

Controlled Flight into Terrain Accidents Among Commuter and Air Taxi Operators in Alaska

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Background: Between 1990 and 1998, aviation accidents in Alaska caused 100 occupational pilot deaths (equivalent to 430/100,000 pilots/year, approximately 86 times the overall U.S. worker fatality rate). Although Alaskan geography and climate increase aviation risks, many accidents were attributed to pilot error. While most accidents occurred during takeoff/landing, most fatalities resulted from Controlled Flight Into Terrain (CFIT). The purpose of this study was to examine risk factors for CFIT. **Methods:** Using National Transportation Safety Board airplane accident data we identified CFIT from flight phase and event description fields, and calculated odds ratios for CFIT/non-CFIT accidents for visual conditions, aircraft features, and pilot experience. **Results:** Between 1991 and 1998, 351 single aircraft commuter and air taxi accidents occurred in Alaska; 59 (17%) were CFIT. Of 140 total fatalities, 82 (59%) occurred in 30 CFIT accidents. There was a twelve-fold risk for death in CFIT vs. non-CFIT accidents (OR = 12.42, 95% CI = 8.19-18.80). Accidents while flying Visual Flight Rules (VFR) into poor visibility were more likely CFIT than non-CFIT (Odds ratio = 46.06, Confidence Interval = 19.32-112.16), and caused 37% of all deaths. Additionally, flights in Instrument Meteorological Conditions (IMC) were 47 times more likely to be CFIT than non-CFIT. No risk for CFIT was shown for flight hours, number of engines, passenger presence, or pilot age. All CFIT were attributed to pilot error, often for continuing VFR into poor visibility. **Conclusion:** CFIT caused most aviation deaths. Further research into human factors contributing to CFIT is needed. Implementation of global-positioning, ground-proximity/avoidance technology, might reduce CFIT incidence.

Keywords: aviation, accidents, controlled flight into terrain, Alaska.

BETWEEN 1990 AND 1998 there were 229 fatal commuter and air taxi accidents in the United States; Alaska accounted for 49 (21%) of these accidents (13). Over the same period, 1990-1998, 100 people working as pilots at the time of the aircraft accident died in Alaska (1). This is equivalent to an occupational fatality rate of 430/100,000 per yr which is approximately 86 times the occupational fatality rate for all workers in the United States* and nearly 5 times the national fatality rate for all pilots†. Additionally, this is almost 24 times the rate for Alaskan workers‡ making aviation the highest-risk occupation in Alaska.

These statistics may, to some extent, reflect the unique physical and demographic features affecting aviation in Alaska. Its northern latitudes, vast mountain ranges, flat marshy tundra, and extensive coastline result in diverse climatic zones and associated variable and often harsh weather. Because of this, conditions of

poor visibility are common. In addition, although over half of the Alaskan population lives in one of the state's three major cities (Anchorage, Fairbanks, and Juneau), much of the remaining population lives in remote villages not connected to the road system and only accessible year-round by aircraft. Commuter and air taxi operators (operating under 14 CFR Part 135) serve as the main link between these villages and regional hubs, and transport people, goods, and mail. In 1994 commuter airlines in Alaska served 238 locations, only 5 of which had road connection to the regional airline hub (14). Compared with the remainder of the United States, Alaska has 76 times as many commuter airline flights per capita (13).

A study by Garrett et al. (8) on work-related aviation fatalities in Alaska from 1990 through 1994 reported the death rate for commercial pilots in Alaska was 2.1 times higher than the overall U.S. rate for commercial pilots. Of the fatal occupational accidents, 64% occurred due to controlled flight into terrain (CFIT). A major risk factor for these fatal occupational accidents was poor weather, defined as Instrument Meteorological Conditions (IMC). Commercial pilots were also more likely to be flying into IMC at the time of a fatal accident than private pilots.

A recent analysis of risk factors for Federal Aviation Regulations (FARs) Part 91 (General aviation [GA]) accidents in the U.S. between 1983 and 1994 found that factors associated with CFIT-type accidents included

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* Overall occupational fatality rate for U.S., 1998 = 5/100,000 per yr (3).

† Overall occupational pilot fatality rate for U.S., 1996 = 88/100,000 per yr (19).

‡ Overall occupational fatality rate for Alaska, 1994-1998 = 18/100,000 per yr (12).

