,000 people since the emergence of civil aviation in the 1920s. The purpose of this report was to provide an overview of CFIT from an international perspective, to examine current and potential CFIT preventative strategies, and to specifically identify those characteristics associated with CFIT in Australia.

A search of the Australian Transport Safety Bureau's (ATSB) aviation safety database identified 25 CFIT accidents and two CFIT incidents in the period 1996 to 2005. General aviation accounted for the greatest proportion of CFIT accidents, fatal accidents and fatalities. Only one CFIT occurrence over the reporting period (VH-TFU, Lockhart River, Queensland, 7 May 2005) involved regular public transport operations, but this accident accounted for nearly one-third of all CFIT fatalities. This highlights the catastrophic impact one CFIT accident involving passenger operations can have.

In line with international experience, nearly two-thirds of CFIT accidents and incidents in Australia occurred in the approach phase of flight, of which half of these were during an instrument approach.

When compared with the total number of accidents recorded by the ATSB over the 10-year period, the results of the study indicate that CFIT in Australia is a rare event. However, when CFIT does occur, the likelihood of it resulting in fatalities is high.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the Transport Safety Investigation Act 2003 and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

About ATSB investigation reports: How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au.

EXECUTIVE SUMMARY

From the emergence of civil aviation in the 1920s to the turn of the century, more than 35,000 people lost their lives in controlled flight into terrain (CFIT) accidents (Bateman, 1999). Two-thirds of all CFIT accidents resulted in the death of all the aircraft occupants (Ison, 2003).

Given the catastrophic nature of CFIT, the international aviation community has invested a considerable amount of time and resources to prevent CFIT, particularly in the commercial sector of the industry. These CFIT preventative strategies have focused on three key areas: technological advancements, education and training, and research and recommendations. While these measures have made a substantial contribution to the reduction in the number of CFIT accidents and incidents over the years, CFIT continues to occur both in the commercial and general aviation sectors.

There have been a number of well-publicised CFIT accidents involving large passenger-carrying aircraft such as that of a Boeing 757 accident in Cali, Colombia in 1995, which took the lives of 160 people, and a Boeing 737 in Dubrovnik, Croatia in 1996. However, closer to home, the Australian aviation industry has also experienced a number of CFIT accidents in recent years. These include that of a Piper PA-31T Cheyenne near Benalla, Victoria in 2004, a Piper PA31-350 Navajo Chieftain at Mount Hotham, Victoria in 2005, and a Fairchild Aircraft Inc. SA227-DC Metro 23 at Lockhart River, Queensland in 2005.

The purpose of this report was to provide an overview of CFIT from an international perspective, to explore the initiatives introduced in an effort to reduce CFIT, and specifically to examine CFIT from an Australian perspective.

The Australian Transport Safety Bureau's (ATSB) aviation safety database was searched to identify those accidents and incidents (occurrences) that met the definition of CFIT used in this report. The study focused on a calendar year period from 1996 to 2005 and examined Australian civil registered aircraft (VH-) within Australian territory involving regular public transport (RPT) and general aviation (GA) operations. The key findings indicated that:

- There were 27 CFIT occurrences over the 10-year reporting period. This included 25 accidents and two incidents. Of the 25 CFIT accidents, 60 per cent were fatal accidents while 40 per cent were non-fatal accidents.
- The 15 CFIT fatal accidents resulted in 47 fatalities.
- Private/business operations accounted for the highest number of CFIT occurrences, recording 14. This was followed by charter and other aerial work GA operations, which recorded eight and four occurrences respectively. There were no high capacity RPT CFIT accidents. Low capacity RPT recorded one accident, but this accident resulted in 15 fatalities, highlighting the serious consequences of CFIT accidents involving RPT operations.
- Fixed-wing aircraft accounted for about two-thirds of CFIT occurrences, while the remaining one-third involved rotary-wing aircraft. In terms of accidents, 71 per cent of fixed-wing accidents were fatal compared with 37 per cent for rotary-wing aircraft. Of the CFIT fatal accidents, fixed-wing aircraft accounted for 91 per cent of all CFIT fatalities while rotary-wing aircraft accounted for 9 per cent.

- The highest number of CFIT accidents and incidents occurred in the approach phase of flight (63 per cent). This figure is consistent with international studies that have identified the approach and landing phases of flight as the most prevalent phase in CFIT accidents. This was followed by the enroute phase (19 per cent), and the manoeuvring and initial climb phases, accounting for 7 per cent each. The lowest number occurred in the climb phase of flight (4 per cent).
- The term CFIT is not confined to controlled flight into *terrain*; it also includes a collision with obstacles (powerlines/wires) and water. A collision with terrain accounted for the greatest proportion of CFIT occurrences, with 62 per cent. Both a collision with obstacles and water equally accounted for the remaining 38 per cent. When the term CFIT is applied to an occurrence, it is often assumed that the surrounding area must have high terrain features. However, research into CFIT has identified that significant terrain is not necessarily a prerequisite for a CFIT occurrence. The nature of the terrain was identified in 12 of the 17 CFIT occurrences involving a collision with terrain. Of this, 75 per cent involved hilly or mountainous terrain, while 25 per cent were in areas of level/flat terrain.
- There is often an underlying assumption that CFIT only occurs in conditions of reduced visibility, however, research has indicated that this isn’t always the case. Of the 27 CFIT occurrences recorded between 1996 and 2005, 59 per cent occurred in reduced visibility conditions, but 37 per cent occurred in clear visibility conditions. In one case, the conditions at the time of the occurrence were unknown.
- Of the 27 CFIT occurrences, only one aircraft (VH-TFU, a Fairchild Aircraft Inc. SA227-DC Metro 23 used on a regional RPT service) was fitted with, and was required to be fitted with ground proximity warning system (GPWS) technology. However, due to a lack of information from the cockpit voice recorder the accident investigation was unable to determine if the GPWS functioned as designed.
- Approach phase CFIT occurrences were further analysed on the basis of whether the accident or incident occurred during a visual or instrument approach. Of the 17 CFIT occurrences in the approach phase, 53 per cent were conducting an instrument approach while 47 per cent were conducting a visual approach. The highest number of instrument approach CFIT occurrences involved satellite-based instrument approaches (67 per cent, n = 6). Of these, four occurrences involved an area navigation global navigation satellite system approach, which only came into service in Australia in the late 1990s, part way through the reporting period. The implementation of approaches with vertical guidance would aid CFIT prevention on approaches previously only capable of providing lateral guidance.

Overall, when compared with the total number of accidents recorded by the ATSB for the 10-year period, the likelihood of a CFIT accident occurring in Australia is very low. However, when CFIT accidents did occur, they resulted in fatalities 60 per cent of the time.

ABBREVIATIONS

ABAS	Aircraft based augmentation system
ADREP	Accident and incident data reporting system
ADS-B	Automatic dependent surveillance-broadcast
ALA	Approach-and-landing accident
ALAR	Approach-and-landing accident reduction
AMSL	Above mean sea level
AOM	Aircraft operating manual
APV	Approach with vertical guidance
ASAP	Aviation safety action programs
ATC	Air traffic control
ATSB	Australian Transport Safety Bureau
BRD	Baseline round dial
CASA	Civil Aviation Safety Authority
CAST	Commercial Aviation Safety Team
CDA	Constant descent angle
CDTI	Cockpit display of traffic information
CFIT	Controlled flight into terrain
CFTT	Controlled flight towards terrain
CPA	Collision prediction and alerting
DME	Distance measuring equipment
EGPWS	Enhanced ground proximity warning system
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FL	Flight level
FMS	Flight management system
FOQA	Flight operations quality assurance
FSF	Flight Safety Foundation
ft	Feet
GA	General aviation
GBAS	Ground based augmentation system
GCAS	Ground collision avoidance system

GPS	Global positioning system
GPWS	Ground proximity warning system
GNSS	Global navigation satellite system
GRAS	Ground based regional augmentation system
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
ILS	Instrument landing system
IMC	Instrument meteorological conditions
JSAT	Joint Safety Analysis Team
JSIT	Joint Safety Implementation Team
kg	Kilogram(s)
LCRPT	Low capacity regular public transport
MAPt	Missed approach point
MDA	Minimum descent altitude
MSA	Minimum safe altitude
MSAW	Minimum safe altitude warning
MTOW	Maximum take-off weight
n	Number of records
NASA	National Aeronautics and Space Administration
NDB	Non-directional radio beacon
NPA	Non-precision approach
NLR	National Aerospace Laboratory (The Netherlands)
NM	Nautical mile(s)
PFD	Primary flight display
QRH	Quick reference handbook
RAM	Route adherence monitoring
RNAV (GNSS)	Area navigation global navigation satellite system
RPT	Regular public transport
SBAS	Satellite based augmentation system
SSR	Secondary surveillance radar
SVS	Synthetic vision system

TAAATS	The Australian Advanced Air Traffic System
TAWS	Terrain awareness and warning system
TCAS	Traffic alert and collision avoidance system
T^2CAS	Terrain and traffic collision avoidance system
TEM	Threat and error management
US	United States
VFR	Visual flight rules
VMC	Visual meteorological conditions
VOR	Very high frequency omni-directional radio range
VSD	Vertical situation display

"In an industry where the risk will never be zero, we face a constant challenge in meeting the public's expectation of perfection as the minimum acceptable standard. However, the aviation industry continues to successfully address that challenge and is continually working to make aviation safer by reducing the risk of an accident."

(Jim Burin, Flight Safety Foundation, 2006a)

1 INTRODUCTION

1.1 Background to the report

In the July 2006 edition of the Flight Safety Foundation's *Aviation Safety World* magazine, the controlled flight into terrain (CFIT) accident was identified as one of 'aviation's historic killers'. Since the 1970s, the international aviation community has invested a considerable amount of time and resources in researching, developing, and implementing a range of measures in an endeavour to reduce CFIT. Most notable are the efforts made by the Flight Safety Foundation through CFIT awareness and education, and the introduction of terrain awareness technologies such as the Ground Proximity Warning System (GPWS) and Terrain Awareness and Warning System (TAWS). Even though these measures have, directly or indirectly, contributed to a reduction in the number of CFIT accidents involving commercial jet aircraft since 1998[1], preventing this type of accident remains a challenge.

Unfortunately, Australia has experienced its share of CFIT accidents in recent years. Three are particularly noteworthy, which together were responsible for 24 fatalities:

- On 28 July 2004, a Piper Aircraft Corporation PA-31T Cheyenne aircraft, registered VH-TNP, departed Bankstown, New South Wales on a private instrument flight rules (IFR) flight to Benalla, Victoria. Instrument meteorological conditions (IMC) at the destination necessitated an instrument approach and the pilot reported commencing a global positioning system (GPS) non-precision approach (NPA)[2] to Benalla. When the pilot had not reported landing, a search for the aircraft was commenced. Late that afternoon the aircraft was located on the eastern slope of a tree covered ridge, approximately 34 kilometres south-east of Benalla. The pilot and five passengers were fatally injured (ATSB, 2006d).
- On 8 July 2005, the pilot of a Piper Aircraft Corporation PA31-350 Navajo Chieftain, registered VH-OAO, submitted a visual flight rules (VFR) flight plan for a charter flight from Essendon Airport to Mount Hotham, Victoria. At the time, the weather conditions in the area of Mount Hotham were extreme. The pilot reported to air traffic control that the aircraft was overhead Mount Hotham and requested a change of flight category from VFR to IFR in order to conduct a Runway 29 area navigation, global navigation satellite system (RNAV (GNSS)) approach. Soon after, the pilot broadcast that the aircraft was on final approach and requested that the runway lights be switched on. No further transmissions were received from the aircraft. The aircraft had flown into trees in a level attitude, slightly banked to the right. Initial impact with the ridge was at about 200 ft below the elevation of the Mount Hotham aerodrome. All three occupants were fatally injured (ATSB, 2006b).

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1 A slight reduction has been recorded using a 5-year rolling average (Burin, 2006a).

2 The GPS NPA is now referred to as an area navigation global navigation satellite system (RNAV (GNSS)) approach.

- On 7 May 2005, a Fairchild Aircraft Inc. SA227-DC Metro 23 aircraft, registered VH-TFU, was being operated on an IFR scheduled passenger service from Bamaga to Cairns with an intermediate stop at Lockhart River, Queensland with two pilots and 13 passengers onboard. While conducting an RNAV (GNSS) approach to Runway 12 at Lockhart River aerodrome, the aircraft impacted terrain. There were no survivors (ATSB, 2007a)[3].

1.2 Objectives of the report

The purpose of this report was to provide both a national and international perspective on CFIT, and the initiatives that have been implemented or are being considered to combat the problem. Specifically, the objectives were to:

- briefly examine CFIT accidents from an international perspective;
- explore the initiatives introduced by the international aviation community in combating CFIT; and
- identify the characteristics associated with CFIT within the Australian context between the period 1996 and 2005.

3 This report refers to this accident as the Lockhart River accident. A copy of the Lockhart River accident investigation report can be found at www.atsb.gov.au.

2 THE MAGNITUDE OF CFIT

The evolution of the aviation industry has taken place at a rapid rate. Significant advancements in technology, particularly in the commercial aviation sector, have seen the reciprocating engine replaced by the jet engine, basic instrument gauges replaced by glass cockpits, vastly improved navigational aids, and enhanced air traffic control (ATC) facilities. Coupled with a better appreciation of human factors and excellent training and educational practices, the number of aircraft accidents has reduced.

In 1947, commercial aviation transported approximately nine million passengers and experienced about 600 fatalities. By comparison, over the 3 years from 2002 to 2005, commercial aviation flew an average of 2.4 billion passengers per year and experienced about 500 fatalities (Burin, 2006b). In general terms, this equates to one fatality per 15,000 passengers (1947) compared with one fatality per 4.8 million passengers (2005). It is expected that the number of people choosing to travel by air will continue to grow. Within the Asia Pacific region, passenger movements were forecast to increase on average by 6.8 per cent annually between 2005 and 2009 (IATA, 2005).

While air travel remains one of the safest modes of transport, controlled flight into terrain (CFIT) continues to remain one of the leading causes of commercial aircraft accidents. More than 35,000 people have lost their lives in CFIT accidents from the emergence of civil aviation in the 1920s to the turn of the century (Bateman, 1999).

2.1 What is CFIT?

The definition of CFIT used by different organisations varies slightly. The definition used in this report was developed by identifying the common elements contained in these definitions. Some of the definitions examined included those used by the International Civil Aviation Organization (ICAO), the Flight Safety Foundation (FSF) and the United States Federal Aviation Administration (FAA).

DEFINITION OF CFIT

For an accident or incident (occurrence) to be classified as a CFIT, it must satisfy the following criteria:

- the aircraft is under the control of the pilot(s);
- there is no defect or unserviceability that would prevent normal operation of the aircraft[4];
- there was an in-flight collision with terrain, water, or obstacles; and
- the pilot(s) had little or no awareness of the impending collision.

Collisions involving intentional low-level operations, such as aerial agriculture, aerial mustering, aerial work, and low flying are not defined as CFIT for the purposes of this report.

4 The intent of this criterion is to exclude collision with terrain (water and obstacles) accidents and incidents where events leading up to the occurrence, such as a mechanical malfunction, resulted in a degradation of aircraft performance.

Accidents that met the definition of a CFIT, but involved aircraft conducting low level operations, were excluded from this study.

When an occurrence is classified as CFIT, it is often assumed that the accident or incident occurred in conditions of reduced visibility, such as in instrument meteorological conditions (IMC) or at night, and that the surrounding terrain was mountainous. While this is often true, it is not always the case. It is possible for CFIT to occur in visual meteorological conditions (VMC) and/or areas absent of significant terrain features.

2.2 Why does CFIT occur?

It seems somewhat inconceivable that an aircraft capable of safe flight can be flown into terrain (water and obstacles) while under the control of the pilot. This raises the question, why does this happen? While CFIT accidents and incidents are often the product of a series of events, the investigation of CFIT over the years has identified loss of situational awareness as a key contributing factor. More specifically, a pilot's loss of vertical and/or horizontal situational awareness in relation to the terrain, obstacles or water.

SITUATIONAL AWARENESS

"Situation Awareness is the accurate perception of the factors and conditions that affect an aircraft and its flight crew during a defined period of time. In simplest terms, it is knowing what is going on around you – a concept embraced to the need to "think ahead of the aircraft" (Schwartz, 1989 cited in Orlady & Orlady, 1999, p. 257).

Situational awareness covers five main areas:

1. Information on the physical state or condition of the aircraft.
2. The position of the aircraft with respect to the flight plan, to natural or manmade obstructions, and to other aircraft (place information).
3. The operating environment, including facilities, traffic density, and weather.
4. Temporal element and time, such as the time the aircraft will reach its destination, the time available for holding, the time limit for available fuel.
5. The state or condition of other members of the operating team and passengers, and cargo onboard.

For CFIT, the greatest concern is a loss of 'place information'. Once a pilot's mental picture of where they are at present, and where they will be in the future diminishes, safety becomes compromised. This is particularly crucial during those phases of flight when terrain clearance is unavoidably reduced (eg initial climb and approach). Reportedly, more than two-thirds of all CFIT accidents result from a loss of vertical situational awareness or an altitude error (Flight Safety Foundation, ICAO, & Federal Aviation Administration, 1996).

There are a number of factors that contribute to a loss of situational awareness. When comparing CFIT occurrences from the 1960s and 1970s to recent times, it is evident that despite the efforts of the international aviation community to reduce CFIT, some common factors have endured. These include those involving flight crew - the use of non-standard phraseology, non-compliance with procedures, fatigue, and visual illusions; ATC - the provision of erroneous altitude/heading directions; and weather, organisational issues, ambiguous aeronautical charts, and non-optimal approach procedure designs (Khatwa & Roelen, 1996).

Other factors that have played a part in CFIT accidents and incidents include 'get-home-itis', where the pilot becomes fixated on reaching the destination point at all costs (also know as 'press-on-itis'), and pilot workload. The latter is especially true for the approach and landing phase of flight where the pilot's workload becomes more demanding. In this phase, the pilot is interpreting approach charts, changing the aircraft's configuration, monitoring traffic, and monitoring the aircraft's altitude and airspeed.

In May 1999, the then Bureau of Air Safety Investigation, which was incorporated into the Australian Transport Safety Bureau (ATSB) from 1 July 1999, released the *Regional Airlines Safety Study Project Report*, which sought to identify safety deficiencies affecting regional airline operations in Australia. As part of this study, a survey was constructed and distributed to employees working within the regional airline industry including pilots, flight attendants, licensed aircraft maintenance engineers, and baggage handlers. The survey focused on a number of aspects such as aircraft operations, flying training, cabin safety, safety culture, and instrument flying, in particular, instrument approach procedures. One of the key safety issues examined within the latter section was the loss of situational awareness, specifically, with respect to terrain clearance. While the results identified that only 5.7 per cent of the pilots had been surprised that the aircraft was closer to terrain than expected, the results were considered significant as the loss of situational awareness can result in a CFIT accident or incident.

