GENERAL AVIATION AND CONTROLLED FLIGHT INTO TERRAIN ACCIDENTS

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ABSTRACT

This paper describes characteristics of general aviation (GA) accidents and identifies factors related to the occurrence of a subset of GA accidents attributed to controlled flight into terrain (CFIT). Using NTSB data from the 31,790 aviation accidents that occurred between 1983 and 1994, inclusive, this research identified GA accidents that could be attributed to CFIT. Statistical analyses identified characteristics of GA CFIT accidents that may be useful for the design or modification of terrain-alerting equipment. Approximately one third of the GA accidents in instrument conditions are related to CFIT. Weather condition and pilot age were also strong predictors of the occurrence of CFIT accidents.

BACKGROUND

The largest proportion of aviation accidents and fatalities occur in GA operations. The need to reduce aviation-related fatalities has received national attention recently. At the "Safer Skies - A Focused Agenda" meeting in April 1998, Vice President Al Gore, Transportation Secretary Rodney Slater, and FAA Administrator Jane Garvey announced a national goal to reduce fatal aviation accidents by 80 percent over the next ten years.

With this national focus on improving aviation safety, it is essential to reduce the accidents and incidents in GA. It is necessary to substantially decrease GA accidents to achieve an 80% reduction in fatal aviation accidents. For example, in 1994 there were 987 fatalities in aviation; GA accidents resulted in 723 fatalities, air carrier accidents had 239 fatalities and commuter airline accidents, 25 fatalities. (U.S. Bureau of the Census, 1997)

The air carriers have recognized that CFIT was a substantial cause of incidents in the past and they have taken measures to reduce CFIT in their operations. The U.S. air carrier fleet began to introduce Terrain Avoidance Warning Systems (TAWS) technology after the 1974 TWA crash at Washington Dulles International Airport. There is evidence that TAWS helps to reorient pilots who have lost situational awareness.(Khatwa and Roelen, 1996). This equipment has contributed to a reduction in CFIT-type accidents for commercial flights.

Phillips (1996) suggests that GA aircraft might also experience a reduced incidence of CFIT due to the benefits of TAWS systems. However, TAWS installations and system upgrades are expensive items for GA operators whose aircraft may lack radar altimeters and integrated caution and warning systems.

The 1998 Nall Report describes the incidence and type of accidents and injuries in general aviation. "The fatal accident rate remains stubbornly close to level, and the leading causal factors are the same this year as they were in the year before and the year before that. Fatal accidents occurred frequently in maneuvering flight and in poor weather." (AOPA, 1998, p.2)

Currently, there is no source that identifies how many and what kinds of GA accidents can be attributed to CFIT. This research analyzed a database of aviation GA accidents that could be attributed to CFIT.

Examining the subset of GA accidents, it is possible to recognize common patterns in CFIT accidents that may be useful for the design or modification of terrain-alerting equipment.

IDENTIFICATION OF CONTROLLED FLIGHT INTO TERRAIN ACCIDENTS

This research developed a working definition of CFIT: *A CFIT accident is any collision with terrain (or water) in which the pilot was in control of the aircraft but was not aware of the airplane's altitude, the terrain elevation, or the airplane's position in terms of latitude or longitude.* Critical to this definition is that the pilot *is in control of the aircraft* at the time of the accident. The working definition builds on Wiener's (1977) definition of CFIT as, "...those [accidents] in which an aircraft, under the control of the crew, is flown into the terrain (or water) with no prior awareness on the part of the crew of the impending disaster."

The working definition suggests areas for remediation. CFIT accidents could be prevented if the factors that contribute to a loss of positional awareness were understood, if training and/or equipment were provided to heighten position awareness in high-risk situations, and if there were better terrain alerting systems for GA aircraft.

Accidents data was extracted from the National Transportation Safety Board's (NTSB's) database of the aviation accidents which occurred between 1983 and 1994, inclusive. The GA accidents in the NTSB database are coded as "Regulation Flight Conducted Under" code on the NTSB Report Form. GA accidents were defined as "14 CFR 91 (only)." The GA subset of the NTSB database of aviation accidents represented 84% of the aviation accidents in the 1983-1994 NTSB database.

It was necessary to identify which accidents in the NTSB database could be attributed to CFIT. To classify accidents as CFIT, we carried out a multi-step process to sort all the aviation accidents between 1983 and 1994, inclusive, using data from the NTSB's Factual Reports. Because CFIT is not explicitly coded, the strategy was to exclude accidents that could be attributed to other causes. We defined a lexicon of terms for accident causes and aviation activities to filter the accidents. The filters were initially applied using machine searches on keywords. The last step was to read and assess each accident report.