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the following: instrument conditions; pilots over 50 yr of age; male pilots; pilots with fewer total hours; and multi-engine aircraft (5).

Another study by Li and Baker (11) of commuter and air taxi accidents found that IMC, multi-engine aircraft, and night accidents were associated with lack of survivability. They also found in a study of GA pilots (10) that IMC, multi-engine aircraft, and night accidents were associated with lack of survivability.

Over half (54%) of the fatal commuter and air taxi accidents in Alaska between 1989 and 1993 were related to flying Visual Flight Rules (VFR) into IMC (14). Until recently, regulations in 14 CFR Part 135 prohibited single engine commercial flights in Alaska from flying under Instrument Flight Rules (IFR). However, in a survey of 44 commercial pilots, conducted as part of the 1995 National Transportation Safety Board (NTSB) Safety Study on Aviation in Alaska, 22 (50%) stated that in response to operational pressures, they had flown VFR into IMC. "The incidence of VFR into IMC... suggests that the possibilities of inadvertent and intentional operation of VFR flights into IMC are accepted and... not unusual" (14). The study concluded that dependence on flying VFR was one of the underlying reasons for the number of VFR into IMC accidents and a leading safety problem for Alaskan commuter airlines and air taxis.

A CFIT accident refers to any collision with land or water in which the pilot was in control of the aircraft, but had lost situational awareness (i.e., was not aware of the plane's altitude, terrain elevation, or latitude and longitude position of the aircraft). CFIT accident designation requires first ruling out any detectable mechanical failure of the aircraft or its equipment. Most CFIT accidents are attributed to pilot error, wherein the pilot intentionally or inadvertently flies the aircraft into IMC. However, attributing pilot error as the cause of an aircraft accident still does not explain the, "lapse in judgment or deterioration in performance by experienced, competent pilots" (15).

The purpose of our study was to analyze the available data on accidents involving commuter and air taxi operations in Alaska to determine if the risk factors previously identified for GA accidents also apply to commercial operators in Alaska. This study included only operators with Part 135 certificates; therefore, not all occupational pilots in Alaska were included.

METHODS

Due to the lack of adequate exposure data for the denominator of all commercial pilots operating in Alaska, a traditional case-control approach such as that used in a previous aviation study by Li and Baker (11) was not feasible. An epidemiological method based on the use of hospital controls was undertaken. The usefulness of this method has been clearly demonstrated by other similar public health studies. For example, Thompson et al. (17) studied the effectiveness of bicycle helmets using head-injured cyclists as cases and non-head-injured cyclists as controls. Thompson et al. (18) also performed a study using this same data and approach where they compared subjects with facial injury

(cases) to those without facial injury (controls). Chalmers et al. (4) compared falls from playground equipment for injured children and non-injured children. For this study, commercial aviation accidents that were CFIT (cases) were compared with all other accidents (controls) which either did not occur during controlled flight or in which the accident may have resulted from the pilot's loss of control due to weather, terrain or mechanical failure.

The analysis used data abstracted from the NTSB accident reports and entered into a database maintained by the Federal Aviation Administration's (FAA) National Aviation Safety Data Analysis Center (NASDAC). According to the FAA and NTSB, an aviation "accident" is "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 and until such time as all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage" (7). This accident data was obtained and entered into a computer database (Corel Paradox) for analysis. Airplane accidents occurring in Alaska between January 1, 1991 and December 31, 1998, involving one aircraft were selected. Because an accident is given a single NTSB number regardless of the number of aircraft involved, it was decided to simplify the analysis by excluding events involving multiple aircraft, such as mid-air collisions. The study was further restricted to accidents involving commuter and air taxi flights operating under Federal Aviation Regulation (FAR) Part 135 or Part 91. Title 14 Code of Federal Regulations (CFR) Part 91 pertains to GA, but has portions that apply to all operators, for instance non-income generating flights such as returning to base. CFR Part 135 pertains to Commuter and Air Taxi Operators. Helicopter accidents were not included in our analysis.

CFIT accidents were determined by using a phase of flight field to select those accidents which occurred during climb, cruise, maneuvering, descent, or approach. A description of the event was then used to exclude those in-flight accidents due to uncontrolled or emergency situations, such as loss of control due to strong winds, mechanical or engine failure, fire, or pilot impairment. These were categorized as non-CFIT accidents in addition to all those accidents that occurred during other phases of flight (e.g., takeoff, landing, taxiing, or standing).