This issue was also highlighted in a recent survey conducted by the ATSB, which examined pilot workload and perceived safety of area navigation global navigation satellite system (RNAV (GNSS)) approaches. The results of the survey indicated, with the exception of the NDB[5] approach, that respondents had trouble maintaining situational awareness more often on an RNAV (GNSS) approach compared with the other types of approaches analysed in the report (Godley, 2006).

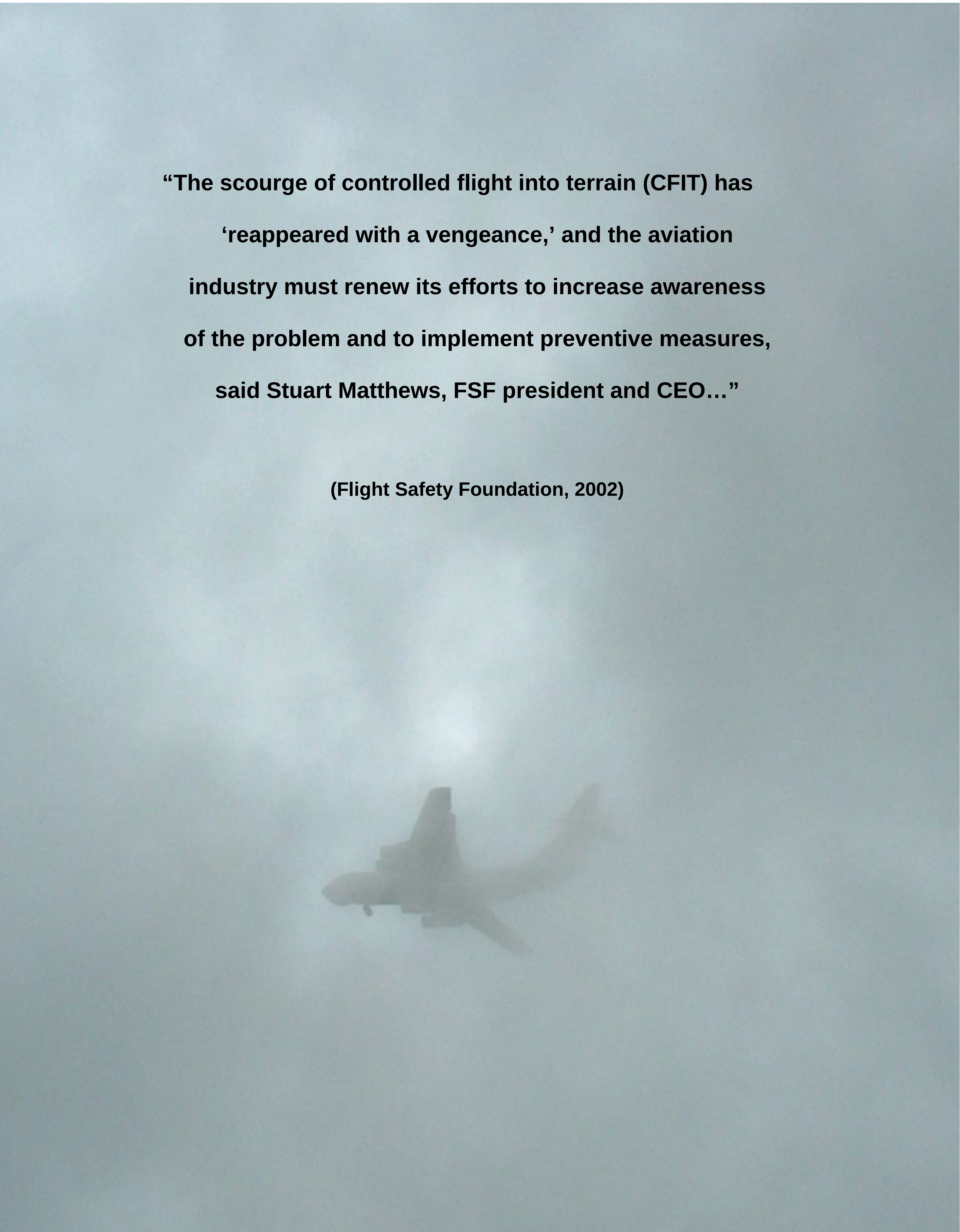
Generally, good situational awareness increases safety, reduces workload, enhances performance and improves decision making. Achieving and maintaining a high level of situation awareness is a product of good operating philosophy, training, standard operating procedures, and crew coordination (Orlady & Orlady, 1999).

While it is important to understand the circumstances leading to CFIT accidents and incidents, it is equally important to recognise that there are instances when a CFIT event was avoided. The analysis of potential CFIT, or controlled flight towards terrain (CFTT) occurrences, could provide a more complete picture of factors that could contribute to a CFIT, and perhaps identify those factors that prevented a CFTT becoming a CFIT. Accordingly, the ATSB will examine this subject in a separate research report.

5 NDB: non-directional radio beacon.

“The scourge of controlled flight into terrain (CFIT) has ‘reappeared with a vengeance,’ and the aviation industry must renew its efforts to increase awareness of the problem and to implement preventive measures, said Stuart Matthews, FSF president and CEO…”

(Flight Safety Foundation, 2002)



3 THE INTERNATIONAL PERSPECTIVE

Controlled flight into terrain (CFIT) remains a significant concern in aviation globally. Despite the introduction of a range of preventative measures, CFIT continues to occur. A considerable amount of research and analysis has been conducted into CFIT in an effort to review safety trends and identify key characteristics. The international perspective has predominantly focused on the air transport sector of the industry. This is because of the potentially high number of fatalities in air transport operations compared with general aviation (GA). Nevertheless, it is important to acknowledge that CFIT occurs in all sectors of aviation.

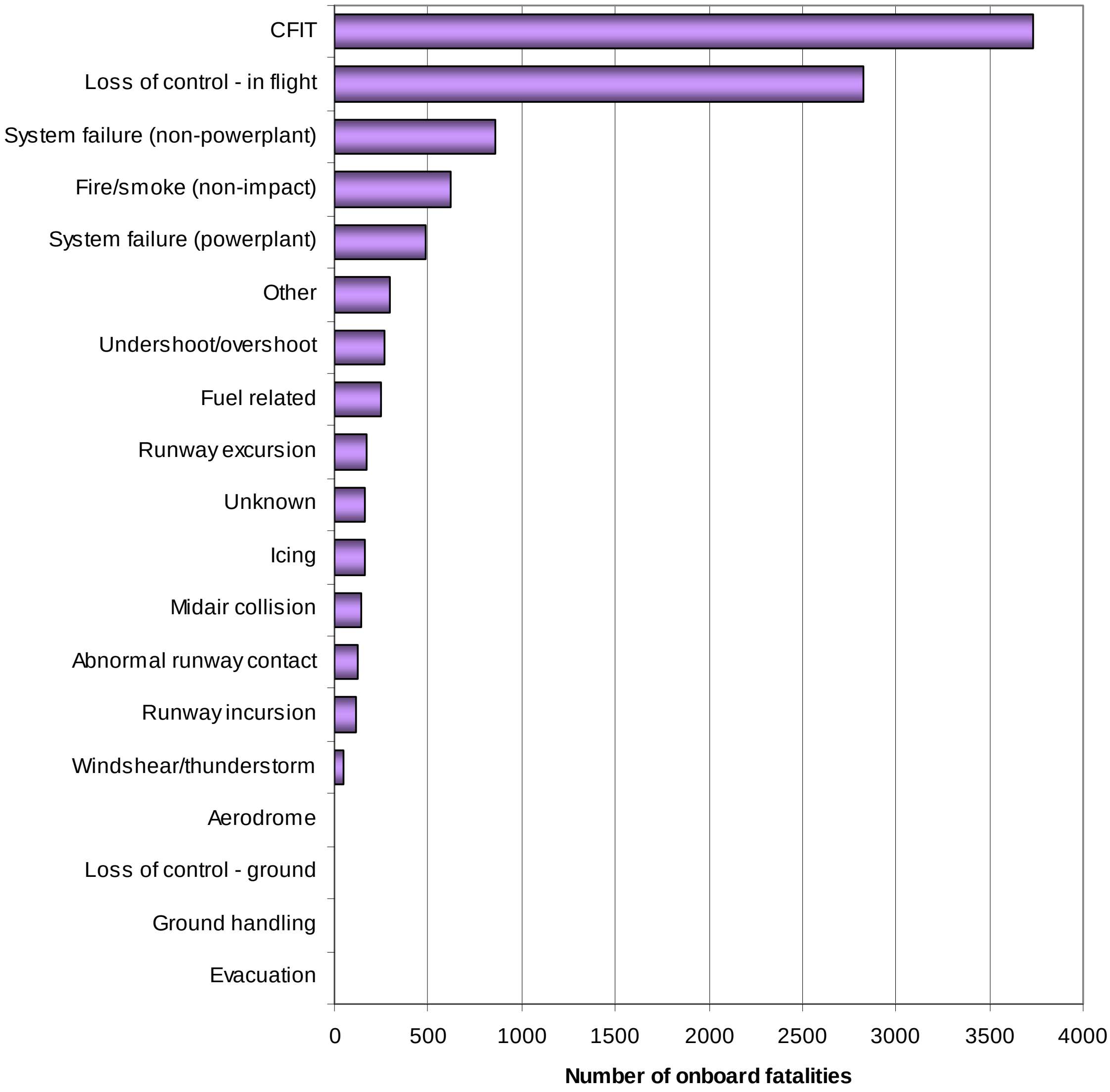
While air traffic has increased, the number of fatal airline accidents decreased in 2006 to 27, equal to the lowest annual figure over the past 10 years. However, despite the decline, CFIT accidents continue to remain prevalent. At least five of these fatal accidents have been confirmed as CFIT, but this could possibly increase to seven pending the completion of accident investigations being conducted at the time of writing this report. Overall, CFIT could account for up to 25 per cent of total fatal airline accident numbers in 2006 (Learmount, 2007). In 2005, commercial jet aircraft were involved in five CFIT accidents. Combined with the three loss of control accidents, these two accident types accounted for 70 per cent of that year’s fatalities. Of significance is that all five CFIT accidents in 2005, and those confirmed in 2006, involved aircraft that come from the 8 per cent of the world jet aircraft fleet not equipped with terrain awareness and warning systems (TAWS). In contrast, 2004 saw no commercial jet aircraft CFIT accidents (Burin, 2006a).

Jet aircraft with a maximum take-off weight (MTOW) less than 60,000 pounds (27,000 kg) operating commercial or corporate/business services experienced one CFIT accident in 2005. Commercial turboprop aircraft were involved in nine CFIT accidents. These aircraft were also not equipped with TAWS. In fact, all CFIT accident aircraft to-date have not been equipped with TAWS (Burin, 2006a).

The Boeing ‘Statistical Summary of Commercial Jet Airplane Accidents Worldwide Operations 1959 – 2005’ (Boeing, 2006) provides a long-term view of the seriousness of CFIT. Of the 237 fatal accidents involving the world-wide commercial jet fleet[6] recorded between 1987 and 2005, 24 per cent (n = 57) were attributed to CFIT. More alarmingly, of the 10,267 fatalities, over one-third (36 per cent) were the result of a CFIT accident (Figure 1).

6 Commercial jet aircraft are defined as aircraft involved in commercial operations with a maximum takeoff weight in excess of 60,000 pounds (27,000 kilograms).

Figure 1: Fatalities and fatal accidents involving the worldwide commercial jet fleet, 1987 to 2005



Source: Boeing, 2006

The National Aerospace Laboratory NLR

In 1997, the National Aerospace Laboratory NLR (The Netherlands) published a report titled *Controlled flight into terrain (CFIT) accidents of air taxi, regional and major operators* (Khatwa & Roelen, 1997). The aim of the report was to identify and analyse factors associated with CFIT accidents within these sectors of the industry. Initiated in association with the Flight Safety Foundation (FSF) and the Netherlands Department of Civil Aviation, the report examined 156 fatal CFIT accidents that occurred between 1988 and 1994. This involved identifying a sample of CFIT accidents from a range of world-wide sources. The report examined world-wide fatal accidents involving fixed-wing aircraft engaged in public transport; scheduled and non-scheduled flights; freight, passenger and positioning flights; and international and domestic flights.

The study made the following key findings:

- North America accounted for 34.6 per cent of the total accident sample. It should be noted that the authors of the report stressed that this figure reflected the accessibility of United States (US) fatal accident data and the high level of commercial activity present in the US.
- Africa experienced the highest CFIT accident rate for scheduled flights involving major operators. This was followed by Latin America and the Asia Pacific region. The lowest rates were experienced by North America and the Middle East.
- Of those cases where data was available, 90 per cent of fatal accidents occurred within 15 NM of the runway threshold. Sixty per cent occurred within 5 NM.
- Thirty cases involved inadvertent visual flight rules (VFR) flight into instrument meteorological conditions (IMC), with the majority involving single-pilot operations in regional and air taxi operators.
- About 70 per cent of the accidents occurred in the approach and landing (47.7 per cent) or descent (21.9 per cent) phases of flight. Approximately one-fifth of the accidents occurred during the enroute phase. Of those where data was available, 95 per cent involved air taxi and regional operators.
- Of the 66 cases where sufficient data was available, 60 per cent of instrument approaches were non-precision. Twenty-five per cent of these were VOR/DME[7] approaches.
- The most prevalent crew error types were procedural, situational awareness, tactical decision making, and monitoring/challenging.
- Seventy-five per cent of the accident aircraft were not equipped with a GPWS[8].

This report provided a valuable insight into the characteristics of CFIT fatal accidents and provided evidence to dispel some of the common assumptions made about CFIT occurrences. In particular, the results indicated that significant terrain features were absent in 40 per cent of the cases. Furthermore, from the available data, 93 accidents occurred in IMC, but 14 occurred in visual meteorological conditions (VMC). Thus, highlighting that while reduced visibility and high terrain might be important, they are not necessary for CFIT.

The International Civil Aviation Organization (ICAO)

The analysis of accident data involving fixed-wing aircraft in air transport operations with a MTOW greater than 2,250 kg highlights the contribution CFIT preventative strategies have had on accident reduction. Figure 2 shows that overall, the number of CFIT accidents involving fixed-wing aircraft declined from 39 in 1995 to 11 in 2004. For the first time since 1990, 2004 recorded no CFIT accidents involving aircraft with a MTOW between 27,000kg and 272,000kg. Furthermore, the decline in the number of fatal accidents between 1995 and 2004 was largely attributed to the prevention of CFIT type accidents (ICAO, 2006).

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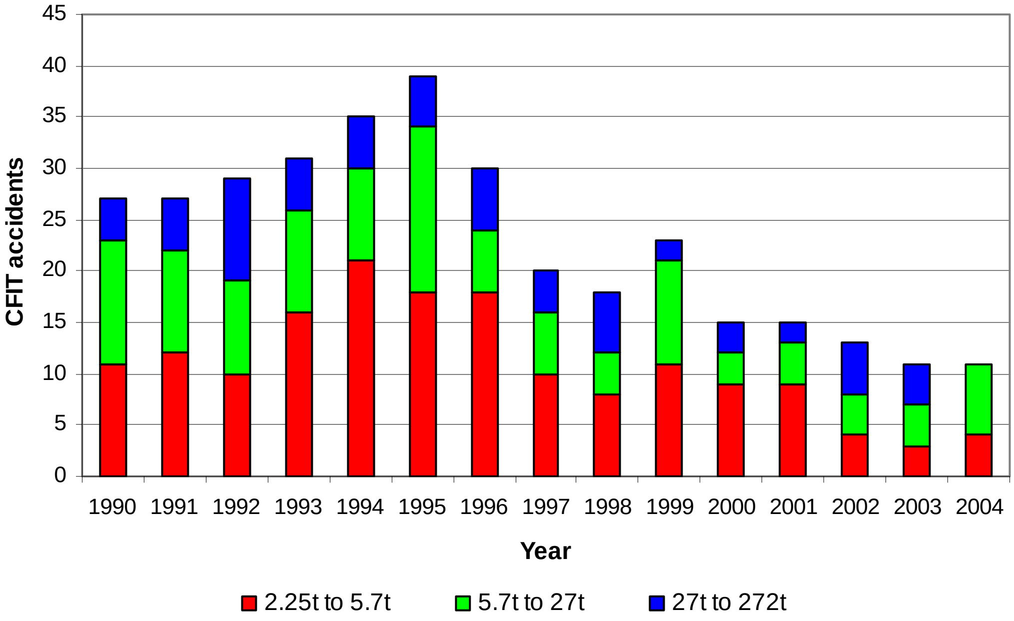
7 VOR/DME: very high frequency omni-directional radio range (VOR), distance measuring equipment (DME).

8 Refer to section 4.1.1 for more information on GPWS.

Figure 2: CFIT accidents involving fixed-wing aircraft with a MTOW greater than 2,250kg in air transport operations, 1990 to 2004



4 GLOBAL STRATEGIES FOR CFIT PREVENTION

"This risk exists universally. Fortunately, many positive steps can be taken to reduce CFIT risk by the civil authorities, airlines, pilots, and controllers through training, and procedures and awareness of the risk, and also through the application of practical technology"

Don Bateman, Allied Signal

Since the beginning of commercial aviation, the aviation industry has explored, researched, designed, and implemented a range of strategies in an effort to reduce, if not eliminate controlled flight into terrain (CFIT) accidents and incidents. These strategies have taken various forms including educational programs, training resources, checklists, research papers, recommendations to aviation manufacturers, operators and governing bodies, and technological developments. The purpose of this chapter is to provide an overview of some of the key strategies and technologies designed to prevent CFIT.

4.1 Technological advancements

Advancements in technology over the decades have had a profound effect on the growth of the aviation industry. Aircraft can fly longer distances in a shorter time, fly to more destinations, operate under more challenging environmental conditions, and so on. These technologies have also contributed to the prevention of CFIT accidents in both air transport and general aviation. This section examines some of the new or emerging technologies that have the potential to reduce CFIT occurrences.

4.1.1 Ground proximity warning system (GPWS)

The introduction of the radio altimeter into large commercial aircraft in the late 1960s made possible the concept of GPWS. Originating at Scandinavian Airlines System, the GPWS was designed by Allied Signal to provide an alert to the pilot based on the aircraft's flight path and terrain clearance. The GPWS used the radio altimeter to provide a 'look-down' capability that measured terrain clearance vertically. The benefits of GPWS were soon recognised by other airline operators who began installing the equipment into their aircraft. By 1973 Boeing offered GPWS as a recommended system on all their aircraft models, and by 1974, began fitting the device to production aircraft as a basic safety system (Bateman, 1994).

After a number of CFIT accidents in the United States (US), in particular, that of a Boeing 727 while on approach to Washington Dulles Airport in 1974, the US Federal Aviation Administration (FAA) mandated the fitment of GPWS in aircraft operating under Federal Aviation Regulation (FAR) Part 121. In 1975, after evaluating airline flight data, the United Kingdom Civil Aviation Authority mandated the installation of GPWS (Flight Safety Foundation et al., 1996).