Non-CFIT accidents occurred due to the following causes: pilot loss of control due to mechanical problems or pilot error, intentionally dangerous flying (aerobatics, crop dusting), crashes in the runway environment, extreme weather affecting flight, in-flight breakup, engine failure, pilot physical impairment, and suicide. To further reduce the pool of aviation accidents and eliminate the accidents not attributable to CFIT, we queried the accident reports using keywords in the accident descriptions. The following keywords eliminated more accidents from the remaining potential pool of CFIT accidents. These keywords used included: physical impairment, midair collisions, aerobatics, buzzing, suicide, incapacitation, standing, taxi, fuel exhaustion, fuel starvation, aircraft control not maintained, total loss of engine power, loss of control, alcohol, impairment, drug use, and aerial application.

It was not possible to identify all the non-CFIT accidents using keyword searches. For the remaining accidents, we read the narrative, causes, and sequence of events sections for each accident and hand-rated each accident. The accident was due to causes other than CFIT if it met one of these criteria: crashes in the runway environment, extreme weather affecting performance, in-flight breakup, intentional aerobatics, intentional buzzing or flying close to the ground, total power loss, pilot loss of control, possible CFIT but evidence for other causes, none of the above but pilot aware of location/terrain.

The remaining accidents were classified as occurring due to CFIT. Using this sequence of eliminating accidents due to causes other than CFIT, the GA accidents attributable to CFIT totaled 1,260 or 4.8% of the GA database of 26,533 accidents. The custom data set created for this study includes accident data for airplanes or helicopters only because the definition of CFIT does not apply to other aircraft (e.g., ultralights, and blimps).

ANALYSIS

General aviation accidents

Aviation accidents were subdivided into GA accidents and non-GA accidents. The classifications of GA and non-GA accidents each have subsets classified as CFIT and non-CFIT accidents. Using these custom-built data sets, accidents attributed to CFIT account for slightly less than 5% of all aviation and general aviation accidents. (Table 1) Despite a steady decline in the incidence of aviation accidents, the proportion attributed to CFIT remains steady at slightly less than 5% of all aviation accidents and of general aviation accidents.

Table 1. All Aviation Accidents and General Aviation Accidents 1983-1994

Year	All Aviation Accidents		GA Accidents	
	All	%CFIT	All	%CFIT
1994	2,181	3.6	1,813	3.8
1993	2,246	5.6	1,883	5.8
1992	2,278	5.7	1,918	5.6
1991	2,386	5.7	1,992	6.1
1990	2,435	5.6	2,026	5.7
1989	2,482	5.1	2,059	5.2
1988	2,636	3.8	2,185	4.1
1987	2,744	3.7	2,291	4.0
1986	2,776	4.1	2,335	4.2
1985	3,005	4.0	2,534	4.2
1984	3,287	3.7	2,732	4.1
1983	3,333	4.3	2,765	4.8
Total	31,789	4.5	26,533	4.8

Table 2 shows that, between 1983 through 1994, the largest number of GA accidents occurred in California. This incidence reflects exposure and risk. California is first in the number of active pilots and second in the number of landing facilities. Alaska is fourth in GA accidents due to all causes but second in the incidence of GA accidents due to CFIT nationally. The aviation risks in Alaska are evident.

The relative risk of CFIT varies by state. GA accidents attributed to CFIT cluster in certain areas. These clusters arise because some places have conditions that are more conducive to CFIT accidents. Disaggregating by state, Table 2 shows where CFIT accidents are, on a relative basis, more likely to occur.

Table 2. Rank Order, GA and CFIT Accidents for U.S. and by State

Rank	GA accidents 1983-1994	%GA accidents CFIT-US	%GA accidents CFIT/state
1	CA (3,199)	CA	WV
2	FL (1,875)	AK	ID
3	TX (1,756)	WA	SD
4	AK (1,753)	CO,TX	VT
5	CO (789)	NY	UT
6	WA (788)	GA	TN
7	AZ (774)	FL	VI
8	MI (759)	ID,PA	VA
9	IL (710)	VA	CA
10	OH (677)	UT	WA

Table 3 shows the incidence of GA and non-GA accidents, accidents attributed to CFIT in GA and in non-GA, and incidence of the fatal accidents and fatalities associated with these subsets of aviation accidents. Proportionally more GA accidents are attributed to CFIT, 4.8%, than non-GA accidents, 3.4%. CFIT accidents have more fatalities in GA and non-GA operations. Approximately one sixth of the fatal GA and non-GA accidents are related to CFIT. There was an average of 1.4 fatalities for GA accidents attributed to CFIT and 2.2 fatalities for CFIT accidents in non-GA operations.