An epidemiologic software program, EPI-INFO, was used to calculate odds ratios for visual conditions, aircraft features, and characteristics of the pilot (which could have affected judgment and decision-making abilities). Specific potential risk factors examined included: number of engines; presence of passengers; pilot age less than 30 or greater than 50; total number of flight hours; total flight hours in the last 24 h, 30 d, and 90 d; total instrument hours; and total hours in make and model of the accident aircraft. These were compared by plotting the hours flown against frequency of accident and establishing cut-off points where the ratio of CFIT/non-CFIT accidents differed from the observed trend. Recent workforce data obtained from the FAA

TABLE I. COMMUTER AND ON DEMAND ACCIDENTS, 1991-1998.

| | All Accidents | All non-CFIT | All CFIT | CFIT VFR/IMC |
|------------------|---------------|--------------|----------|--------------|
| Total accidents: | 357 | 292 | 59 | 38 |
| Total on board | 1060 | 884 | 176 | 128 |
| Fatal accidents: | 56 | 26 | 30 | 17 |
| Total on board | 156 | 68 | 88 | 57 |
| Fatalities | 140 | 58 | 82 | 52 |
| Pilot fatalities | 51 | 23 | 28 | 16 |

indicate approximately 2,600 pilots currently fly commercially for commuter or air taxi operations in Alaska; 2100 of these pilots are estimated to fly for Part 135 operators.

RESULTS

During the 8 yr from 1991-98 there were 1303 single aircraft accidents in Alaska. Of these accidents, 78% occurred under FARs pertaining to general aviation (CFR Part 91) standards and 21% under commuter and air taxi operations (Part 135). The remaining 1% were large commercial aircraft (Part 121) or were unknown; these accidents were not included in the analysis nor were occupational accidents for operators without a Part 135 certificate. There were also 61 helicopters, one ultralight, and one glider that were excluded from the study. From the remaining accidents, there were 351 commuter and air taxi accidents, 26% occurred while flying under the less restrictive Part 91 and 74% under Part 135. Although the proportion of flight hours flown under Part 91 by commuter and air taxi is unknown, the proportion of accidents in this category is of interest.

Of the 351 commuter and air taxi accidents, 180 (51%) were takeoff or landing accidents, 90 (26%) involved loss of control or an emergency, 59 (17%) were CFIT accidents, and 10 (5%) occurred while taxiing or standing. The CFIT accidents occurred during cruise (53%), maneuvering (31%), approach (8%) and descent, climb, or takeoff (8%). All CFIT pilots were instrument rated and 97% of non-CFIT pilots were instrument rated; these high values for instrument rating would be expected for commercial pilots. Over 99% of the subjects were male and all CFIT pilots were male. Because of the small values for instrument ratings and gender, analyses were not completed for these variables as they might not accurately reflect relationships among the variables. These 351 accidents had a total of 884 people on board. Of these accidents, 56 (16%) were fatal, accounting for 140 fatalities including 51 pilot fatalities (Table I). This is equivalent to a fatality rate for the commuter and air taxi pilots of 300/100,000 per yr using a denominator of 2100 pilots.

Of the 59 CFIT accidents, 29 were fatal, accounting for 59% of all the fatalities. Only 38 (11%) of the accidents involved flying VFR into IMC. However, 17 of those were fatal accidents, accounting for 52 (37%) of all deaths and 16 (31%) of the pilot deaths. In contrast, only

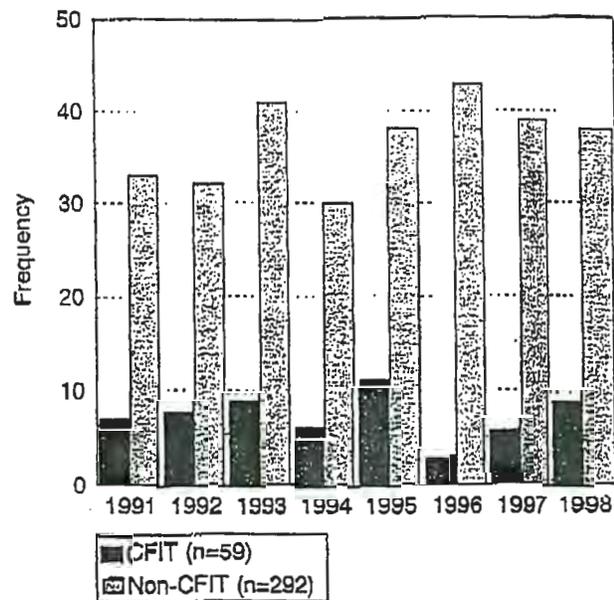


Fig. 1. Annual incidence of commuter and air taxi crashed: CFIT (n = 59) (Black bar) and Non-CFIT (n = 351) (gray bar) in Alaska, 1991-98.