In 1978, the International Civil Aviation Organization (ICAO) introduced requirements for the fitment of GPWS in certain aircraft categories. Since that time, GPWS has been mandated by regulatory authorities around the world for fitment, primarily in commercial transport aircraft ranging from aircraft used in regional operations (eg SAAB 340, Dash 8) to large aircraft used for domestic and international operations (Wylie, 1999).

While the installation of GPWS made a valuable contribution to the reduction of CFIT, early models were marred by false alarms (the aircraft would not impact with terrain irrespective of whether avoiding action was taken), late warnings (insufficient time for pilots to respond), and in some cases no warnings (particularly in certain aircraft configurations such as landing).

The unreliability of first generation GPWS was highlighted by the Air Transport Association of America, which stated that "pilots will quickly lose confidence in the system if this continues for even a short period of time. Once they lose confidence, it will be practically impossible to regain" (Flight Safety Foundation et al., 1996).

Subsequent generations of GPWS have become more reliable. Nevertheless, research conducted by Honeywell Chief Engineer Don Bateman identified that in 38 per cent of the commercial CFIT accidents where GPWS was installed; the system had triggered and was providing the terrain warning. This suggests that crews failed to respond or to react effectively to the GPWS alerts (Carlisle, 2001).

This issue was recently highlighted in the accident of a Boeing 737-497 (B737), registered PK-GZC, which overran the departure end of runway 09 at Adi Sucipto Airport, Yogyakarta, Indonesia, on 7 March 2007. Of the 140 persons on board the aircraft, 21 were fatally injured and 12 were seriously injured. The investigation determined that the approach and landing to runway 09 was flown at an excessively high airspeed and a steep flight path angle, resulting in an unstabilised approach. A subsequent review of the aircraft's flight recorder identified that the GPWS had provided 15 alerts and warnings throughout the approach including 'SINK RATE', 'TOO LOW TERRAIN', AND 'WHOOP, WHOOP, PULL UP'. The pilot in command did not respond to any of these alerts and warnings. The investigation also determined that the operator's simulator training for the B737 did not cover vital actions and required responses to GPWS and EGPWS alerts and warnings (NTSC, 2007).

4.1.2 Terrain awareness and warning system (TAWS)

One of the main disadvantages of the GPWS was that the system could not provide adequate warning of steep rising terrain, such as a cliff, or accommodate turning paths (DeMeis, 1997). However, advancements in technology over the years have seen the GPWS evolve with the development of a new generation of systems called terrain awareness (avoidance) and warning systems (TAWS). In addition to the 'look-down' capability provided by GPWS, TAWS provides a 'look-ahead' capability, which uses aircraft position data, aircraft altitude, and a worldwide terrain database to predict potential conflicts between the aircraft's flight path and the surrounding terrain. Therefore, TAWS consists of a forward looking terrain avoidance function that looks ahead, both along and below the lateral and vertical flight path of the aircraft and alerts the pilot of a potential conflict with terrain (Aircraft Electronics Association, n.d.).

The predictive component of TAWS also provides the pilot with a greater time to respond to an alert and take the appropriate action. Terrain awareness and warning systems further enhance pilot situational awareness by providing coloured terrain information on a terrain display in the cockpit.

The benefits of TAWS technology have been well recognised with several variations now available on the market including the enhanced ground proximity warning system (EGPWS), developed by Honeywell; the ground collision avoidance system (GCAS), developed by Thales Avionics; and the terrain and traffic collision avoidance system (T^2CAS), developed by Aviation Communication and Surveillance Systems.

The pioneer of TAWS, the EGPWS, incorporates a digital terrain database that provides a two-dimensional view of colour-coded terrain information to assist pilots in maintaining safe altitude and clearance (Uhlarik, Peterson, & Herold, 1998). The system provides features including enhanced terrain and obstacle detection, geometric altitude, ‘look ahead’ alert/warning algorithms that increase the alert time for potential flight into terrain at high ground speeds, automatic altitude callouts that assist altitude awareness during the approach and landing phases of flight, and a ‘peaks mode’ that displays high terrain, greater than 2,000 ft, below the aircraft (Honeywell, n.d.).

The third variation of TAWS is the T^2CAS. Developed by the Aviation Communication and Surveillance Systems (an L-3 Communications and Thales Company), T^2CAS combines the technology of the traffic collision avoidance system (TCAS) and that of TAWS. The key feature of the T^2CAS system is the collision prediction and alerting (CPA) function, which predicts terrain hazard situations and generates aural, visual and graphical-display alerts to the pilot. The system will alert the pilot when the CPA computation determines that the aircraft’s projected flight path may intersect the correlated terrain elevations underlying that flight path (ACSS, 2003).

4.1.3 Situation display systems

While technology such as the GPWS has made an important contribution to reducing the chances of CFIT, it operates on the ‘warn-act’ model. That is, the system provides a warning to the pilot when a potential conflict with terrain (water and obstacles) is imminent. Theoretically, this means that the pilot has already lost situational awareness and must perform the appropriate manoeuvre to avoid a CFIT. These concerns were also highlighted by the Society of Automotive Engineers, which stated that terrain separation assurance systems should be designed in a way that allows the user to immediately interpret the situation, subsequently decreasing mental workload and reducing the potential for interpretation errors (NASA, 2004a). The requirement is for a system that is intuitive, that enhances situational awareness, yet doesn’t divert the pilot’s visual attention and cognitive resources away from the primary task. That is, a system that helps prevent, rather than inform the pilots of a potential CFIT (Snow, 1999 cited in NASA, 2004a, pp. 6).

The issue of providing intuitive displays was also discussed by Theunissen, who examined the concept of natural versus coded information. Natural information is similar to the information provided to a pilot by simply looking outside the window under visual meteorological conditions (VMC). Coded information, on the other hand, infers that information provided to the pilot requires some degree of interpretation in order to understand its significance. For a pilot to maintain situational awareness in conditions of reduced visibility, natural information should be presented to the pilot, which is intuitive and can be interpreted more expediently compared with coded information (Theunissen, 1997, cited in NASA, 2004a, pp. 6). Systems such as the vertical situation display (VSD) and synthetic vision systems (SVS) have applied these principles.

Vertical situation displays (VSD)

In an effort to reduce CFIT and approach-and-landing accidents (ALA), Boeing developed an intuitive VSD. Combined with the terrain mapping feature of TAWS, VSD provides flight crews with a graphical presentation of the aircraft's vertical flight path relative to the surrounding terrain. Previously, flight crews had to use a variety of sources such as altitude readings, terrain depiction systems, GPWS, and the flight management computer to attain a mental model of the aircraft's vertical situation. However, in time-critical, high workload environments, typically experienced during the approach and landing phase of flight, the ability to maintain an accurate mental model of the aircraft's position using these sources may be affected. Terrain awareness and warning systems provide flight crews with terrain proximity warnings and a lateral view of the surrounding terrain.

The VSD, on the other hand, provides a vertical picture of the terrain. During the approach phase, VSD further assists the flight crew by depicting the final approach segment of the aircraft's intended approach path. As the approach continues, the terrain alerting function of TAWS is gradually disabled to eliminate nuisance alerts (Carbaugh, Chen, Jacobsen, Myers, & Wiedemann, 2002).

Vertical situation displays also have positive benefits for crews conducting constant-angle, area navigation, and required navigation performance approaches by providing graphical validation of the approach path selected by the crew. The use of VSD has the potential to increase flight crew situational awareness, particularly, vertical situational awareness, and allow crews to respond appropriately to potential CFIT situations (Carbaugh et al., 2002).

Synthetic vision systems (SVS)

In an effort to eliminate the contribution of poor visibility to losing situational awareness, researchers from the National Aeronautics and Space Administration (NASA) Langley Research Center have tested and evaluated the efficacy of SVS. The SVS concept is designed to simulate VMC conditions, irrespective of the actual weather conditions at the time. The system provides the pilot with intuitive out-the-window terrain and obstacle information by combining global positioning system (GPS) signals with an on-board terrain, obstacle and airport information database to display a terrain picture to the pilot.

A number of tests have been conducted by NASA in different operational settings to evaluate the effectiveness of SVS technology, some of which included:

- A group of general aviation (GA) pilots, eight highly experienced in instrument flight rules (IFR) operations, eight relatively experienced, and eight with no IFR qualifications, participated in the simulation phase of the SVS-GA program. Each pilot flew a total of 12 approaches using SVS and conventional baseline round dial (BRD) displays in a Boeing 757 fixed-base simulator that was modified to replicate a Cessna 206. During the simulation exercise, four of the non-IFR qualified pilots became disorientated and subsequently crashed while attempting to navigate the aircraft towards the runway using BRD instrumentation. When using the SVS technology, all of the non-IFR qualified pilots successfully landed the aircraft, matching the performance of the highly experienced IFR pilots using BRD displays (NASA, 2005).
- Another experiment sought to test whether a primary flight display (PFD) with synthetic terrain, such as SVS, would improve a pilot's ability to detect and avoid a potential CFIT compared with conventional displays. Each pilot flew a total of 22 approach-departure procedures in a simulator under instrument meteorological conditions (IMC) to Eagle Country Regional airport, which is surrounded by terrain. During the final run, flight guidance cues were changed to direct the aircraft's departure flight path into terrain. All of the pilots who had a SVS display identified and avoided the terrain. Those pilots who flew the approach using conventional PFD (TAWS and VSD) had a CFIT. Furthermore, the results of the experiment revealed that SVS increased situational awareness, decreased workload, and improved flight technical errors compared with the conventional displays (NASA, 2004a).
- A group of 17 pilots from the US FAA, the US Air Force, the Joint Aviation Authority, the aerospace industry and major airlines flew 22 flights in a Gulfstream GV business jet equipped with SVS technology. In order to simulate reduced visibility conditions, the pilot's windshield was often covered and flights were conducted at night. As a result, the pilots had to rely on the SVS display for navigation (NASA, 2004b).
- Two experiments were conducted to evaluate SVS for CFIT prevention in both GA and commercial operations.
    - The first experiment involved 27 participants, of which 14 were visual flight rules (VFR) pilots with less than 400 hours experience and limited instrument training, six instrument pilots with less than 1,000 hours, four test pilots, and three project pilots. The purpose of this experiment was to place an inexperienced VFR pilot into an IMC situation with an altimeter error while in close proximity to terrain to show that an otherwise unavoidable CFIT situation could be prevented using SVS technology. The results determined that none of the instrument and professional pilots experienced a CFIT. For the VFR pilots, only two experienced a CFIT situation. The results of one pilot were treated with caution as the pilot experienced significant difficulties with flying the aircraft throughout the experiment. The second pilot stated that something felt wrong, but was captured by the incorrect altimeter reading and failed to crosscheck the instruments.

- The second experiment focused on air transport pilots and introduced a lateral path error in flight management system guidance that brought the aircraft into close proximity with terrain during a go-around procedure. Of the 16 participants, 12 flew the scenario with a SVS enhanced PFD or head-up display while the remaining four participants flew with a baseline display. All 12 SVS pilots noticed and avoided the CFIT situation while the four baseline pilots had a CFIT event (Prinzel, Hughes, Arthur, Kramer, Glaab, Bailey, Parrish, & Uenking, n.d.).

In addition to the benefits for CFIT prevention, SVS also provides information on other traffic (both in-flight and on the ground) and has the potential to increase the efficiency of the air traffic system by providing new instrument approach flight paths, which subsequently reduce aircraft spacing requirements.

Like VSD technology, SVS takes a proactive approach to CFIT prevention. The critical information displayed to the pilot from SVS is presented in a manner that is easier to mentally assimilate, thus enhancing situational awareness, decreasing workload and consequently increasing safety (Prinzel et al., n.d.).

4.1.4 Assisted-recovery systems

The concept of terrain avoidance has been taken to a new level with the development of technologies that have the capability of automatically taking control of an aircraft and executing a recovery to avoid a collision with terrain and obstacles. In a collaborative program involving Lockheed Martin, NASA and the Swedish Air Force, the US Air Force developed such a system for the F-16 fighter aircraft called the auto-GCAS.

In civil aviation, Honeywell has also developed an assisted-recovery system that automatically takes control of an aircraft to avoid terrain and obstacles. According to Honeywell, there are approximately 30,000 transport aircraft fitted with EGPWS technology under global mandates, which have flown in excess of 200 million flights with the system. There are also 40 reported cases where EGPWS warnings have alerted flight crews in situations where an accident might otherwise occurred. While the success of such systems for CFIT prevention is well-documented, the potential for human error remains. The assisted-recovery system is designed as a last line of defence and would activate only after the pilot has failed to respond to aural cautions and warnings.

The system is triggered based on a time to impact and a comparison of information obtained from sensors and a digital terrain database. The pilot is notified that a recovery is in progress, and once the hazard has been avoided, control of the aircraft reverts to the pilot. However, like GPWS and TAWS, it is important to preclude any false alarms, which may become more of a nuisance rather than a benefit. A 3-day trial of the assisted-recovery system was conducted in California using an Airbus A319. The program, loaded onto a laptop computer, took control of the aircraft via autopilot. While the system showed some positive results, the test pilots, who could see the mountain approaching, experienced difficulties in allowing the aircraft to fly long enough for the system to engage. However, it is when the pilot cannot see the terrain or obstacles that this system would be most effective (Hughes, 2005).

4.1.5 Global positioning system (GPS)

Terrain avoidance technologies such as GPWS and TAWS have contributed to the reduction of CFIT in air transport, but the availability is somewhat limited for GA aircraft.

The operating environments of GA aircraft would require differing operational modes from the standard GPWS/TAWS. For example, GA aircraft typically operate at lower altitudes compared with commercial aircraft. In this environment, GPWS/TAWS would provide many false alarms, which could potentially undermine a pilot's confidence in the system, especially in a situation where terrain is present. Moreover, the cost is likely to be prohibitive, and space in smaller GA aircraft is at a premium, presenting practical difficulties in seeking to accommodate GPWS/TAWS. However, advanced avionics, including glass cockpit displays, have become more accessible and financially viable for the GA aircraft owner/operator (Baldwin, Cassell, & Smith, 1995).

One advance for GA has been the introduction of the GPS receiver, which has now become as common as traditional navigational aids such as the non-directional radio beacon (NDB) and very high frequency omni-directional radio range (VOR). Global positioning system units are relatively affordable, and since March this year, have been approved for primary-means navigation[9]. Global positioning system technology has developed rapidly over the last decade, and some units have expanded the navigational capabilities by incorporating terrain awareness functions.

For example, the Garmin GPSMAP 296 unit combines inputs from inbuilt terrain, obstacle and electronic flight databases to provide a depiction of hazards that require the attention of the pilot. The unit contains a look-ahead warning function that provides the pilot with additional time to make critical decisions regarding the flight path; allows the pilot to set the minimum limits to receive terrain cautions and view the elevation or relative altitude of obstacles; and provides terrain proximity cautions and alerts whenever a potential hazard exists (Garmin, 2004).

The addition of terrain alerting has the potential to provide safety benefits for the GA sector, particularly in single-pilot operations. However, the system should be used as an aid to assist with situational awareness rather than as a last line of defence against CFIT.

4.1.6 Automatic dependent surveillance-broadcast (ADS-B)

Another possible measure for CFIT prevention in GA is the automatic dependent surveillance-broadcast (ADS-B) system, which has been examined and implemented by various countries around the world.

Often referred to as 'virtual radar', ADS-B provides a low cost alternative to secondary surveillance radar (SSR). The ADS-B avionics enables the automatic broadcast of an aircraft's identity, position, altitude, speed, and other parameters at half-second intervals, using systems such as a barometric encoder and global navigation satellite system (GNSS)[10].

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9 TSO 145/146 equipment

10 The GPS non-precision approach is now referred to as an RNAV (GNSS) approach.

Offering a capability similar to SSR, ADS-B aircraft transmissions can be received by a system of ground stations to provide surveillance coverage over a wider area. Referred to as ADS-B OUT, this provides air traffic control with the ability to accurately track aircraft (AOPA, 2007b). The benefits of ADS-B also extend beyond that of air-to-ground capabilities by providing an air-to-air function. As transmissions are being broadcast about an aircraft's position and altitude, they may also be received and displayed to other aircraft equipped with a cockpit display of traffic information (CDTI). This air-to-air capability is called 'ADS-B IN'.

Successful operational trials conducted by Airservices Australia in Bundaberg, Queensland, have led to the implementation of the ADS-B Upper Airspace Program. Under this program, 28 ADS-B ground stations will be installed at various remote locations around Australia, co-located with existing radio communication facilities. An aircraft's position and altitude will be transmitted to ATC centres to enable radar-like services in areas of airspace where radar coverage is not available above flight level (FL) 300 (Airservices Australia, 2006).

While the present application of ADS-B in Australia focuses on aircraft operating at altitudes above FL300, the benefits of ADS-B at lower altitudes have also been recognised, particularly for CFIT prevention in GA. The carriage of a GNSS receiver to provide ADS-B position data in the GA cockpit can assist pilots in maintaining horizontal situational awareness; however, coupled with terrain displays that provide aural and/or visual terrain indicating functions, a pilot's vertical situational awareness is also greatly enhanced. Such displays have the potential to provide pilots with an increased awareness of the aircraft's flight path relative to the surrounding terrain, and hence, reduce the likelihood of a CFIT (Tulip, 2005).

The operational benefits of ADS-B have also been recognised elsewhere as part of the Capstone trial to improve safety in Alaska where the FAA assessed the use of new cockpit avionics in GA aircraft. The system, consisting of a multi-function display unit, a GPS display and ADS-B avionics provided pilots with a moving-map display that showed the aircraft position and relative height of the surrounding terrain to the aircraft.

Using a custom map function, pilots were able to overlay the relative terrain with airport and other information. The assessment revealed that the moving map display increased pilot awareness of terrain and airports, in particular, in maintaining an awareness of the runway location during conditions of low visibility (Williams, Yost, Holland, & Tyler, 2002).

In Australia, over the period 1991 and 2000, CFIT was the second most common accident type of the 215 GA fatal accidents recorded by the Australia Transport Safety Bureau (ATSB). More specifically, CFIT during 'normal' operations accounted for 12 per cent of all fatal GA accidents (n = 26) and 13 per cent of all associated fatalities (n = 52). A large proportion of these accidents occurred in poor visibility (ATSB, 2004a). In an effort to analyse the safety impact of ADS-B at lower altitudes, a Civil Aviation Safety Authority (CASA) review panel was formed to analyse the potential for moving map displays in the prevention of the 26 CFIT GA fatal accidents that occurred during 'normal operations'.