Table 3. Aviation Accidents and Fatalities; CFIT Accidents and Fatalities

Accidents	GA	CFIT/ GA	Non-GA	CFIT/ Non-GA
1983-1994	26,533	4.8%	5,042	3.4%
Per Year	2,211	105	420	14
Fatal accidents/ Year	443	72 (16%)	58	10 (17%)
Fatalities/ Accident	.39	1.4	.74	2.2

Visual conditions, pilot and aircraft characteristics

Table 4 shows that approximately one third, 32%, of the GA accidents in IMC conditions are due to CFIT as compared to one fifth, 21%, of the non-GA accidents. CFIT is a disproportionately greater risk in GA operations in IMC. Impaired visual conditions, i.e., IMC, overcast, and dark night were present in 69% of the CFIT accidents in GA as compared to 49% of the CFIT accidents in non-GA.

Table 4. GA, Non-GA, and CFIT Accidents and by Visual Conditions, 1983-1994

Visual Conditions	GA	CFIT/ GA (%)	Non-GA	CFIT/ Non-GA(%)
VMC	24,053	2	4,468	1
IMC	2,142	32	500	21

Dawn	240	7	136	5
Daylight	20,239	2	3,905	2
Overcast	709	18	133	17
Dusk	979	6	146	1.2
Bright night	425	8	104	4
Dark night	2,524	19	663	11

Table 5 shows that, when GA IFR-rated pilots had accidents in IMC conditions, almost one third of these accidents, 30%, can be attributed to CFIT. When VFR-rated pilots fly into IMC conditions inadvertently, 35% of their accidents are due to CFIT. One fifth of the non-GA accidents attributed to CFIT occur when IFR rated pilots operate in IMC conditions.

Table 5. GA and CFIT Accidents by Pilot and Aircraft Characteristics, 1983-1994

Pilot/ Aircraft Characteristics	GA	CFIT/ GA (%)	Non-GA	CFIT/ Non-GA (%)
Pilot age >50	8,026	5.4	1,055	3
Pilot age <50	18,507	4.5	3,987	3
Male pilot	25,180	4.9	4,874	3
Female pilot	984	2.7	69	4
Flight hours, 25th Percentile+	4,454	5.5	3,193	3
Flight hours,75th Percentile or lower	7,289	3.7	12	0
VFR rating	14,628	3.9	1,294	1
VFR rating in VMC	13,759	2	1,270	1
VFR rating in IMC	869	35	18	17
IFR rating	11,103	5.6	3,623	4.4
IFR rating in VMC	9.850	2.5	3,099	1.4
IFR rating in IMC	1,253	30	472	21
Single engine	23,559	4.4	3,140	3
Multi-engine	2,803	8	1,853	4.3

Relationships between visual conditions, pilot and aircraft characteristics and aviation accidents

Tests of significance (chi-square) measured the association between visual condition, pilot and aircraft characteristics, and whether an accident was related to CFIT or other causes. Three sets of aviation accidents were tested, i.e., all accidents, general aviation accidents and non-GA accidents. The following independent variables had statistically significant relationships for all three sets of aviation accidents. Accidents at night were more likely to be CFIT ($p<.001$) than accidents occurring during the daytime. For all aviation and for general aviation, accidents on dark nights were more likely to be CFIT than accidents on bright nights ($p < 0.001$); for non-GA aviation accidents, ($p = 0.048$). Accidents in cloudy conditions were more likely to be CFIT than accidents in clear or thin overcast ($p<0.001$). All aviation and general aviation accidents in IMC were more likely to be related to CFIT than those occurring in VMC ($p= 0.000$); for non-GA accidents, ($p< 0.001$). Nighttime and dark nights are associated with CFIT in all aspects of aviation. CFIT is also more likely to happen in all aviation operations when meteorological conditions impair visibility due to cloud cover and IMC.

In the three sets of accidents, accidents with IFR rated pilots were more likely to be classified as CFIT than accidents with VFR rated pilots ($p< 0.001$). In all aviation and general aviation accidents, multiple engine aircraft were more likely to be involved in CFIT than single engine aircraft ($p<0.001$); for non-GA accidents, ($p = 0.004$). In all aviation, and GA accidents, pilots with less flight time were more likely to have had an accident classified as CFIT. This relationship suggests that more skilled pilots and more complex airplanes are more likely to continue to operate in more difficult conditions.