26 (9%) of the 292 non-CFIT accidents were fatal. Other CFIT, i.e., those not due to VFR into IMC, accidents were primarily due to inattention to terrain and altitude. All of the CFIT accidents were attributed to pilot error (Fig. 1).

The annual number of commuter and air taxi accidents has not changed over the 8-yr period. Similarly, the annual number of CFIT accidents has not changed either. However, among the CFIT accidents, there ap-

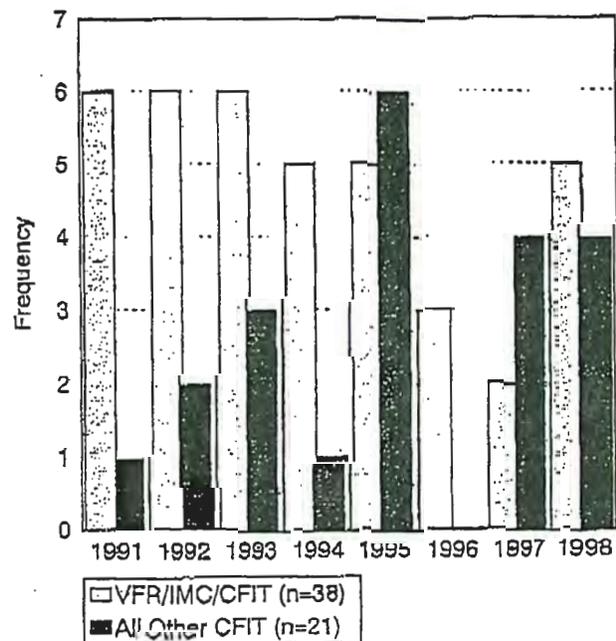


Fig. 2. Annual number of CFIT due to VFR into IMC crashes (n = 38) (gray bar) and all other CFIT crashes (n = 21) (black bar) in Alaska, 1991-98.

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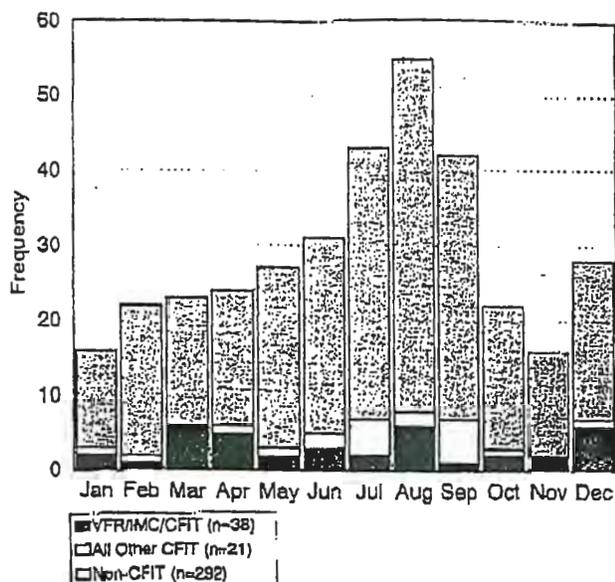


Fig. 3. Total Crashes (n = 351) by month in Alaska, 1991-98: Non-CFIT (n = 292) (gray bar); CFIT due to VFR into IMC (n = 38) (black bar); and all other CFIT crashes (n = 21) (white bar).

pears to have been an incremental decline in VFR into IMC over the same period (Fig. 2). Monthly Air Traffic Control (ATC) activity shows that the summer months of June, July, and August are the busiest times of the year (6). However, the amount of instrument activity remains fairly constant over the year, with only a slight rise in the summer indicating that most of the increased activity in the summer months is due to VFR operations.

Examination of the monthly incidence of all commuter and air taxi accidents and the portion that were CFIT accidents shows that most accidents occurred in August and the fewest in November (Fig. 3). Two peaks in December and March did not correspond to an increase in ATC activity, but did correspond to peaks in CFIT accidents. This may be due to increased pressures on pilots to continue flights during these months due to Christmas travel and mail as well as travel for community activities such as spring break and the Iditarod Race.