To assess the potential for CFIT prevention, the panel assumed that each accident aircraft was fitted with an ADS-B transmitter, which had GPS position output driving a cockpit display with a terrain indicating function. Taking into consideration the pilot's workload at the time, the panel considered whether the pilot would have had sufficient time within which to understand the significance of the terrain information displayed on the moving map and to take avoiding action at some point in the flight prior to impact. For those CFIT accidents involving VFR flights into IMC, the panel considered whether or not a moving map display would have assisted the pilot in planning a safe descent below the cloud. The panel concluded that 50 per cent of the CFIT fatal accidents reviewed and 50 per cent of the associated fatalities could have been prevented if the pilot had been able to effectively utilise information from a GPS driven moving map terrain display and taken avoiding action (Tulip, 2005).

Air traffic control radar coverage is currently not available across all of Australia due to the cost of infrastructure and the small number of aircraft operating in the centre of the country (DFAT, 2005). The introduction of ADS-B technology in these areas could provide potential safety benefits through more rapid and targeted search and rescue responses, reduced collision risks around regional airports, and reduced CFIT risks through enhanced terrain awareness (Airservices Australia, 2005).

The long-term outlook for ADS-B

The benefits of ADS-B and GNSS have been well recognised as a suitable replacement or supplement to Australia's existing air navigation and surveillance systems. On 7 August 2007, the Minister for Transport and Regional Services, The Honourable Mark Vaile, invited the public to comment on a proposal to expand the use of ADS-B and GNSS avionics for air traffic surveillance and aircraft navigation in Australia.

A joint consultation between Airservices Australia, the Australian Defence Force, the CASA, and the Department of Transport and Regional Services, the paper sets out a proposal for the wider application of satellite technology for navigation and surveillance in Australia, the required rules to support the proposal, and the requirements of the aviation industry.

Some of the key benefits outlined in the proposal include:

- low cost surveillance;
- a reduction in fuel burn and greenhouse gas emissions through preferred routes and levels, more efficient diversions, and increased accuracy of navigation;
- improved in-flight emergency response and search and rescue;
- improved operational efficiency for regular public transport operations;
- a reduction in violations of controlled airspace;
- improved communication and situational awareness for both pilots and air traffic controllers;
- the potential for a reduction in CFIT due to more accurate navigation and the availability of GNSS to provide terrain displays; and
- safer operations into regional airports.

It is proposed that the transition to the new system would be completed between 2012 and 2014, by which time a considerable percentage of Australia's current surveillance and navigation infrastructure will have reached their end of life. After the transition phase, aircraft will largely depend on ADS-B for enroute surveillance, GNSS for enroute and non-precision approach navigation and, in many cases, moving map ADS-B traffic displays in the cockpit for surveillance and to enhance situational awareness (Airservices Australia, Australian Defence Force, Civil Aviation Safety Authority, & Department of Transport and Regional Services, 2007).

4.1.7 Air traffic system

Minimum safe altitude warning (MSAW)

Technologies developed for the cockpit to aid CFIT prevention have been further complemented by those developed for the air traffic system. One of the most significant enhancements to the air traffic system was the introduction of the minimum safe altitude warning (MSAW).

The MSAW function is a software enhancement that relies on existing radar hardware to alert air traffic controllers, both visually and aurally, when an aircraft descends below, or is predicted to descend below the minimum safe altitude.

The enhancement is installed at individual airports and consists of a terrain database and configuration information tailored specifically to that airport. The system relies on two monitoring functions to identify low-flying aircraft. The first is general monitoring, which tracks all aircraft operating within the MSAW area. The system identifies the maximum terrain elevation for the area in which the aircraft is operating and applies a margin to determine the minimum safe altitude (MSA). If the aircraft descends below this MSA, the system alerts ATC.

The second function, approach path monitoring, tracks aircraft operating in 'capture boxes'. That is, areas where aircraft typically perform final approach manoeuvres. It simulates a glideslope descent path to determine if an aircraft on final approach has descended, or is projected to descend, below the correct path (Greenwell & Knight, 2003). Countries, including the US and Australia, have introduced the MSAW function into their respective air traffic systems at various locations in an effort to reduce potential CFIT situations from occurring.

A study undertaken in France in 2001 sought to compare the performance of TAWS (GCAS) with the performance of ATC terrain warning systems. Confirmed CFIT and near-CFIT flight paths were simulated and reconstructed using both systems. The results of the study found that the systems were complementary. Depending on the nature of the scenario, in most cases, the ATC terrain warning system compensated for failures of the GCAS and vice versa (ICAO, 2003a).

Route adherence monitoring (RAM)

In Australia, the primary system for civil ATC is The Australian Advanced Air Traffic System (TAAATS). The TAAATS technology integrates information from a range of sources to synthesise a track that is presented to the air traffic controller as the aircraft progresses along its flight path. The system also includes a number of safety functions that automatically alert the controller to potential conflicts between aircraft, or deviations by aircraft from their assigned altitude or flight paths.

One such function is the route adherence monitor (RAM) alert. The RAM alert provides the controller with both audio and visual cues when an aircraft diverges from its flight planned route (ATSB, 2006d). The RAM alert has the potential to provide another line of defence against CFIT.

4.2 Education and training

The Flight Safety Foundation (FSF) has been at the forefront of CFIT education and training[11]. In the early 1990's, the FSF led an international campaign to reduce the number of CFIT accidents. With guidance from the International Air Transport Association (IATA) and ICAO, a FSF-led CFIT Task Force was established. The Task Force included representatives from airlines, aircraft manufacturers, equipment and airframe manufacturers, civil aviation authorities, professional aviation organisations and other technical, research and professional organisations.

The aim of the Task Force was to raise a global awareness of CFIT accidents and to establish measures for CFIT prevention, with the ultimate goal of reducing the number of CFIT accidents by 50 per cent by the year 1998.

In order to achieve this reduction, the FSF developed the following tools and resources for the aviation industry, which are freely available from the FSF's website (Flight Safety Foundation, n.d.-b):

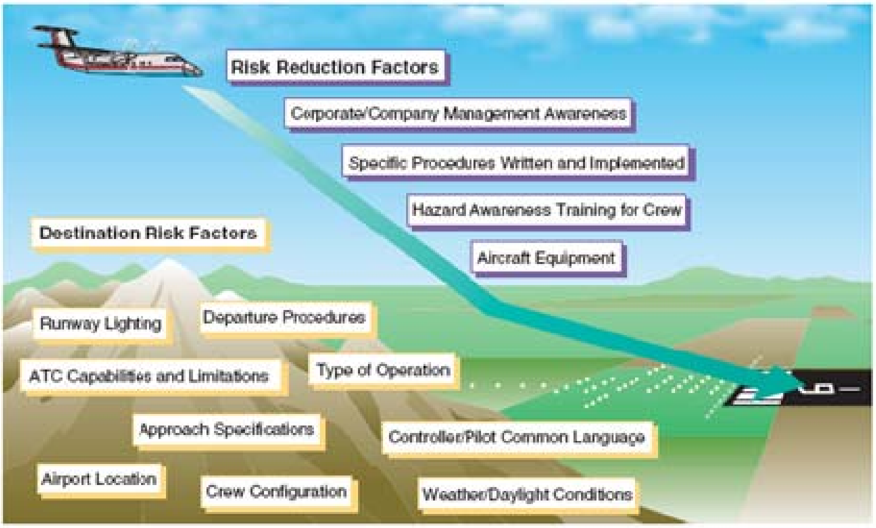
- *FSF CFIT Alert*: emphasises the importance of an immediate and decisive response by flight crews to GPWS/TAWS warnings.

> **EXTRACT FROM THE FSF CFIT ALERT**
>
> Flight Safety Foundation recommends that aircraft operators implement the following GPWS/TAWS procedures:
>
> - When a GPWS/TAWS warning occurs in IMC or at night, pilots must immediately conduct the pull-up maneuver published in the aircraft operating manual (AOM) or the quick reference handbook (QRH);
> - In the absence of an AOM/QRH procedure, a maximum-performance climb must be initiated immediately and continued until the GPWS/TAWS warning stops and the flight crew determines that terrain clearance is assured;
> - A pull-up maneuver must be conducted immediately, except when the aircraft is in clear daylight visual metrological conditions and the flight crew knows that a pull-up maneuver is not required; and
> - Air traffic control must be notified as soon as possible after a pull-up maneuver is conducted.

- *FSF CFIT Checklist*: designed as a risk assessment tool, which helps pilots and operators assess the CFIT risk for specific flights. The checklist is divided into three parts, with numerical values assigned to factors that are used to calculate a numerical total. Part 1 examines CFIT risk factors at the destination, Part 2 examines CFIT risk-reduction factors, and Part 3 calculates the CFIT risk score. Figure 3 provides examples as to what factors are considered in the checklist.

11 Further information on the FSF can be found at www.flightsafety.org.

Figure 3: CFIT risk factors



Source: (FAA, 2004)

- *CFIT: Awareness and Prevention* video is designed primarily for regional and business aircraft operators and provides CFIT statistics, examines CFIT accidents, and presents cockpit voice recorder and data simulations to illustrate accident reduction strategies.
- *CFIT Education and Training Aid*: a two-volume package that examines CFIT hazards, provides special educational material and a model training program, and details CFIT avoidance strategies. Section 1 provides a broad overview of the package for senior management. Section 2 is aimed at those responsible for governing, regulating and managing the industry and identifies areas where they can best put their efforts in CFIT prevention. Section 3 is aimed at operators and provides a history of CFIT, causal factors, traps and solutions. Section 4 provides an example of a CFIT training program while Section 5 contains selected readings. This package was jointly prepared with ICAO and the FAA.

The FSF expanded their efforts to include ALA. As a result, the FSF Approach-and-Landing Accident Reduction (ALAR) Task Force was created in 1996. The goal of the Task Force was to reduce the worldwide fatal ALA rate within 5 years of completing its work in 1998. In doing so, the FSF has developed the following:

- *Approach-and-landing Risk Awareness Tool*: the tool is a list of risk factors that can be used to supplement the flight crew approach briefing by increasing the crews awareness of the hazards associated with a particular approach.
- *Approach-and-landing Risk Reduction Guide*: designed to assist chief pilots, flight crews, dispatchers, and schedulers in identifying policies and procedures that require refinement to ensure the safety of flight operations.
- *ALAR Briefing Notes*: contains a number of documents on a variety of subjects such as standard operating procedures, approach briefings, human factors, crew resource management, approach hazards, non-precision approach, etc.
- *FSF ALAR tool kit*: a compact disc aimed at safety professionals and training organisations working to prevent approach-and-landing accidents, including CFIT. The disc is a comprehensive resource containing briefing notes, videos, presentations, risk awareness checklists and other products (Flight Safety Foundation, n.d.-a).

Threat and error management (TEM)

Threat and error management (TEM) focuses simultaneously on the operating environment and the humans working in that environment with the aim of promoting a proactive philosophy, providing flight crews with the necessary tools to maximise safety margins. Used as an organisational safety management tool, TEM proposes that threats[12] and errors[13] can lead to undesired aircraft states[14] if not identified and managed effectively by the flight crew (Merritt & Klinect, 2006).

Unlike the air transport sector, sophisticated technologies such as GPWS and TAWS are not viable for GA, and hence, GA pilots have to rely on human awareness and procedural tools for CFIT prevention. The concept of TEM has been largely applied in the airline environment; however, there are potential benefits for the application of TEM as a CFIT preventative tool in GA (Poduval, 2005).

The Australian Guild of Air Pilots and Air Navigators, with the assistance of the ATSB and CASA, are in the process of implementing TEM training for the GA sector. The course is designed to introduce a set of operational tools and skills that act as counter measures for identifying and managing safety issues. While specifically targeted at flying instructors, pilots of all levels of experience are encouraged to participate (GAPAN, n.d.).

Further tools such as the FSF CFIT Checklist could provide another measure of identifying potential threats by allowing pilots to recognise the CFIT risk factors at the destination aerodrome prior to a flights departure.

4.3 Research and analysis

Considerable amount of time and resources have been invested by organisations around the world in researching the various aspects of CFIT in an effort to understand this occurrence type, and to provide the aviation community with the necessary information to reduce CFIT accidents and incidents.

Flight Safety Foundation

Organisations such as the FSF have published a number of comprehensive reports on CFIT and ALA including:

- Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents: this report analysed 287 fatal ALAs, 76 ALAs and serious incidents, and examined crew behavioural markers during line audits.
- Airport Safety: A Study of Accidents and Available Approach-and-landing Aids: this study was conducted under the auspices of the FSF for the Netherlands Directorate-General of Civil Aviation to examine the influence of precision terminal approach and guidance equipment (or lack of) on risk.

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12 Threats: events or errors that occur outside the influence of the flight crew, for example, high terrain, adverse weather conditions, aircraft malfunctions, and dispatch errors.

13 Errors: actions or inactions that lead to a deviation from flight crew or organisational intentions or expectations eg handling, procedural, and communication errors.

14 Undesired aircraft state: a position, condition, attitude or configuration of an aircraft that reduces safety margins and results from flight crew error, actions or inactions eg unstable approaches, altitude deviations, and hard landings.

These reports are only a small selection of the reports published by the FSF. The FSF website provides a comprehensive resource for a range of aviation related subjects such as CFIT. These can be found at www.flightsafety.org.

In addition to the above, the FSF CFIT Task Force made a number of recommendations to ICAO, which were accepted and have since been actioned (Flight Safety Foundation, n.d.-c):

- broaden the requirements for the use of GPWS;
- early model GPWS equipment to be replaced by models that have predictive terrain hazard warning functions;
- colour-shaded depictions of terrain altitude be shown on instrument-approach charts;
- aircraft operators are warned against the use of three-pointer and drum-pointer altimeters;
- all countries adopt the use of hectopascals for altimeter settings;
- improved design and presentation of non-precision instrument approach procedures with a standard three-degree approach slope, except where prohibited by obstacles;
- the use of automated altitude call-outs; and
- recognition of the important CFIT-avoidance benefits provided by the global positioning system/global navigation satellite system (GPS/GNSS).

The FSF ALAR Task Force concluded that (Flight Safety Foundation, n.d.-d):

The main causes of ALA accidents are:

- the failure to recognise the need for a missed approach and to execute a missed approach; and
- unstabilised approaches.

The risk of an ALA accident is:

- increased in operations conducted in low light and poor visibility, on wet or contaminated runways, and with the presence of visual/physiological illusions; and
- decreased by the global sharing of aviation information.

Approach-and-landing safety can be improved by:

- effectively using the radio altimeter;
- establishing and adhering to adequate standard operating procedures and flight crew decision-making processes;
- improving communication and a mutual understanding between controllers and pilots of each other's operational environment; and
- the collection and analysis of in-flight data to identify trends.

The Federal Aviation Administration (FAA)

In 1998, the FAA announced a major initiative to achieve significant reductions in the number of fatal accidents by 2007. The Safer Skies agenda used a data-driven approach to identify the causes, and determine the most appropriate form of action, to break the chain of events leading to an accident. As part of the Safer Skies initiative, the Commercial Aviation Safety Team (CAST), which focus on the leading causes of commercial aviation accidents, sought to reduce the commercial aviation accident rate in the US by 80 per cent by the year 2007 (FAA, n.d.).

In addition to the work undertaken by the FSF, CAST addressed the issue of CFIT with their own seven-point program. The key elements were (FAA, 2001):

- using TAWS technology to provide flight crews with aural and visual warnings of potential terrain conflicts;
- CFIT prevention training for both pilots and air traffic controllers;
- the use of flight operations quality assurance (FOQA) and aviation safety action programs (ASAP) to provide operators with the tools to identify safety issues and trends. This information allows operators to take corrective action before an accident or incident occurs;
- recommending procedures, displays and training that will enable pilots of commercial aircraft to fly a stabilised vertical approach path for all instrument approaches;
- a jointly developed standard operating procedures template that ensures all flight crews are trained to use the same procedures in the same way;
- the MSAW of the air traffic control system is configured correctly and functioning properly, and all controllers are adequately trained in using the system; and
- the development of low-cost analytical tools for FOQA and ASAP data, and synthetic vision technology.

Another aspect of the Safer Skies program focused on significantly reducing GA fatal accidents over the period 1996 to 2007. The GA CFIT Joint Safety Analysis Team (JSAT) conducted a detailed analysis of 195 CFIT accidents occurring over a 2-year period (1993 to 1994). Consequently, the CFIT JSAT developed 55 interventions to address accident causes, which were further narrowed to 10 interventions considered to be the most effective and feasible to implement (FAA, 2000). These included:

- increase pilot awareness on accident causes;
- improve safety culture;
- promote the development and use of low cost terrain clearance and/or look ahead technologies;
- improve pilot training;
- improve the quality and substance of weather briefs;
- enhance the Biennial Flight Review and/or instrument competency check;
- develop and distribute mountain flying technique guidance material;
- standardise and expand the use of markings for towers and wires;

- use high visibility enhancing features on obstructions; and
- eliminate the pressure to complete the flight where continuing may compromise safety.

As follow-on from the CFIT JSAT, the FAA chartered a second team, the CFIT Joint Safety Implementation Team (JSIT), to develop an implementation plan for incorporating the intervention strategies identified by the CFIT JSAT.

In March 2003, the FAA published a research report, which examined 16,500 GA accidents occurring between 1990 and 1998 using the human factors analysis and classification scheme. The report, titled *A Human Error Analysis of General Aviation Controlled Flight Into Terrain Accidents Occurring Between 1990-1998,* identified at total of 1,407 CFIT accidents over the reporting period. These accidents revealed a number of differences in the pattern of human error associated with CFIT accidents in GA and validated the efforts of the CFIT JSAT and CFIT JSIT (Shappell & Wiegmann, 2003).

The National Aerospace Laboratory (NLR)

The NLR is an independent technological institute, based in The Netherlands, that conducts applied research on behalf of the aviation and space industries. In doing such, the NLR has published a number of research reports that have provided the aviation community with a valuable insight into CFIT related issues, including:

- Controlled flight into terrain (CFIT) accidents of air taxi, regional and major operators: identified and analysed factors associated with CFIT accidents involving air taxi, regional and major operators between 1988 and 1994 (NLR-TP-97270). This report was also published by the FSF in the April-May 1996 edition of the Flight Safety Digest.
- Flight simulator evaluation of the safety benefits of terrain awareness and warning systems: investigated safety aspects of terrain awareness and warning systems, specifically evaluating the independent effects of terrain awareness information and predictive terrain alerting (NLR-TP-99379).
- Operational safety implications of GPS based non-precision approach operations: assessed the relative safety of GPS-based non-precision approaches against conventional-based non-precision approaches (NLR-TP-2000-152).

The above reports are available from the NLR's website at www.nlr.nl.

The Australian Transport Safety Bureau (ATSB)

The ATSB research report 'General Aviation Fatal Accidents: How do they happen?', released in June 2004, examined fatal accidents between the period 1991 and 2000 involving Australian civil-registered aircraft operating in general aviation (ATSB, 2004a).