In general aviation, when the pilot was over age 50, accidents were more likely to be attributed to CFIT than in accidents with younger pilots ($p = 0.001$). In general aviation, accidents with pilots with fewer flight hours were more likely to be attributed to CFIT than accidents with pilots with more hours ($p<0.001$). General aviation accidents with male pilots were more likely to be classified as CFIT than accidents with female pilots ($p = 0.002$). Accidents in IMC with VFR pilots were more likely to be CFIT than accidents in IMC with IFR pilots ($p = 0.021$).

The significant relationships were analyzed to assess the relative contribution of each of the variables measuring visual conditions, pilot, or aircraft characteristics to the likelihood of an accident being attributed to CFIT. The logistic regressions examined how the variables significantly related to the incidence of CFIT accidents, e.g., pilot age, sex, total flying time, rating, and weather condition, contributed to CFIT. Weather conditions (IMC and VMC) and pilot age were the strongest predictors of the occurrence of CFIT accidents.

Logistic regressions unraveled factors contributing to the relationship between accidents attributed to CFIT and older pilots. Pilot age was only significant for IFR-rated pilots in GA accidents. Pilot age is statistically associated with the occurrence of CFIT only when the pilot has an IFR rating.

Logistic regressions were performed for IFR and VFR pilots to see how the variables of age and visual conditions were related to CFIT. In GA accidents, visual conditions were significantly associated with the occurrence of CFIT accidents for both IFR and VFR pilots.

In summary, analyses of this NTSB database provide insight into factors related to GA accidents attributable to CFIT. These analyses show that 4.8% of GA accidents are related to CFIT. GA accidents attributable to CFIT result in 1.4 fatalities per accident, compared with 0.33 fatalities for all GA accidents. Accidents attributed to CFIT account for 17% of the fatalities in GA. Instrument conditions and older pilots contribute to CFIT accidents in GA. Approximately one-third (32%) of the GA accidents in instrument conditions are related to CFIT.

RESULTS

The following conclusions are drawn from these statistical analyses:

ACCIDENTS:

- 4.8% of GA accidents are related to CFIT
- 32% of GA accidents in IMC conditions are related to CFIT

FATALITIES:

- There are 1.4 fatalities per accident in GA accidents related to CFIT;
- GA accidents, due to all other causes, have an average of 0.33 fatalities per accident.
- 17% of people killed in GA are in accidents related to CFIT.
- 16% of the fatal GA accidents were due to CFIT.

INFLUENCES:

- IFR-rated GA pilots, age 50 and over, have significantly more accidents related to CFIT than IFR-rated GA pilots under age 50.
- Significantly more accidents attributed to CFIT occurred during IMC conditions than during VMC conditions.
- California and Alaska have the most CFIT accidents nationally but CFIT accounts for a disproportionate share of GA accidents in certain states, i.e., West Virginia and Idaho.

It is of concern that accidents attributed to CFIT more often involve fatalities. Although only 4.8% of GA accidents occur due to CFIT, these accidents result in 1.4 fatalities per accident. This is over four times the number of fatalities associated with GA accidents. In total, accidents attributed to CFIT account for 17% of all the fatalities in GA.

CONCLUSION

CFIT accidents account for 17% of GA fatalities, which underscores the need for further research into factors contributing to CFIT accidents.

CFIT accidents represent 32% of the GA accidents in IMC conditions. When looking at accidents in IMC weather conditions, other studies have also indicated that CFIT accidents play a major role. (AOPA Air Safety Foundation, 1996) Moving maps with terrain displays may provide a way to better orient GA pilots in low-visibility situations because electronic moving map displays can alert pilots to avoid accidents before they occur.

Instrument conditions and older pilots are overrepresented in CFIT accidents. IMC conditions may demand sensory or cognitive tasks that vary with age. Other studies have indicated that older pilots with low annual hours (a category that is primarily GA pilots) have a higher accident rate overall. (Khatwa and Roelen, 1996) It has also been shown that CFIT rates are higher in situations where pilots inadvertently fly from VMC to IMC conditions. These issues, differential sensory and cognitive capabilities, lower annual flight hours, and inadvertent flying into altered conditions seem to contribute disproportionately to the incidence of CFIT accidents. Further examination of these relationships is warranted.

Accidents in multi-engine planes are disproportionately represented in the classification of accidents related to CFIT, and this relationship needs more study. Older pilots may be more likely to fly multi-engine planes. Alternatively, multi-engine aircraft may fly longer distances, and over unfamiliar terrain more frequently.

In summary, analyses of this partitioned database provided a way to identify factors that are associated with CFIT-type accidents.

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