CFIT accidents were 10 times more likely to be fatal vs. non-CFIT accidents, and there was 12 times the risk

TABLE II. ODDS RATIOS FOR EXPOSURE AND OUTCOME OF CFIT TO NON-CFIT FATAL ACCIDENTS.

| Exposure | Outcome | | Odds Ratio (95% CI) |
|-------------------|-----------------|---------------------|---------------------|
| | Fatal Accidents | Non-Fatal Accidents | |
| CFIT Accident | 30 | 29 | 10.58 (5.26-21.40)* |
| Non-CFIT Accident | 26 | 266 | |
| | Number died | Number Survived | |
| CFIT Accident | 82 | 94 | 12.42 (8.19-18.88)* |
| Non-CFIT Accident | 53 | 826 | |

* p < 0.05.

TABLE III. ODDS RATIOS FOR EXPOSURES FOR CFIT TO NON-CFIT ACCIDENTS.

| Exposure | CFIT | Non-CFIT | Odds ratio (95% CI) |
|-------------------|------|----------|-----------------------|
| IMC | 39 | 15 | 47.49 (20.19-114.19)* |
| VMC† | 15 | 274 | |
| Due to VFR-IMC | 38 | 11 | 46.06 (19.32-112.46)* |
| VFR-VMC, IFR-IMC | 21 | 280 | |
| Night | 6 | 15 | 2.03 (.67-5.95) |
| Daylight | 50 | 254 | |
| Single engine | 49 | 234 | 1.13 (.51-2.55) |
| Multiple engines | 10 | 54 | |
| Two/more on board | 41 | 195 | 1.14 (.6-2.19) |
| Only one on board | 18 | 98 | |
| Age > 50 yrs | 11 | 54 | 1.02 (.47-2.24) |
| Age < 50 yrs | 48 | 231 | |
| Age > 30 yrs | 13 | 62 | 1.00 (.48-2.05) |
| Age < 30 yrs | 46 | 219 | |

* p < 0.05.

† VMC = Visual Meteorological Conditions

for death among those involved in a CFIT vs. a non-CFIT accident (Table II). CFIT accidents were 46 times more likely than non-CFIT accidents to have occurred as a result of flying VFR into IMC. Of the CFIT accidents, 85% occurred during daylight, 10% at night, and 5% in either the morning or evening. There was no increased risk for CFIT vs. non-CFIT for accidents at night, number of engines, pilot age, or presence of passengers (Table III).

No significant associations were found for CFIT vs. non-CFIT for those pilots with less than 6000 total hours or total hours in make and model of the accident aircraft. Indicators of recent activity and possible fatigue did not show any association for CFIT or non-CFIT for total hours flown in the last 24 h, 30 d, and 90 d. The amount of instrument time flown was also not significantly associated with CFIT accidents (Table IV).

Overall, there was no decline in the total commuter or air taxi accidents, or those that were CFIT accidents during the period 1991-98. However, there was a slight

TABLE IV. ODDS RATIOS FOR FLIGHT EXPERIENCE AND CFIT TO NON-CFIT ACCIDENTS.

| Flight experience (hours) | CFIT | Non-CFIT | Odds Ratio (95% CI) |
|---------------------------|------|----------|---------------------|
| Last 24 hours | | | |
| <6 h | 38 | 173 | 1.18 (.54-2.62) |
| >6 h | 11 | 59 | |
| Last 30 d | | | |
| <100 h | 41 | 190 | 1.27 (.57-2.90) |
| >100 h | 10 | 59 | |
| Last 90 d | | | |
| <250 h | 37 | 195 | 0.92 (.46-1.88) |
| >250 h | 15 | 73 | |
| Instrument hours | | | |
| <200 h | 26 | 115 | 0.96 (.47-1.97) |
| >200 h | 18 | 77 | |
| Make and Model | | | |
| <1000 h | 36 | 170 | 1.01 (.53-1.96) |
| >1000 h | 19 | 91 | |
| Total | | | |
| <6000 | 41 | 169 | 1.68 (.88-3.25) |
| >6000 | 17 | 118 | |

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decline for VFR into IMC accidents. Only 17% of all accidents were CFIT accidents, yet these accounted for 59% of all the deaths, and 55% of all pilot deaths, giving an extremely high fatality rate of 300/100,000 per yr.