Of the 215 fatal accidents and 413 fatalities analysed in the report, 64 accidents (30 per cent) were classified as CFIT and accounted for 26 per cent of the fatalities (n = 109). The CFIT accidents were divided into two groups: low-level operations and normal operations, to distinguish between those accidents where the requirement to see-and-avoid obstacles, objects and terrain was expected and hence planned for by the pilot, and with those accidents where the pilot's planned flight path should have meant that objects, obstacles and terrain would be avoided.

The report identified the following key findings:

- Low-level operations accounted for 59 per cent (n = 38) of the CFIT fatal accidents, most of which were categorised as wire-strikes. This is particularly concerning given that the pilot could see the environment.
- Of the 38 CFIT fatal accidents involving low-level operations, 22 accidents (58 per cent) occurred during necessary low-level flight (eg aerial agriculture, aerial mustering, survey operations) and 16 (42 per cent) occurred during unnecessary low-level flight (eg illegal low-level flying).
- The 26 CFIT fatal accidents occurring during normal operations were further examined to take into account whether the pilot was flying the aircraft visually or via instruments, and whether or not the pilot could see the external environment From this, it was determined that the majority of CFIT fatal accidents within this category occurred when the pilot was unable to see the external environment, whether operating under VFR or IFR.

On 8 July 2005, a Piper PA31-350 collided with terrain while approaching Mount Hotham airport in Victoria (ATSB, 2006b). The accident claimed the lives of the pilot and two passengers. The ATSB's accident investigation identified that extreme weather conditions, and unsafe pilot attitudes and practices resulted in this CFIT accident. The accident aircraft was not fitted, nor was it required to be fitted with TAWS. In March 2006, the ATSB reviewed other CFIT accidents and subsequently issued a recommendation to CASA to review the requirement for TAWS equipment in Australian registered turbine-powered aircraft with a MTOW below 5,700 kg against the international standards with an aim of reducing the potential for CFIT accidents (R20060008).

Furthermore, the ATSB recommended that CASA consider the US National Transportation Safety Board's recommendations for the fitment of TAWS in turbine-powered helicopters with a seating capacity of six or more.

The Civil Aviation Safety Authority accepted the recommendation and stated that they would consider the following:

- cost benefit analysis of costs to industry;
- how fitment would improve safety in this class of aircraft;
- CASA policy on fare paying passengers;
- impact on freight operators;
- training in the use of the equipment; and
- the lead time required prior to fitment.

On 17 July 2007, the ATSB received advice from CASA stating that they are in the process of investigating both the capital and installation costs for TAWS and that they will also examine the applicability to the fleet and the associated safety benefits. This process is expected to take about three to four months (ATSB, 2007b)

5 CFIT: AUSTRALIA IN REVIEW

Between 1990 and 2005, the number of fatal accidents and fatalities involving Australian civil registered aircraft (VH-) operating within Australian territory significantly declined. In particular, fatal accidents recorded an average annual decrease of about 6 per cent. The highest number of fatal accidents and fatalities recorded over the reporting period occurred in 1990. The year 2005 saw an increase in the number of fatalities compared with 2004, primarily the result of a single fatal accident near Lockhart River, Queensland on 7 May 2005, which claimed the lives of 15 people. However, both the number of fatal accidents and fatalities for 2005 were still below the annual average calculated for the 16-year reporting period (ATSB, 2006a).

Benchmarked against the United States, Canada, the United Kingdom and New Zealand, Australia has a good safety record. To date, Australia has recorded no hull losses or fatal accidents involving high capacity regular public transport (RPT) jet aircraft, thus confirming that Australia has one of the best safety records in the world. However, given the low number of accidents experienced in Australia, a single fatal accident involving an RPT aircraft, either high or low capacity, would have a significant affect on Australia's fatal accident and fatality record (ATSB, 2006c).

Since the 1980's, air travel in Australia has increased considerably, with domestic and international passenger movements on RPT flights increasing at an average annual growth rate of 5.8 per cent. Over the last 20 years, passenger movements have more than tripled, from about 32 million in 1984/85 to more than 98 million in 2004/05 (BTRE, 2006). By contrast, activity in the general aviation (GA) sector has remained generally constant. In the 10 years since 1996, GA activity has decreased slightly from about 1.8 million hours flown to 1.72 million hours flown. Activity was highest in 1998, when 1.88 million hours flown was recorded (BTRE, 2007).

However, like elsewhere, Australia has experienced a number of significant controlled flight into terrain (CFIT) accidents and incidents. While this report covers the period 1996 to 2005, earlier accidents in Australia serve to highlight the severity of CFIT accidents:

- On 27 April 1995, an Israel Aircraft Industries Westwind 1124 aircraft, registered VH-AJS, was on a scheduled instrument flight rules (IFR) freight service from Darwin via Tindal, Alice Springs, and Adelaide to Sydney. While conducting a locator/non-directional radio beacon (NDB) approach to Alice Springs, Northern Territory at night in clear moonless conditions, the aircraft collided with the top of the Ilparpa Range. All three occupants suffered fatal injuries. The subsequent investigation revealed that the crew had descended to the incorrect minimum descent altitude before reaching the appropriate sector of the approach (BASI, 1996a).

- On 19 March 1994, a Piper PA-23-250 Aztec aircraft, registered VH-BOC, was being operated on a VFR flight from Cairns to Palm Island via Innisfail, Queensland. While enroute, the aircraft was observed on air traffic control radar to deviate from the planned track and descend from the cruising altitude of 5,000 ft above mean sea level (AMSL). The aircraft subsequently impacted the rainforest canopy at 4,200 ft AMSL. All four occupants received fatal injuries. The accident investigation indicated that the deviation from the planned track and cruising altitude may have been due to the deteriorating weather conditions (BASI, 1996b)
- On 11 June 1993, a Piper PA31-350 Chieftain aircraft, registered VH-NDU, was being operated on an IFR scheduled passenger service from Sydney to Cootamundra, with an intermediate stop at Young, New South Wales. While on a right base leg for a landing approach to runway 01 at Young, in conditions of low cloud and darkness, the aircraft impacted trees. All seven occupants suffered fatal injuries. The subsequent investigation determined that the aircraft was flown below the minimum circling altitude without adequate visual reference (BASI, 1994).
- On 11 May 1990, a Cessna 500 Astec Eagle aircraft, registered VH-ANQ, was being operated on a charter flight from Proserpine to Mareeba, Queensland with 11 persons on board. While on descent to Mareeba, air traffic control instructed the aircraft to descend to 7,000 ft. This transmission, and other subsequent transmissions to the aircraft, went unanswered. The wreckage of the aircraft was located on the eastern slopes of Mt Emerald, 15 kilometres south of Mareeba airport. The causal factors associated with the accident could not be determined (BASI, n.d.).

5.1 Data analysis

The Australian Transport Safety Bureau (ATSB) aviation safety accident and incident database was searched to identify occurrences involving Australian civil registered aircraft (VH-) operating within Australian territory between the period 1996 and 2005 that resulted in a collision with terrain. This dataset was then further analysed to eliminate those occurrences involving a collision between an aircraft and the ground (water or obstacles) where there was a question over whether the pilot retained control of the aircraft; or evidence to suggest that pilot had sufficient awareness of the surrounding terrain. If the pilot was unaware of the impending collision, and the aircraft was under the control of the pilot, the occurrence was classified as CFIT, and hence, included in the dataset (see the definition described in Section 2.1).

Sport aviation, gliding and ballooning aircraft were excluded from the dataset. Controlled flight into terrain occurrences involving intentional low level operations (eg aerial agriculture and stock mustering) were also excluded from this study.

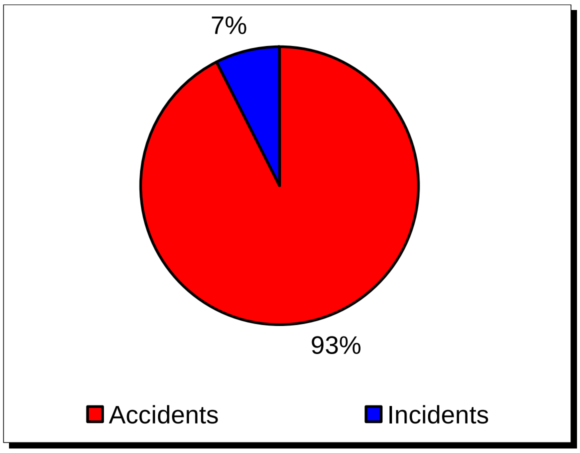
In the case where insufficient information was available to determine whether an occurrence was classifiable as CFIT, the occurrence was excluded from the dataset. As a result, the number of CFIT occurrences presented in this report may be under-estimated.

5.2 CFIT in Australia

Between the period 1996 and 2005, a total of 27 CFIT accidents and incidents were recorded by the ATSB. The highest number of CFITs occurred in 1998, when six were recorded, and the lowest in 2002, when none were recorded. Over the course of the reporting period, Australia averaged about three CFIT occurrences per year.

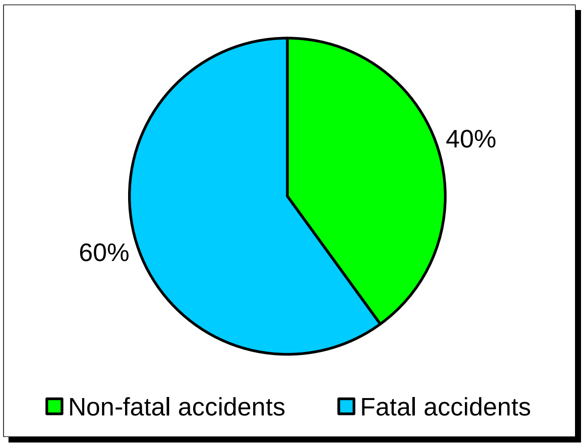
Figure 4 shows that of the 27 CFIT occurrences, 93 per cent (n = 25) were classified as accidents and the remaining 7 per cent (n = 2) as incidents (refer to Appendix A for the definition of an accident and incident).

Figure 4: Australian CFIT accidents and incidents, 1996 to 2005



Of the 25 CFIT accidents recorded by the ATSB, 60 per cent were fatal accidents (n = 15) resulting in 47 fatalities. The remaining 40 per cent were non-fatal accidents (Figure 5). Nearly a third of non-fatal accidents resulted in some injury to the occupants.

Figure 5: Australian CFIT fatal and non-fatal accidents, 1996 to 2005



The prevalence of CFIT accidents within Australia can be seen by comparing CFIT with Australia's total accident record. The following table compares the number of CFIT accidents, fatal accidents and fatalities with the total number of accidents, fatal accidents and fatalities recorded by the ATSB involving Australian civil registered aircraft (VH-) within Australian territory during the 1996 to 2005 reporting period for RPT and GA operations only.

CFIT ACCIDENTS IN CONTEXT

During the 1996 to 2005 reporting period, the ATSB recorded a total of 1,709 accidents involving VH- registered aircraft within Australian territory operating in the RPT and GA sectors of the industry. This included 167 fatal accidents, which resulted in 343 fatalities.

Accidents	CFIT	25	**1.5%**
	All	1,709	
Fatal accidents	CFIT	15	**9.0%**
	All	167	
Fatalities	CFIT	47	**13.7%**
	All	343	

Controlled flight into terrain accidents account for only a very small proportion of Australia's total accident record (1.5 per cent). However, in terms of fatal accidents and fatalities, they account for a greater proportion, 9.0 per cent and 13.7 per cent respectively.

Overall, the likelihood of a CFIT accident occurring is rare, with CFIT accidents accounting for only 1.5 per cent of all accidents recorded during the 10-year reporting period. However, 60 per cent of CFITs resulted in fatal injuries to the aircraft occupants, underscoring the severity of this type of occurrence. Although only a small proportion of all accidents, CFITs accounted for 9.0 per cent of all fatal accidents and 13.7 per cent of all fatalities.

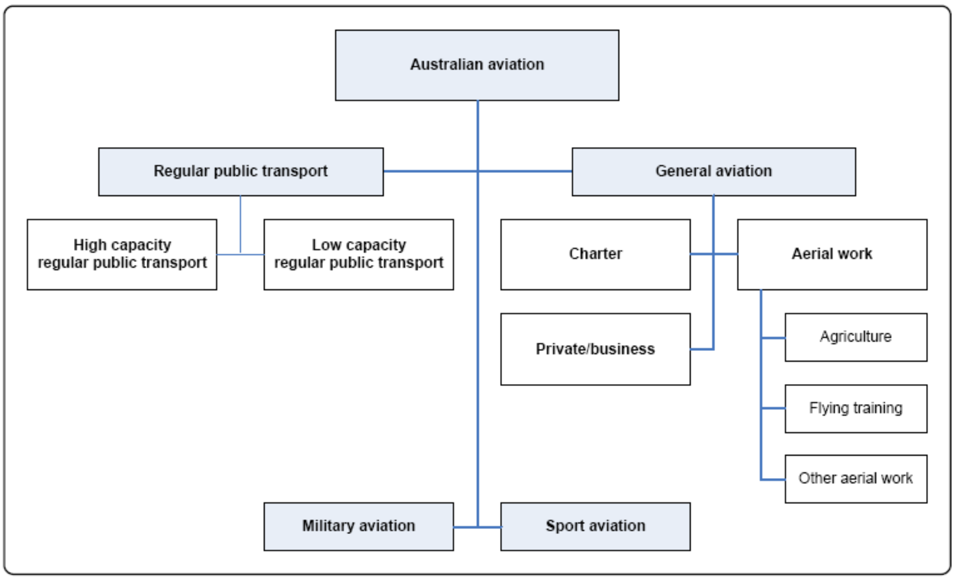
Due to the low number of CFIT occurrences recorded in Australia over the 10-year period, any assessment and interpretation of the numbers should be treated with caution.

5.3 Operation type

The ATSB is responsible for the independent investigation of accidents and incidents involving civil aircraft in Australia. For recording and statistical purposes, the ATSB divides the Australian aviation industry into four main categories. These are RPT, GA, sport aviation and military aviation. The ATSB's aviation accident and incident database captures data predominantly involving RPT and GA aircraft. As shown in Figure 6, RPT is divided into high capacity and low capacity (LCRPT) operations. General aviation is divided into charter, aerial work, and private/business operations.

Some data on sport and military operations are included in the database, but investigations into accidents involving sport operations (eg ultralights, microlights, gyrocopters, gliders and hang gliders) will only be conducted if it benefits future safety, and sufficient resources are available (ICAO, 2003b). Military operations are normally overseen by military safety authorities. For a more detailed description of these categories, refer to Appendix B.

Figure 6: The Australian aviation industry



Incidents

The two CFIT incidents recorded during the 1996 to 2005 period involved other aerial work and private/business operations. In both cases, the aircraft collided with an obstacle while conducting a visual approach:

- The pilot of the Bell Jetranger helicopter was positioning for a landing at a campsite next to the Thredbo River. While making an approach into the sun, the helicopter struck a suspended wire (ATSB occurrence: 199800418).
- The pilot made a pre-landing pass over the private airstrip at 500 ft above ground level but did not sight two powerlines about 30 metres from the southern threshold. During the approach, the nosewheel struck and severed one powerline, and the propeller severed the other (ATSB occurrence: 200504999).

Accidents

Over half of the 25 CFIT accidents involved private/business operations (n = 13). This was followed by charter and other aerial work, which accounted for eight and three accidents respectively. The lowest number involved LCRPT operations, which recorded one CFIT accident (Table 1).

Table 1: CFIT occurrences by operation type, 1996 to 2005

	Accidents	Incidents	*Total*
Regular public transport			
LCRPT	1	0	***1***
General aviation			
Charter	8	0	***8***
Other aerial work	3	1	***4***
Private/business	13	1	***14***
Total	***25***	***2***	***27***

Fatal accidents

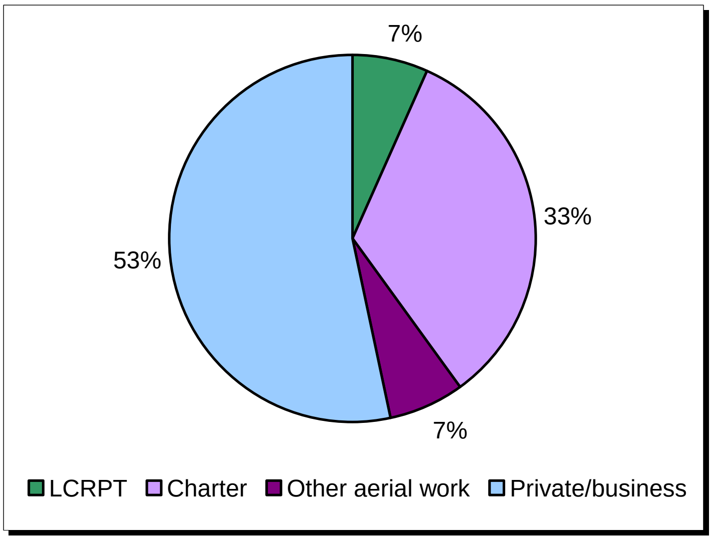
Of the 25 CFIT accidents, 60 per cent were fatal (n = 15) while the remaining 40 per cent were non-fatal (n = 10). While Table 2 shows some variation in the proportion of fatal and non-fatal accidents amongst the operational categories, in general, there is a significantly high risk of a CFIT accident resulting in fatalities across all categories.

Table 2: CFIT non-fatal and fatal accidents by operation type, 1996 to 2005

	Accidents		
	Non-fatal	Fatal	***Total***
Regular public transport			
LCRPT	0	1	***1***
General aviation			
Charter	3	5	***8***
Other aerial work	2	1	***3***
Private/business	5	8	***13***
Total	***10***	***15***	***25***

Figure 7 shows that over half of all the CFIT fatal accidents recorded during the reporting period involved private/business operations (n = 8). This was followed by charter, which accounted for 33 per cent (n = 5), and other aerial work and LCRPT operations, both accounting for 7 per cent each (n = 1).

Figure 7: CFIT fatal accidents, 1996 to 2005



Fatalities

Between 1996 and 2005, Australian aviation experienced 15 CFIT fatal accidents, which resulted in 47 fatalities (Table 3). The highest number of fatalities occurred in the private/business category (n = 20), followed by LCRPT and charter, which accounted for 15 and 11 fatalities respectively. The lowest number involved other aerial work operations, which recorded one fatality.

Table 3: CFIT fatal accidents and fatalities, 1996 to 2005

	Fatal accidents	Fatalities
Regular public transport		
LCRPT	1	15
General aviation		
Charter	5	11
Other aerial work	1	1
Private/business	8	20
Total	***15***	***47***

Overall, GA accounted for the greatest proportion of CFIT accidents (96 per cent), fatal accidents (93 per cent), and fatalities (68 per cent).

While RPT operations recorded only one CFIT fatal accident over the reporting period, it was responsible for about one-third (n = 15) of all CFIT fatalities. The Lockhart River accident, Australia's worst civil aviation accident since 1968, highlights the consequences of CFIT in air transport operations. Furthermore, it explains the international focus on CFIT, where considerable resources have been invested in developing better strategies to prevent CFIT in passenger carrying operations.