DISCUSSION

This study has sought to examine risk factors associated with CFIT accidents in the aviation industry in Alaska. A reduction in the number of CFIT accidents will not dramatically change the number of accidents, but it will reduce the number of total fatalities, and greatly decrease the pilot fatality rate.

A strong association was found between VFR flights into IMC and CFIT accidents. Therefore, interventions that target both human factors and navigational technology will need to be considered to reduce CFIT accidents. In regards to human factors, elements such as company operational procedures, management involvement in go/no-go decisions, training in pilot decision-making, and the personal or operational pressures that influence the pilot's judgment and performance should be examined.

Technology-based solutions for this problem involve promotion and installation of enhanced Ground Proximity Warning Systems (GPWS), improved Ground Collision Avoidance Systems (GCAS), new Global Positioning System (GPS) technology, and the expansion of navigational aids and weather reporting systems. In 1975 the FAA mandated the installation of GPWS for FAR part 121 operators. Since then, there has been a dramatic reduction in Part 121 CFIT accidents in the U.S., from an average of eight per year to one every 2 yr (2). Current FAA regulations for part 135 do not require GPWS in aircraft that carry less than 10 passengers. In an analysis of 108 CFIT accidents around the world between 1988-94 involving air taxi, regional and major operators, 75% were not fitted with GPWS. Additionally, in about 70% of the accidents it was not required. A fifth of these accidents occurred due to inadvertent VFR flight into IMC; most of these were single-pilot flights involving regional and air taxi operators (9). The recent FAA approval of IFR for single engine Part 135 carriers will allow for planned instrument flights and, therefore, may reduce the likelihood of VFR flights into IMC. However, the cost of the additional equipment and maintenance required may delay, if not prohibit, full implementation by many companies.

Although a previous study of GA accidents showed an association with CFIT and pilot age (5), our study did not find any association between pilot age or pilot experience and CFIT accidents. A study of 188 accidents involving corporate/executive pilots also did not show a significant difference for fatal or non-fatal accidents and pilot age, make and model time, or total time (16). Although there was no association detected between age and CFIT accidents, the reasons for the accident, or the inappropriate decision which led to it, may vary depending on the pilot's age and experience. An accident may be the result of the poor decisions or wrong actions of a young or inexperienced pilot, or it may be the result of inappropriate decisions or complacency that occur with older age and/or more flying time.

Company operating practices may also be a contributing cause. Further examination of this requires more research and is beyond the scope of this study.

The question of flight experience in Alaska is obviously important. However, this information is not readily available. The NTSB records the pilot's state of residence based on home address. This may not reflect the pilot's experience in Alaska, as many return seasonally, but do not establish permanent residency. Others may have an Alaska address but may have only recently started working in the state.

There are certain limitations to this study. The lack of readily available denominator data for all commercial pilots, including those who have not had accidents, (e.g., number of flight hours or number of flight departures), necessitates the use of a case-control analysis. In this study CFIT aircraft accidents were used as cases and non-CFIT accidents as controls. Although there are limitations inherent in comparing one accident population to another accident population, there is, nevertheless, some merit in this type of comparison (17,18). Thus, a sound epidemiologic method has been established which may be useful for further risk analysis studies of CFIT accidents.

The high occupational pilot fatality rate in Alaska and the high fatality rate associated with CFIT accidents reinforces the importance of addressing this type of accident and examining the associated risk factors. Understanding the factors that result in a pilot flying a perfectly good aircraft into the ground due to inappropriate or poor decision making and/or inadequate situational information could help in the design of appropriate training programs and other interventions. This would ultimately result in a major reduction of commercial aviation fatalities.

The National Institute for Occupational Safety and Health, in conjunction with the FAA, NTSB and the National Weather Service, has recently undertaken a joint initiative with the goal of reducing the number of occupational fatalities in aircraft accidents by 50%. Over the next decade we will attempt to accomplish this via more detailed analysis of accident and denominator data, collaborative development of voluntary standards with the air taxi industry, and evaluation of new technologies for their effectiveness in preventing CFIT in single-engine air taxi operations. The elimination of CFIT accidents alone would reduce the number of commercial aviation fatalities in Alaska by over 70%. If successfully implemented, intervention strategies that address human factors and make full use of new technologies could save many Alaskan lives.

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