5.4 Aircraft type

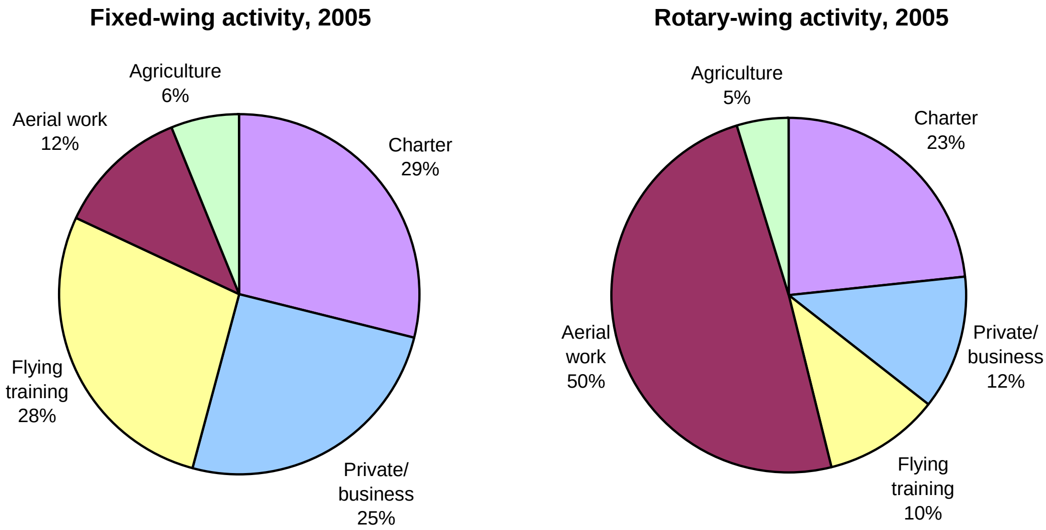
When analysing accident and incident data based on aircraft type, that is, fixed-wing or rotary-wing[15], it is important to acknowledge that each aircraft type has different capabilities that lend themselves to different functions. For example, fixed-wing aircraft are typically used for carrying passengers, transporting cargo, and travelling long distances. Rotary-wing aircraft are optimised for travel over shorter distances, and for operations into confined spaces, such as search and rescue operations, and transporting persons to oil rigs and ships.

General aviation activity data collected by the Bureau of Transport and Regional Economics measures the distribution of activity across the operational types by fixed-wing and rotary-wing aircraft.

15 The terms fixed-wing and aircraft, and rotary-wing and helicopter are used interchangeably throughout this report when describing each of these categories.

Figure 8 provides a general representation of fixed-wing and rotary-wing activity within the GA sector and highlights the differing nature of operations undertaken by each aircraft type. These characteristics are important when analysing data that specifically involves operating near terrain, water and obstacles.

Figure 8: General aviation fixed-wing and rotary-wing activity, 2005



Regular public transport operations in Australia are solely conducted using fixed-wing aircraft.

About two-thirds of the 27 CFIT occurrences involved fixed-wing aircraft (n = 18) while the remaining nine occurrences involved rotary-wing aircraft. Table 4 provides a breakdown of CFIT occurrences and fatalities by aircraft types and highlights the following:

- *Incidents:* both aircraft types recorded one CFIT incident each.
- *Accidents:* both fixed-wing and rotary-wing aircraft recorded five non-fatal CFIT accidents. In contrast, fixed-wing aircraft accounted for 80 per cent of CFIT fatal accidents (n = 12), while rotary-wing aircraft accounted for the remaining 20 per cent (n = 3).
- *Fixed-wing aircraft:* of the 17 accidents involving fixed-wing aircraft, 71 per cent were fatal accidents, while the remaining 29 per cent were non-fatal accidents.
- *Rotary-wing aircraft:* of the eight accidents involving rotary-wing aircraft, 37 per cent were fatal accidents, while the remaining 63 per cent were non-fatal accidents.
- *Fatalities:* the 12 CFIT fatal accidents involving fixed-wing aircraft resulted in 43 fatalities, while the three CFIT fatal accidents involving rotary-wing aircraft resulted in four fatalities. The high number of fatalities associated with fixed-wing is partly attributed to the 15 fatalities resulting from the Lockhart River accident.

Table 4: CFIT occurrences and fatalities by aircraft type, 1996 to 2005

	Incidents	Accidents		Fatalities
		Non-fatal	Fatal	
Fixed-wing	1	5	12	43
Rotary-wing	1	5	3	4
Total	***2***	***10***	***15***	***47***

In terms of operation type (Table 5), the highest number of CFIT occurrences involving fixed-wing aircraft occurred in the private/business category (n = 10). This was followed by charter, which recorded five CFIT occurrences, and other aerial work, which recorded two. The lowest number was recorded by LCRPT, which recorded one CFIT occurrence during the reporting period. Similarly, the highest number of CFIT occurrences involving rotary-wing aircraft also occurred in the private/business category (n = 4), followed by charter (n = 3). The lowest was recorded in other aerial work, which recorded two.

Table 5: CFIT occurrences by operation type and aircraft type, 1996 to 2005

	Fixed-wing	Rotary-wing	***Total***
Regular public transport			
LCRPT	1	0	***1***
General aviation			
Charter	5	3	***8***
Other aerial work	2	2	***4***
Private/business	10	4	***14***
Total	***18***	***9***	***27***

While rotary-wing aircraft accounted for one-third of CFIT occurrences, they only account for 11 per cent of aircraft on the civil aircraft register. Fixed-wing aircraft, on the other hand, account for about 78 per cent[16]. The greater representation of rotary-wing aircraft involved in CFIT occurrences compared with the proportion of rotary-wing aircraft on the civil register may be partly attributed to their operating environment.

Table 6 provides a breakdown of the operational sub-types for each aircraft type and shows some degree of variability between fixed-wing and rotary-wing operations, reflecting the different nature of operations undertaken by each aircraft type. For example, fixed-wing charter operations were involved in cargo and passenger carrying operations, while rotary-wing aircraft were primarily involved in positioning the helicopter after conducting marine pilot transfer operations.

16 As at 15 April 2007, there was a total of 12,601 aircraft on the civil aircraft register of which 9,848 were fixed-wing aircraft and 1,362 were rotary-wing aircraft.

Table 6: CFIT occurrences by operation sub-type and aircraft type, 1996 to 2005

	Sub-type	Fixed-wing	Rotary-wing	***Total***
Regular public transport				
LCRPT		1	0	***1***
General aviation				
Charter	Cargo	3	0	*3*
	Passenger	2	1	*3*
	Positioning	0	2	*2*
	Sub total	*5*	*3*	***8***
Other aerial work	Aerial ambulance	2	0	*2*
	Search and rescue	0	1	*1*
	Unknown	0	1	*1*
	Sub total	*2*	*2*	***4***
Private/business	Business	4	1	*5*
	Ferry	0	1	*1*
	Pleasure/travel	5	1	*6*
	Practice	1	0	*1*
	Unknown	0	1	*1*
	Sub total	*10*	*4*	***14***
Total		***18***	***9***	***27***

The following table provides a breakdown of CFIT accidents, fatal accidents and fatalities for fixed-wing and rotary-wing aircraft compared with the total number of accidents, fatal accidents and fatalities recorded by the ATSB between 1996 and 2005.

The proportion of CFIT accidents, fatal accidents and fatalities involving fixed-wing aircraft compared with the total number of fixed-wing accidents, fatal accidents and fatalities was similar to that of the overall CFIT statistics. Fixed-wing CFIT accidents accounted for only 1.3 per cent of all fixed-wing accidents. Fatal accidents (9.6 per cent) and fatalities (15.6 per cent) accounted for a greater proportion.

The proportion of rotary-wing CFIT accidents compared with the total number of rotary-wing accidents was slightly higher than that experienced by fixed-wing, accounting for 2.3 per cent. The proportion of fatal accidents on the other hand was slightly lower, accounting for 7.1 per cent. However, in terms of the proportion of fatalities, fixed-wing aircraft accounted for over twice the amount of fatalities (15.6 per cent) compared with rotary-wing aircraft (6.0 per cent). This reflects the different operational roles of each aircraft type, with fixed-wing aircraft regularly used for passenger carrying operations and rotary-wing aircraft often used for aerial work operations, with fewer persons on board. To illustrate this, the Lockhart River accident alone accounts for 5.4 per cent of the total number of fixed-wing fatalities recorded by the ATSB during the 1996 to 2005 reporting period.

CFIT ACCIDENTS IN CONTEXT - AIRCRAFT TYPE

During the reporting period, a total of 1,356 accidents involved fixed-wing aircraft, of which 125 were fatal accidents resulting in 276 fatalities. Rotary-wing aircraft recorded 350 accidents, 42 fatal accidents and 67 fatalities.

Fixed-wing

Accidents	CFIT	17	**1.3%**
	All	1,356	
Fatal accidents	CFIT	12	**9.6%**
	All	125	
Fatalities	CFIT	43	**15.6%**
	All	276	

Rotary-wing

Accidents	CFIT	8	**2.3%**
	All	350	
Fatal accidents	CFIT	3	**7.1%**
	All	42	
Fatalities	CFIT	4	**6.0%**
	All	67	

Irrespective of the aircraft type, when compared to the total number of accidents, fatal accident and fatalities the catastrophic nature of CFIT is prevalent. While CFIT accidents are rare, for both fixed-wing and rotary-wing aircraft, when they do occur, there is an increased likelihood that they will result in a fatality. This is more so noticeable for fixed-wing aircraft, accounting for 15.6 per cent of the total number of fatalities compared with 6.0 per cent for rotary-wing aircraft.

5.5 Phase of flight

Australia's operating environment is generally favourable for aviation. The terrain is relatively flat with some areas of steeply rising prominent ranges. A number of Australia's airports are close to significantly high terrain such as Alice Springs, Cairns, Canberra, Hobart, Tamworth and Townsville. Conducting IFR approaches into these airports may impose an increased workload, particularly for single pilot operations and hence, increase the risk of a CFIT (CASA, 1997).

Controlled flight into terrain can occur during most phases of flight, however, the analysis of CFIT occurrence worldwide has identified that this type of event predominately occurs during the approach and landing phase. Figure 9 shows that the Australian data reflects that of the international experience, with the highest proportion of CFIT accidents and incidents occurring during the approach phase (63 per cent). This was followed by the enroute phase, which accounted for 19 per cent, and the manoeuvring and initial climb phases, which accounted for 7 per cent each. The lowest proportion of CFIT accidents and incidents occurred during the climb phase of flight (4 per cent).

Figure 9: Proportion of CFIT occurrences by phase of flight, 1996 to 2005

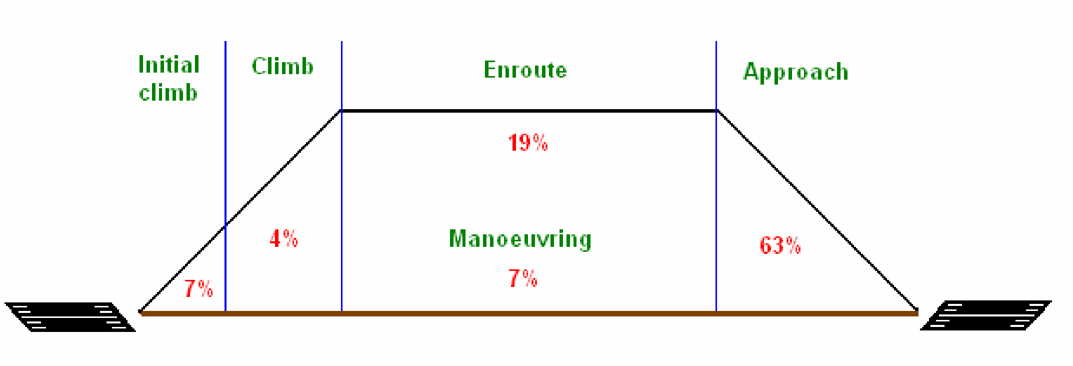


Table 7 provides a breakdown of CFIT incidents, accidents and fatalities by phase of flight and highlights the following:

- *Incidents:* the two incidents recorded during the reporting period both occurred in the approach phase of flight.
- *Accidents:* the highest number of accidents occurred during the approach phase of flight (60 per cent). This was followed by the enroute phase (20 per cent), and the manoeuvring and initial climb phases, each accounting for 8 per cent. The lowest number of accidents was recorded in the climb phase, accounting for 4 per cent.
- *Non-fatal accidents:* 70 per cent of non-fatal accidents occurred in the approach phase. The initial climb, climb and manoeuvring phases accounted for 10 per cent each. There were no non-fatal accidents recorded in the enroute phase.
- *Fatal accidents:* about half of all fatal CFIT accidents occurred during the approach phase (53 per cent), followed by the enroute phase, which accounted for 33 per cent. All of the CFIT accidents recorded in the enroute phase of flight were fatal accidents. The initial climb and manoeuvring phases accounted for 7 per cent each. The climb phase recorded nil fatal accidents.
- *Fatalities:* the highest number of fatalities occurred during the approach phase, accounting for 70 per cent. This was followed by the enroute phase (19 per cent) and initial climb (9 per cent). The lowest number of fatalities recorded occurred in the manoeuvring phase of flight (2 per cent).

Table 7: CFIT occurrences and fatalities by phase of flight, 1996 to 2005

	Incidents	Accidents		Fatalities
		Non-fatal	Fatal	
Initial climb	0	1	1	4
Climb	0	1	0	0
Enroute	0	0	5	9
Manoeuvring	0	1	1	1
Approach	2	7	8	33
Total	***2***	***10***	***15***	***47***

Table 8 shows the number of CFIT occurrences by operation type and phase of flight. Across all operation types, the greatest number of CFIT occurrences were in the approach phase of flight, of which private/business operations accounted for 47 per cent (n = 8), charter operations 29 per cent (n = 5), other aerial work 18 per cent (n = 3) and LCRPT 6 per cent (n = 1). The enroute phase of flight recorded the second highest number of CFIT occurrences, of which private/business operations accounted for 60 per cent (n = 3) and the remaining 40 per cent attributed to charter operations (n = 2). This was followed by the initial climb phase, which recorded two CFIT occurrences in the private/business category, and manoeuvring, with other aerial work and private/business operations recording one occurrence each. The climb phase of flight recorded the lowest number of CFIT occurrences with one occurrence attributed to charter operations.

Table 8: CFIT occurrences by operation type and phase of flight, 1996 to 2005

	Initial climb	Climb	Enroute	Manoeuv-ring	Approach	***Total***
Regular public transport						
LCRPT	0	0	0	0	1	***1***
General aviation						
Charter	0	1	2	0	5	***8***
Other aerial work	0	0	0	1	3	***4***
Private/business	2	0	3	1	8	***14***
Total	***2***	***1***	***5***	***2***	***17***	***27***

Overall, CFIT fatal accidents involving fixed-wing aircraft accounted for 91 per cent of the CFIT fatalities recorded during the 1996 to 2005 period. Rotary-wing aircraft accounted for the remaining 9 per cent. Table 9 shows that the greatest number of fatalities involving fixed-wing aircraft occurred in the approach phase of flight (77 per cent). This was followed by enroute (12 per cent), initial climb (9 per cent) and the manoeuvring phase (2 per cent). All CFIT fatalities involving rotary-wing aircraft occurred during the enroute phase of flight.

Table 9: CFIT fatalities by phase of flight and aircraft type, 1996 to 2005

	Fixed-wing	Rotary-wing	***Total***
Initial climb	4	0	***4***
Climb	0	0	***0***
Enroute	5	4	***9***
Manoeuvring	1	0	***1***
Approach	33	0	***33***
Total	***43***	***4***	***47***

5.6 CFIT collision type

While the term CFIT refers specifically to controlled flight into *terrain*, terrain is defined more broadly to include water and obstacles. Obstacles refer to objects extending above the surface of the ground such as powerlines/wires and towers. Of the 27 CFIT occurrences recorded during 1996 to 2005, 62 per cent involved a collision with terrain. The remaining 38 per cent was equally divided between a collision with water and a collision with obstacle, accounting for 19 per cent each (Figure 10).

Figure 10: Proportion of CFIT occurrences by CFIT collision type, 1996 to 2005

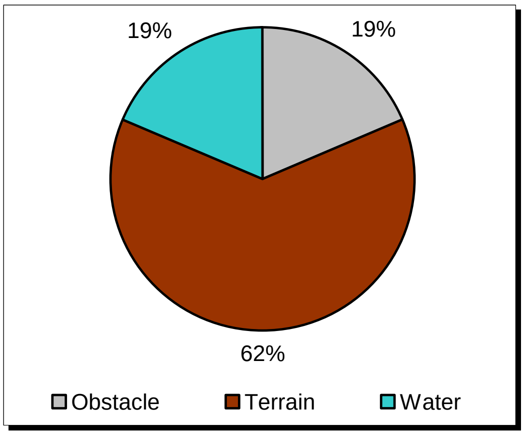


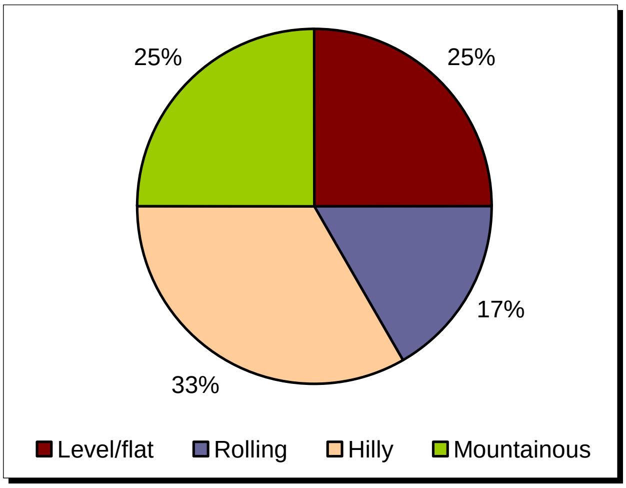
Table 10 shows that the majority of fixed-wing CFIT occurrences involved a collision with terrain. Rotary-wing aircraft on the other hand were more evenly distributed among the three collision types, with the highest number involving a collision with water. These differences probably reflect the nature of operations undertaken by each aircraft type.

Table 10: CFIT occurrences by aircraft type and CFIT collision type, 1996 to 2005

	Terrain	Obstacle	Water	***Total***
Fixed-wing	14	3	1	***18***
Rotary-wing	3	2	4	***9***
Total	***17***	***5***	***5***	***27***

Previous research has indicated that about two-thirds of CFIT occurrences were in hilly or mountainous-terrain environments and about one-third were in areas of flat terrain (Khatwa & Helmreich, 1998-1999). The type of terrain was recorded in 12 of the 17 CFIT occurrences involving a collision with terrain. Of the cases where terrain features were known, 33 per cent was hilly, 25 per cent was mountainous, 25 per cent was level/flat and 17 per cent was rolling terrain (Figure 11). Overall, 75 per cent of collision with terrain occurrences involved hilly or mountainous[17] terrain while 25 per cent were in areas of level/flat terrain. However, when taking into consideration water as a level/flat terrain surface, this proportion differs somewhat. With the additional five occurrences involving a collision with water, 54 per cent involved hilly or mountainous terrain while 46 per cent were in areas of level/flat terrain (including water). This reinforces that mountainous or steeply rising terrain is not a precondition for CFIT accidents or incidents.

Figure 11: Proportion of collision with terrain occurrences by terrain type, 1996 to 2005



The 2003 accident of a Beech Super King Air at Coffs Harbour highlights the possibility of a CFIT occurring in the absence of significant terrain features.

ACCIDENT SYNOPSIS

On 15 May 2003, a Raytheon Beech Super King Air B200C, registered VH-AMR, was on a routine aeromedical flight from Sydney to Coffs Harbour, New South Wales under IFR. While conducting a global positioning system (GPS) non-precision approach to runway 21 at Coffs Harbour, the aircraft impacted the sea. The impact occurred immediately after the pilot initiated a go-around procedure. Although the aircraft sustained structural damage and the left main landing gear detached, the aircraft remained airborne. None of the four occupants received injuries as a result of the accident. The weather conditions at the time included heavy rain and restricted visibility. The investigation determined that this CFIT accident resulted from an inadvertent descent below the minimum descent altitude on the final segment of the approach, fortunately without the catastrophic consequences often associated with a CFIT accident (ATSB, 2004b).

17 Any reference to ‘hilly or mountainous’ terrain also includes ‘rolling’ terrain.

While the above indicates that significant terrain features are not a prerequisite for a CFIT, it may increase the risk of fatal injury. As Table 11 shows, 81 per cent of all fatalities resulting from a CFIT accident between 1996 and 2005 involved a collision with hilly or mountainous terrain. By contrast, only 4 per cent involved level/flat terrain and water.

Table 11: CFIT fatalities by terrain significance, 1996 to 2005

	Fixed-wing	Rotary-wing	***Total***
Obstacle	0	0	***0***
Terrain - level/flat	1	0	***1***
Terrain - hilly/mountainous	37	1	***38***
Terrain - unknown	5	2	***7***
Water	0	1	***1***
Total	***43***	***4***	***47***

5.7 Environmental conditions

When the term CFIT is applied to an occurrence, it is often assumed that the environmental conditions at the time of the occurrence were poor. That is, the accident or incident occurred in conditions of reduced visibility such as instrument meteorological conditions (IMC) or at night. However, CFIT refers to a broad spectrum of occurrences including flights operated under IFR, where the pilot navigates by reference to the aircraft instruments, or visual flight rules (VFR), where the pilot navigates with visual reference to the ground, or during a transition from one mode to another (Bailey, Peterson L M, Williams, & Thompson, 2000).

Table 12 shows that of the 27 CFIT occurrences recorded between 1996 and 2005, 63 per cent (n = 17) were operated under VFR while 37 per cent (n = 10) were operated under IFR. Given that VFR pilots navigate with visual reference to the outside environment, it was surprising to find that 76 per cent of the VFR occurrences were in visual meteorological conditions (VMC). Also of concern was the fact that the remaining 24 per cent involved VFR pilots operating in IMC, where the weather conditions at the time restricted the pilot's visibility, and in some cases, visual reference to the ground was lost altogether. Of the 10 CFIT occurrences operating under IFR, 60 per cent were in IMC, but 20 per cent were in VMC. In the remaining 20 per cent of IFR occurrence, the actual weather conditions at the time were unknown. One occurred at night and the other during the daytime.

Table 12: CFIT occurrences by flight rule and flight conditions, 1996 to 2005

	VMC	IMC	Unknown	***Total***
VFR	13	4	0	***17***
IFR	2	6	2	***10***
Total	***15***	***10***	***2***	***27***

In order to gain an insight into the environmental conditions at the time of the accident or incident, the 27 CFIT occurrences were divided into two categories based on flight conditions and time of day (clear visibility and reduced visibility). Those cases where the environmental conditions at the time were IMC, or the time of day was twilight or night, were categorised as ‘reduced visibility’ occurrences. Those occurrences operating under VMC in daylight were categorised as ‘clear visibility’ occurrences. Of the 27 CFIT occurrences 59 per cent (n = 16) occurred in reduced visibility conditions, 37 per cent in clear visibility conditions (n = 10), and the remaining 4 per cent was unknown (n = 1). Fixed-wing and rotary-wing aircraft each accounted for half of all CFIT occurrences in clear visibility conditions. These proportions were somewhat different in reduced visibility conditions with fixed-wing aircraft accounting for 75 per cent and rotary-wing aircraft the remaining 25 per cent. The environmental conditions at the time of the occurrence were unknown in one case (Table 13).

Table 13: CFIT occurrences by aircraft type and environmental conditions, 1996 to 2005

	Clear visibility	Reduced visibility	Unknown	***Total***
Fixed-wing	*5*	*12*	*1*	***18***
Rotary-wing	*5*	*4*	*0*	***9***
Total	***10***	***16***	***1***	***27***

Note: One of the two occurrences where the meteorological conditions at the time of occurrence was unknown (Table 12) occurred at night and hence was categorised as ‘reduced visibility’.

Of the 17 CFIT accidents and incidents occurring in the approach phase of flight, 71 per cent were in conditions of reduced visibility while the remaining 29 per cent were in conditions of clear visibility. This highlights the inherent risks associated with operating at lower altitudes, particularly in poor weather conditions and at night, where visual cues may be restricted or non-existent. The number of CFIT occurrences in the enroute phase was equally divided between the two visibility categories, accounting for two occurrences each. The manoeuvring phase of flight also recorded one occurrence each per category. The initial climb phase recorded two CFIT occurrences, both in clear visibility conditions while the climb phase recorded one occurrence in reduced visibility conditions (Table 14).

Table 14: CFIT occurrences by phase of flight and environmental conditions, 1996 to 2005

	Clear visibility	Reduced visibility	Unknown	***Total***
Initial climb	2	0	0	***2***
Climb	0	1	0	***1***
Enroute	2	2	1	***5***
Manoeuvring	1	1	0	***2***
Approach	5	12	0	***17***
Total	***10***	***16***	***1***	***27***

5.8 GPWS/TAWS

The Australian aviation industry has benefited from the efforts of the international aviation community in designing and implementing CFIT preventative strategies. One such key measure is the introduction of terrain awareness technologies such as the ground proximity warning system (GPWS) and terrain awareness and warning system (TAWS).

During the reporting period, only one CFIT occurrence involved an aircraft that was fitted with, and was required to be fitted with GPWS technology. This occurrence was the Lockhart River accident, which resulted in 15 fatalities. The aircraft, a Fairchild Aircraft Inc. SA227-DC Metro 23, was a twin-engine turboprop certified to seat up to 19 passengers, with a maximum take-off weight (MTOW) of 7,484 kg. At the time of the accident, 7 May 2005, the aircraft was only required to be fitted with a GPWS as the requirement for the fitment of TAWS had not yet come into effect. However, during the accident investigation, it was reported that the operator intended to comply with the TAWS requirement by 30 June 2005.

The investigation into the Lockhart River accident was unable to determine if the GPWS functioned as designed during the flight due to a lack of information available from the cockpit voice recorder. However, data from the flight data recorder was provided to the GPWS manufacturer (Honeywell) to conduct a computer simulation of the final stages of the flight to determine if any warning would have been provided by the GPWS if it was functioning as designed. The simulation indicated that the GPWS should have provided a one second 'terrain terrain' alert about 25 seconds prior to impact, followed by a second 'terrain terrain' alert and a continuous 'pull up' warning for the final 5 seconds of flight. A number of studies have examined pilot response times to GPWS alerts and indicate that alerts and warnings in the final 5 seconds of a flight would not be sufficient time for the flight crew and aircraft to respond effectively. One of the well known disadvantages of GPWS is that in some cases the system does not provide adequate time to allow the pilot to respond to an alert and take avoiding action. This issue has been addressed with TAWS, which provides the pilot with a greater time to respond to an alert and take avoiding action.

To enable a comparison between GPWS and TAWS, Honeywell conducted a further computer simulation of the accident flight using an enhanced ground proximity warning system (EGPWS). This simulation found that TAWS would have provided a 'caution terrain' alert about 32 seconds before impact, and a 'terrain terrain' alert followed by repetitive 'pull up' warnings during the final 28 seconds before impact. If the accident aircraft had been fitted with TAWS, it is probable that this CFIT fatal accident would have been avoided.

The following timeline was adapted from the Lockhart River accident and provides a basic history of the Australian regulations pertaining to the fitment of GPWS/TAWS technology in turbine-powered aircraft conducting RPT and charter operations under IFR.

GPWS/TAWS timeline

Pre- November 1996	GPWS only required for aircraft with a MTOW above 15,000kg or authorised to carry more than 30 passengers.
November 1996	CASA issued a Discussion Paper to review the requirements of GPWS for aircraft with a MTOW over 5,700kg or authorised to carry more than nine passengers.
October 1998	CAO 20.18 amended to include requirements of GPWS in aircraft with a MTOW above 5,700kg or carrying more than nine passengers by *October 1999*.
Late 1990s	TAWS was being developed and would become available in mid 2000.
May 1999	Regional Airlines Association of Australia (RAAA) asked CASA to consider an exemption from fitting older GPWS to aircraft by October 1999 and undertake to fit TAWS by January 2001.
September 1999	CAO 20.18 amended to incorporate the *January 2001* deadline for TAWS.
October 1999	Operators undertaking to install TAWS by January 2001 and not install GPWS, were required to provide CFIT awareness training to pilots. This course had to be included in the operator's operations manual.
August 2000	RAAA advised CASA that some aircraft had not been issued with a FAA Supplemental Type Certificate (STC) for fitment of TAWS.
October 2000	CAO 20.18 amended requiring operators of aircraft affected by STC issue to fit GPWS in lieu of TAWS by 1 January 2001. This also included a requirement to fit TAWS by the end of *June 2005*.
December 2000	The requirement for CFIT awareness training no longer applies.
July 2005	Aircraft with a MTOW greater than 15,000kg or carrying more than 10 passengers must be fitted with TAWS. Aircraft with a MTOW of 5,700 kg or less, but is carrying 10 or more passengers must be fitted with TAWS-B[18].
March 2006	ATSB recommends that CASA review the requirements for TAWS in turbine-powered aircraft with a MTOW below 5,700kg against the international standards (ATSB Recommendation: R20060008).
July 2007	CASA informs ATSB they are investigating the cost of TAWS and that they will look at the applicability to the fleet and the safety benefits (R20060008).

18 TAWS-B+ system: TAWS that is equipped with a visual display and complies with the requirements for Class B equipment expressed in TSO-C151, TSO-C151a or TSO-C151b (Civil Aviation Order 20.18).

The benefits of TAWS were further highlighted on 24 July 2004 when a Boeing 737-838 aircraft, registered VH-VXF, received a terrain proximity caution from the EGPWS while on descent to the south-east of Canberra airport, Australian Capital Territory. The aircraft was being operated on an overnight scheduled passenger service from Perth, Western Australia to Canberra with 87 persons on board. When the aircraft was 10.9 NM south of Canberra, it proceeded beyond the limits of the Church Creek holding pattern. As a result, the crew manoeuvred the aircraft closer to terrain than intended and the flight crew received a 'Caution Terrain' message from EGPWS. The crew responded and climbed the aircraft to a higher altitude. The aircraft had passed 0.6 NM north abeam and 810 ft higher than the closest terrain. The investigation revealed a number of factors contributing to the incident, including pilot fatigue, the misinterpretation of instrument approach charts, incorrect data entry into the flight management computer, and the availability of ATC services. This incident illustrates the valuable contribution of TAWS to flight safety (ATSB, 2005).

5.9 The approach

Given that the approach phase of flight accounted for the greatest number of CFIT incidents, accidents, fatal accidents and fatalities recorded between 1995 and 2006, this area warrants further examination.

Typically, the approach to a runway for the intention of landing can be conducted by using two methods of navigation: the first relies on visual reference to the outside environment and the second relies on reference to the instrumentation within the cockpit.

Table 15 shows the number of CFIT accidents and incidents occurring in the approach phase of flight by the navigation method used. Of the 17 CFIT occurrences in the approach phase, 47 per cent were conducted using visual navigation (n = 8) while 53 per cent were using instrument navigation (n = 9).

Table 15: CFIT approach occurrences by approach type, 1996 to 2005

	Incident	Accidents		Fatalities
		Non-fatal	Fatal	
Visual	2	5	1	2
Instrument	0	2	7	31
Total	***2***	***7***	***8***	***33***

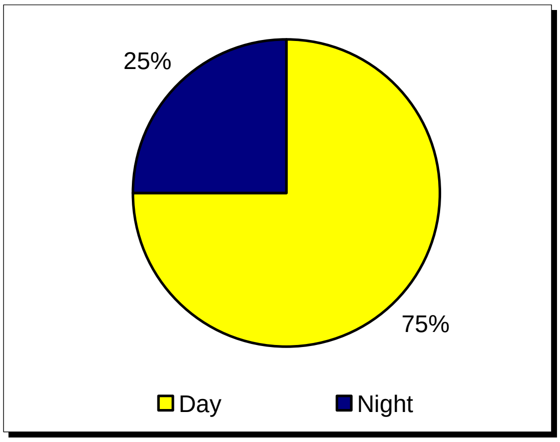
Visual approaches

When conducting a visual approach, the pilot must have sight of the runway at all times. The pilot estimates the approach glide path angle to the runway threshold based on visual reference to the runway and aerodrome, and if available, visual landing aids such as the T-visual approach slope indicator system and precision approach path indicator. However, at night there are fewer visual cues available for the pilot to navigate, and hence, the pilot relies on runway lighting and visual landing aids to determine the correct approach path for landing.

A pilot may become susceptible to visual illusions with a reduction in, or lack of visual cues at night, especially if the area under the aircraft during the approach is dark, either water or unilluminated terrain. These conditions are conducive to what is commonly referred to as the ‘black hole’ effect. When an approach is made over an area of darkness, pilots are given the impression that the altitude of the aircraft is higher than is actually the case. As a result, pilots will fly lower and consequently land short of the runway (Wiener & Nagel, 1988). Operating under these conditions is of particular concern if the pilot does not recognise the existence of this illusion.

Of the eight CFIT accidents and incidents occurring during a visual approach (Figure 12), 75 per cent were conducted during the day (n = 6) while 25 per cent were conducted at night (n = 2).

Figure 12: Proportion of visual approach CFIT occurrences by time of day, 1996 to 2005



Instrument approaches

In general, there are two categories of instrument approaches: precision and non-precision approaches.

A precision approach provides both lateral and vertical guidance to an aircraft approaching a runway. In Australia, the only precision approach operating is the instrument landing system (ILS), which is only available at airports served regularly by RPT services (37 ILS approaches are published in Australia). The ILS consists of two key components; the localiser, which provides lateral guidance, and the glideslope, which provides vertical guidance. The signals from these components are displayed to the pilot pictorially and show if the aircraft is above or below the desired glidepath and/or to the left or right of the extended runway centreline. To date, there have been no CFIT occurrences recorded in Australia where an aircraft was conducting a precision approach.

The non-precision approach differs from a precision approach in that it provides lateral guidance only. This means that the descent path and altitudes need to be calculated by the pilot based on information contained in approach charts and/or that obtained from instrument approach aids (eg DME[19] information).

19 DME: Distance measuring equipment.

The task of interpreting the aircraft's position relative to the surrounding terrain has changed from a perceptual task (matching the approach path with the aircraft's position) to a cognitive task, where the pilot is required to calculate the aircraft's vertical position.

Given that the primary cause of CFIT is a loss of situational awareness, in particular, a loss of vertical situational awareness, this is an especially relevant risk factor for CFIT. Research conducted for the Netherlands Directorate-General of Civil Aviation, under the auspices of the Flight Safety Foundation, identified a five-fold increase in accident risk in commercial aircraft flying a non-precision approach compared with a precision approach (Enders J. H., Dodd R., Tarrel R., Khatwa R., Roelen A. L. C., & Karwal A. K., 1996).

Non-precision approaches (NPAs), as defined in Civil Aviation Advisory Publication 178-1(1) *"are designed as a series of decreasing minimum altitudes to a minimum descent altitude (MDA). A fix is located at each point at which critical obstacles have been passed by an adequate margin, and it is safe to continue descent to the next safe altitude"*. These approaches may use a number of terrestrial-based navigation aids (NDB, very high frequency omni-directional radio range (VOR), distance measuring equipment (DME))[20] or satellite-based navigation aids such as area navigation global navigation satellite system (RNAV (GNSS)).

An NPA is designed to permit a safe descent to the MDA, by which any further descent must not be commenced unless the pilot has established visual contact with the runway. If the NPA is aligned with the runway, once visual at or above the MDA, the pilot can continue the descent and land 'straight-in' (straight-in approach). If the NPA is not suitably aligned with the runway, the approach is terminated at a 'circling' MDA (circling approach), from which point the pilot manoeuvres the aircraft into position for landing (CASA, 2004). This manoeuvring may involve one or several turns to align the aircraft with the runway. Each circling approach differs according to factors such as the alignment of the instrument approach and runway, the surrounding terrain, and the weather at the airport. Studies into CFIT have identified the straight-in approach to be 25 times safer than a circling approach (McColl & Warland-Browne, 2001).

The Bureau of Air Safety Investigation (now the ATSB) final report into the fatal CFIT accident of a Piper PA31-350 Navajo Chieftain aircraft, VH-NDU, on 11 June 1993 at Young aerodrome, New South Wales made a recommendation (R940182) to the Civil Aviation Authority to (BASI, 1994):

> "…implement as a matter of urgency the ICAO PANS-OPS requirement for an instrument approach procedure which provides for a straight-in approach aligned with the runway centreline at all possible locations."

Since this time, the number of circling approaches in Australia has declined with the re-publishing of many NDB and VOR approaches to runway-aligned approaches and the introduction of the RNAV (GNSS) approach, which is also runway-aligned (Mallett, 2006).

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20 For a description of these types of non-precisions approaches, refer to ATSB Research Report: B2005/0342 "Perceived Pilot Workload and Perceived Safety of RNAV (GNSS) Approaches".

The benefits of a straight-in approach were further highlighted in an ATSB study on *Perceived Pilot Workload and Perceived Safety of RNAV (GNSS) Approaches*, where 30 per cent of respondents indicated that the runway alignment of the RNAV (GNSS) approach was perceived as a positive contribution towards safety (Godley, 2006).

Traditionally, NPAs were flown using the 'dive and drive' method. Referred to as the step-down approach, these were flown as a series of descending steps conforming to the minimum altitudes published on the approach chart. This technique resulted in an unstabilised approach characterised by continual changes in power settings and pitch attitudes. This not only increased pilot workload, but also required an increased awareness of the aircraft's position relative to the ground. Many CFIT accidents have been attributed to the step-down approach, with pilots descending prior to a step is reached or failing to arrest the descent (CASA, 2004). Between 1984 and 1997, the Flight Safety Foundation Approach-and-Landing Accident Reduction Task Force determined that CFIT was involved in 37 per cent of approach-and-landing accidents and incidents worldwide. Of these, 57 per cent occurred during a step-down NPA (Flight Safety Foundation, 2000).

The traditional 'dive and drive' method may have been acceptable for early piston commercial aircraft. However, larger more modern aircraft are much faster, heavier and less manoeuvrable, and subject to greater inertia. The need for a stabilised NPA became more apparent, which saw the step-down approach replaced by the constant-descent angle (CDA) approach. In order to achieve a constant rate of descent, the CDA approach is typically flown at flight path angle of approximately 3-degrees. The aircraft's speed, power setting and attitude remain stable, thus reducing pilot workload. While the CDA provides for a stabilised approach and has contributed to the reduction of CFIT accidents and incidents, on its own it has not eliminated the risk of CFIT during the approach and landing phases of flight.

The CFIT occurrences during a NPA have been attributed to a range of causes, some of which include the aircraft being operated in IMC below the approved MDA, pilots not complying with the requirements of the published instrument approach procedures, an inadvertent descent below the MDA, the misinterpretation of approach charts, and in some cases, pilots adopting their own approach procedure.

These issues were highlighted in the *Regional Airline Safety Study*, which investigated the level of safety in the regional airline industry (BASI, 1999). Overall, the findings of the report indicated that in 1996/97, the safety health of the regional airline industry was good. However, when examining aspects relating to non-compliance with instrument flight rules, a small number of respondents indicated that they had descended below safety altitudes. These deviations included:

- descending below the steps during a DME or global positioning system (GPS) arrival while in IMC;
- descending to the circuit altitude at night outside the instrument approach circling area; and
- descending below the instrument approach MDA while in IMC.

While the number of deviations revealed from the study was small, any descent below the safety altitude, in conditions under which terrain clearance cannot be assured, increases the risk of CFIT, and hence represents a significant safety issue.

Table 16 shows the number of CFIT instrument approach occurrences by the type of navigational aid used and operation type. The highest number of accidents and incidents involved RNAV (GNSS) approaches, accounting for 44 per cent (n =4). This was followed by the NDB, which accounted for 33 per cent (n =3) and the GPS arrival, which accounted for 22 per cent (n = 2). All operation types recorded one occurrence involved in an RNAV (GNSS) approach[21]. Private/business operations recorded two CFIT occurrences involved an NDB approach while charter operations recorded one. Charter and other aerial work recorded one occurrence each with a GPS arrival.

Table 16: CFIT instrument approach occurrences by operation type, 1996 to 2005

	GPS arrival	RNAV (GNSS)	NDB	***Total***
Regular public transport				
LCRPT	0	1	0	***1***
General aviation				
Charter	1	1[22]	1	***3***
Other aerial work	1	1	0	***2***
Private/business	0	1	2	***3***
Total	***2***	***4***	***3***	***9***

The number of RNAV (GNSS) CFIT occurrences may reflect the rapid growth in the number of published RNAV (GNSS) approaches, and widespread acceptance across all sectors of aviation as GPS units become increasingly affordable. In Australia, the first GPS NPA began in 1998 at Goulburn Airport, near Canberra. By 2006, this had expanded to around 260 airports in Australia, providing more than 400 RNAV (GNSS) approaches. Formally known as a GPS NPA, an RNAV (GNSS) approach provides pilots with lateral guidance based on latitude and longitude positions called waypoints. These waypoints are pre-programmed into a GPS receiver or flight management system (FMS). Throughout the approach, the GPS/FMS displays each leg as a track, and the distance to the next waypoint in the approach sequence. Based on this information, and the altitudes published in the approach chart, the pilot must determine what altitude to descend to. Like other NPAs, the RNAV (GNSS) approach does not provide glideslope information.

A survey conducted by the ATSB sought to gain an understanding of pilot experiences and perceptions of RNAV (GNSS) approaches in Australia (Godley, 2006). The report found:

- RNAV (GNSS) approaches were perceived to be safer than that of a NDB approach, equivalent to a visual approach at night. However, it was perceived to be less safe than the other approaches examined in the survey including VOR/DME, DME arrival, and ILS.

21 RNAV (GNSS) only became available in the late 1990s, part way through the period studied here, yet account for nearly half of CFIT occurrences during an instrument approach.

22 The ATSB investigation found that the pilot had informed ATC of his intentions to fly the RNAV (GNSS) approach but in fact did not fly the published approach procedure (ATSB, 2006b). It could be argued that this occurrence be excluded from the RNAV (GNSS) approach category in this table.

- For Category A (single engine and smaller twin-engine aircraft) and Category B aircraft (larger twin-engine propeller aircraft), RNAV (GNSS) approaches were more difficult than the other approaches, with the exception of the NDB. Conversely, the workload of RNAV (GNSS) approaches for pilots of Category C aircraft (predominately high capacity jet airline aircraft) was perceived to be lower compared with the other approaches.
- The average number of instances involving the loss of situational awareness on RNAV (GNSS) approaches for Category A and B aircraft pilots was higher than for all other approaches, with the exception of the NDB. This was not the case for pilots of Category C aircraft, where no difference for situational awareness was found between each of the NPA types.
- For pilots of Category C aircraft, the loss of situational awareness experience on an RNAV (GNSS) approach was similar to that of the other approach types, with the exception of the ILS.

The study also identified a number of issues relating to the unique design of an RNAV (GNSS) approach, in that distances are referenced to waypoints rather than the runway or the missed approach point (MAPt). This aspect was cited as the most common reason for increasing mental workload as pilots require additional thinking time to undertake mental calculations in order to maintain situational awareness. Furthermore, 14 per cent of respondents identified that a lack of distance information to the MAPt lowered the perceived safety of the approach, while 12 per cent cited not being able to ensure situational awareness as a factor.

As a result of studies into CFIT accidents during the approach phase of flight, ICAO has introduced a third type of approach called an approach with vertical guidance (APV). This type of approach differs from a NPA in that it provides both lateral and vertical guidance. While this type of approach is not classified as a precision approach, it provides pilots with constant vertical descent guidance, similar to that provided by an ILS. An APV can be provided by two methods. The first is barometric vertical navigation, where the FMS generates a continuous descent path using information from a barometric altimeter, and the second is geometric vertical guidance provided by an augmented satellite-based signal (IATA, 2006). The latter method can use either aircraft based augmentation systems (ABAS), satellite based augmentation systems (SBAS), ground based augmentation systems (GBAS), or ground based regional augmentation system (GRAS) to enhance the accuracy, integrity, availability and continuity of service of the underlying satellite navigation system of GNSS.

Ground based augmentation systems have been trialled in Australia. In November 2006, a Qantas aircraft landed on Sydney airport’s runway 16 Left using GBAS to conduct an approach (AOPA, 2007a).

Of the nine CFIT instrument approach occurrences, 67 per cent (n = 6) involved a satellite-based instrument approach. This included four RNAV (GNSS) approaches, which only became widely available in Australia part way through the 1996 to 2005 reporting period. The prevalence of satellite-based approaches may reflect the growing popularity of these types of approaches and a shift away from the traditional terrestrial-based navigation aids. From this, it appears that there is scope to reduce CFIT further by developing and implementing APV, which can provide vertical guidance on approaches previously only capable of providing lateral guidance. This capability can assist pilots with maintaining vertical and lateral situational awareness and hence, reduce the risk of CFIT.

In light of the benefits associated with APV, CASA issued applications for tender in January 2007 to review existing and emerging technological solutions for GNSS APV and to conduct a cost-based analysis. The aim of the study is to assist CASA in determining the most viable option for GNSS augmentation technology or technologies to support APV operational requirements for the future (CASA, 2007a). In July 2007, CASA announced that a consultant, Booz Allen Hamilton, had been selected to complete the study. The study is expected to take approximately six months to complete, with the findings presented to the aviation industry and the Aviation Policy Group[23] (CASA, 2007b).

23 The Aviation Policy Group is a Government advisory group formed to establish a better working relationship across the four agencies responsible for airspace policy, regulation, and service provision. The Group consists of representatives from CASA, Airservices Australia, the Department of Transport and Regional Services, and the Department of Defence.

6 CONCLUSION

Controlled flight into terrain accidents have been labelled as one of ‘aviation’s historic killers’. The international aviation community’s response to controlled flight into terrain (CFIT) has focused on preventative strategies such as educational packages, the comprehensive research and analysis of CFIT accidents, and the development and enhancement of terrain awareness technologies. However, despite these efforts CFIT remains a challenge.

The purpose of this report was to provide an overview of CFIT from an international perspective and to examine, in detail, CFIT in the Australian context. The analysis focused on a 10-year period from 1996 to 2005 and specifically examined those CFIT occurrences where the pilot’s flight planned path should have meant that the aircraft would avoid terrain, obstacles and water.

The efforts of the international aviation community have largely focused on the air transport sector. This is entirely understandable given the high number of fatalities associated with one CFIT accident involving a large passenger aircraft. However, CFIT occurs in all sectors of the aviation industry. In Australia, the majority of CFIT occurrences involve general aviation operations. Scheduled passenger operations recorded only one accident during the reporting period. This one accident resulted in 15 fatalities, thus highlighting the catastrophic nature one CFIT accident involving passenger operations can have.

During the last decade, Australia has seen the emergence of satellite-based approaches, such as the area navigation global navigation satellite system (RNAV (GNSS)) in place of the traditional terrestrial-based navigation aids such as the non-directional radio beacon and very high frequency omni-directional radio range. Nearly half of Australia’s CFITs during an instrument approach involved RNAV (GNSS). This type of approach offers considerable benefits in terms of accurate tracking, but without augmentation, it lacks the capacity to provide vertical guidance. Currently, Australia is examining the options available for the provision of RNAV (GNSS) approaches with vertical guidance.

Satellite-based technology has also provided an alternative means to Australia’s existing, yet ageing, air traffic management infrastructure by way of automatic dependent surveillance broadcast (ADS-B) and GNSS. These systems together can provide a more accurate means of navigation and increase situational awareness for pilots when coupled with cockpit terrain displays.

The availability of RNAV (GNSS) approaches and ADS-B are important developments, which once implemented, may further reduce the risk of CFIT.

The results of this study also challenge some of the underlying assumptions often made about CFIT. That is, this report shows that these types of accidents and incidents can occur in conditions of clear visibility and in areas with no significant terrain features.

In general, when compared with the total number of accidents recorded in the Australian Transport Safety Bureau’s aviation safety database for the 10-year period, CFIT in Australia is a rare event. However, should a CFIT occur, there is a high risk that it will result in fatal injuries to the aircraft occupants. A continued focus on developing preventative strategies is therefore warranted in an effort to reduce the risk of CFIT further.

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8 APPENDICES

8.1 Appendix A: Definition of an accident and incident

The definition of an aircraft accident, as used in this report, has been developed by the International Civil Aviation Organization (ICAO) and adopted by its member States. The definition is provided in Annex 13 to the Convention on International Civil Aviation (ICAO, 2001):

> **Accident -** an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which:
>
> a) a person is fatally or seriously injured as a result of:
>
> – being in the aircraft, or
>
> – direct contact with any part of the aircraft, including parts which have become detached from the aircraft, or
>
> – direct exposure to jet blast,
>
> except when the injuries are from natural causes, self-inflicted or inflicted by other persons, or when the injuries are to stowaways hiding outside the areas normally available to the passengers and crew; or
>
> b) the aircraft sustains damage or structural failure which:
>
> – adversely affects the structural strength, performance or flight characteristics of the aircraft, and
>
> – would normally require major repair or replacement of the affected component,
>
> except for engine failure or damage, when the damage is limited to the engine, its cowlings or accessories; or for damage limited to propellers, wing tips, antennas, tires, brakes, fairings, small dents or puncture holes in the aircraft skin; or
>
> c) the aircraft is missing or is completely inaccessible.
>
> *Note 1. For statistical uniformity only an injury resulting in death within thirty days of the date of the accident is classified as a fatal injury by ICAO.*
>
> *Note 2. An aircraft is considered to be missing when the official search has been terminated and the wreckage has not been located.*

The ICAO definition for an aircraft accident has been adopted by Australia and has been incorporated into ATSB investigative and data analysis processes. In this report, accidents involving a fatal injury are referred to as 'fatal accidents'.

8.2 Appendix B: Categorisation of the Australian aviation industry

The main statistical groups used in this report include:

Regular public transport[24]

Regular public transport operations refer to commercial operations used for the purpose of transporting persons generally, or transporting cargo for persons generally. These operations are conducted for hire or reward in accordance with fixed schedules to and from fixed terminals over specific routes with or without intermediate stopping places between terminals.

- ***High capacity RPT*** [25]

Regular public transport operations conducted in high capacity aircraft. A high capacity aircraft refers to an aircraft that is certified as having a maximum capacity exceeding 38 seats or a maximum payload exceeding 4,200 kg.

- ***Low capacity RPT***[26]

Regular public transport operations conducted in aircraft other than high capacity aircraft. That is, aircraft with a maximum capacity of 38 seats or less, or a maximum payload of 4,200 kg or below. The ATSB refers to these aircraft as low capacity aircraft.

General aviation

'General aviation' is defined as all non-scheduled civil flying activity other than RPT and sport aviation operations.

- ***Charter operations***

Charter operations involve the carriage of cargo and/or passengers on non-scheduled operations by the aircraft operator, or the operators' employees, in trade or commerce, excluding regular public transport operations.

- ***Aerial work***[27]

Aerial work operations comprise agricultural operations, flying training and other aerial work.

a. **Agricultural operations -** operations involving the carriage and/or spreading of chemicals, seed, fertilizer or other substances for agricultural purposes. It includes operations for the purpose of pest and disease control. Agricultural operations are a component of aerial work, but are usually separated for analysis purposes.

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24 CAR 206 (1) (c) and CAR 2 (7) (c).

25 Civil Aviation Orders Section 82.0.

26 Civil Aviation Orders Section 82.0.

27 Due to the large proportion of aerial work operations associated with agricultural operations and flying training, these groups are separated for analysis. The remaining aerial work operations are referred to as 'other aerial work'.

b. **Flying training -** flying under instruction for the issue or renewal of a licence, rating, aircraft type endorsement or conversion training, including solo navigation exercises conducted as part of a course of applied flying training. Flying training is a component of aerial work, but is usually separated for analysis purposes.

c. **Other aerial work -** includes operations conducted for the purposes of aerial work other than 'flying training' and 'agricultural operations'. Operations classified as other aerial work include aerial operations involving surveying and photography, spotting, ambulance, stock mustering, search and rescue, towing (including glider, target and banner towing), advertising, cloud seeding, fire fighting, and coastal surveillance.

- ***Private and business***

Flying conducted for non-commercial purposes.

a. Private flying refers to flying for recreation or personal transport.

b. Business flying is a component of private operations where an aircraft is used in the support of a business or profession but the aircraft is not operated directly for hire or reward.

Sport aviation

Sport aviation refers to operations by hang gliders, balloons, autogyros, gliders/sailplanes, ultralights and airships. Sport aviation aircraft have been excluded from this report.

Military aviation

Military operations are generally overseen by military safety authorities.

8.3 Appendix C: Report dataset

Number	Date	Manufacturer	Model	Operation type	Phase of flight	Visibility	CFIT type
199600012	3/01/1996	Piper Aircraft Corp	PA-32RT-300	Private/business	Initial climb	Clear visibility	Terrain
199600399	08/02/1996	Piper Aircraft Corp	PA-31-350	Charter	Approach	Reduced visibility	Terrain
199602526	11/08/1996	Mooney Aircraft Corp	M20E	Private/business	Approach	Reduced visibility	Terrain
199700822	16/03/1997	Piper Aircraft Corp	PA-38-112	Private/business	Approach	Clear visibility	Obstacle
199701900	13/07/1997	Piper Aircraft Corp	PA-28R-201T	Private/business	Approach	Reduced visibility	Terrain
199702473	02/08/1997	Piper Aircraft Corp	PA-23-250	Private/business	Manoeuvring	Clear visibility	Terrain
199800418	09/02/1998	Bell Helicopter Co	206B (II)	Other aerial work	Approach	Clear visibility	Obstacle
199801298	10/04/1998	Bell Helicopter Co	206B (III)	Charter	Climb	Reduced visibility	Water
199801517	03/05/1998	American Aircraft Corp	AA-5A	Private/business	Enroute	Reduced visibility	Terrain
199802757	20/07/1998	Partenavia Costruzioni Aeronautiche SPA	P.68B	Charter	Approach	Reduced visibility	Terrain
199803049	07/08/1998	Grumman American Aviation Corp	GA-7	Charter	Approach	Reduced visibility	Terrain
199803297	18/08/1998	Bell Helicopter Co	206B (II)	Private/business	Enroute	Clear visibility	Terrain
199901009	12/03/1999	Bell Helicopter Co	206L-3	Charter	Enroute	Reduced visibility	Water

Number	Date	Manufacturer	Model	Operation type	Phase of flight	Visibility	CFIT type
200000622	21/02/2000	Hughes Helicopters	369E	Charter	Approach	Clear visibility	Water
200002134	15/05/2000	Cessna Aircraft Company	172H	Private/business	Approach	Clear visibility	Obstacle
200004369	27/09/2000	Hughes Helicopters	269C	Private/business	Enroute	Clear visibility	Terrain
200101537	10/04/2001	Aero Commander Div	500-S	Charter	Enroute	Unknown	Terrain
200102061	06/05/2001	Beech Aircraft Corp	76	Private/business	Approach	Reduced visibility	Terrain
200102083	27/04/2001	Bell Helicopter Co	407	Other aerial work	Manoeuvring	Reduced visibility	Water
200105769	10/12/2001	Beech Aircraft Corp	B200C	Other aerial work	Approach	Reduced visibility	Terrain
200302172	15/05/2003	Raytheon Aircraft Co	Beech Super King Air B200C	Other aerial work	Approach	Reduced visibility	Water
200402797	28/07/2004	Piper Aircraft Corp	PA-31T	Private/business	Approach	Reduced visibility	Terrain
200402845	23/07/2004	Robinson Helicopter Co	R22 BETA	Private/business	Approach	Reduced visibility	Terrain
200501977	07/05/2005	Fairchild Industries Inc	SA227-DC	LCRPT	Approach	Reduced visibility	Terrain
200503265	08/07/2005	Piper Aircraft Corp	PA-31-350	Charter	Approach	Reduced visibility	Terrain
200504733	16/09/2005	Robinson Helicopter Co	R44	Private/business	Initial climb	Clear visibility	Obstacle
200504999	01/10/2005	Cessna Aircraft Company	R172K	Private/business	Approach	Clear visibility	Obstacle

CFIT: Australia in context 1996 - 2005