A Multifaceted Public Health Approach to Statewide Aviation Safety

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Background *During the 1990s, Alaskan pilots had one of the most hazardous occupations in the US. In 2000, a multifaceted public health initiative was launched, focusing on Alaskan air taxi/commuter (AT) operations, including risk factor identification, improved weather information, and the formation of an industry-led safety organization.*
Methods *Effectiveness was assessed by comparing rates of crashes using Poisson regression, comparing trends in annual numbers of crashes, and assessing changes in the number and type of controlled flight into terrain (CFIT) events.*
Results *The greatest improvements were seen in Alaska fatal AT crashes with a 57% decrease in rates between time periods. While the number of AT crashes in the rest of the US steadily declined during 1990–2009, Alaska only showed significant declines after 2000. CFIT crashes declined but remained more deadly than other crashes.*
Conclusions *This coordinated effort was successful in reducing crashes in the Alaskan AT industry.* Am. J. Ind. Med. 55:176–186, 2012. *© 2011 Wiley Periodicals, Inc.*

KEY WORDS: CFIT; controlled flight into terrain; Part 135; effectiveness; accidents

INTRODUCTION

The public health model asserts that through an evidence-based, scientific approach, injuries can be prevented [Mercy et al., 1993] and that this is best accomplished through the combined activities of diverse disciplines and organizations [Mercy et al., 1993; Stout, 2008]. This approach includes an ever-refining cycle of surveillance, risk factor identification, development and implementation of prevention strategies, evaluation and repetition/refinement until the identified injuries are severely reduced or eliminated [Conway et al., 1999; Smith, 2001; Stout and Linn, 2001]. The National Institute for Occupational Safety and Health (NIOSH) has applied this approach to reducing the number and rate of occupational injuries and fatalities with tangible results [Stout and Linn, 2001, 2002; Stout, 2008]. An important aspect of this approach, and one that is often given the least emphasis, is the evaluation of the effectiveness of the interventions.

During the 1990s, Alaska workers had the highest occupational fatality rate in the nation—over three times the national rate [Alaska Department of Health and Social Services, 2010]. Aircraft crashes were the second leading cause (following drowning) of occupational death in Alaska during this time, taking the lives of 192 workers [Conway et al., 2002]. Most of these occupational fatalities occurred during air taxi or commuter operations, which provide transportation to over 200 rural communities and other remote sites in the state. Commercial pilots in Alaska during this time had an occupational fatality rate of 410 deaths per 100,000 workers—five times greater than the rate for all US pilots and nearly 100 times greater

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Institution where work was performed: Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Alaska Pacific Regional Office.

Disclosure Statement: None of the authors or their institutions has received payment or services from a third party for any aspect of the submitted work. We have no financial relationships to disclose and have not been involved in other activities that readers could perceive to have influence, or that give the appearance of potentially influencing our work.

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Accepted 15 November 2011
DOI 10.1002/ajim.21993. Published online 13 December 2011 in Wiley Online Library (wileyonlinelibrary.com).

than the rate for all US workers [Bensyl et al., 2001]. Research from the National Transportation Safety Board (NTSB) and NIOSH found that the most deadly aviation crashes in Alaska formed a repeated pattern: departure in good visibility conditions followed by continuation into limited visibility conditions and/or poor weather, which resulted in crashing into mountains or other terrain [National Transportation Safety Board, 1989; National Transportation Safety Board, 1995; Thomas et al., 2000]. The act of flying an airworthy, pilot-controlled, aircraft into mountains, water, or other terrain is called controlled flight into terrain (CFIT) and is the second leading cause of commercial aviation fatalities worldwide [Boeing, 2010]. During 1991–1998 CFIT accounted for only 17% of all crashes to air taxi and commuter fixed-wing aircraft in Alaska, but accounted for 59% of all deaths and 55% of all pilot deaths [Thomas et al., 2000]. Many of these CFIT crashes occurred after the pilot had flown from an area of good visibility allowing for visual flight rules into an area of deteriorating visibility which required the use of instruments for safe flight navigation (instrument meteorological conditions) [Thomas et al., 2000; Kobelnyk, 2004]. Visual flight rules (VFR) govern flights conducted under conditions where pilots are able to use visual references outside the aircraft to navigate and avoid obstacles and terrain. Visual meteorological conditions (VMC) are those that meet requirements for visual flight rules; they have visibility and cloud ceiling minima. Instrument flight rules (IFR) govern the conduct of flight under instrument meteorological conditions (IMC); they require pilots to use instruments inside the aircraft for navigation and utilize established routes and procedures to avoid obstacles and terrain.

Researchers have tried to understand the factors which play into a pilot's decision to fly into adverse weather or continue into poor visibility conditions. Reviews of aviation crash reports and studies with private and commercial pilots in simulators have identified several hypotheses, including poor situational awareness where the pilot does not adequately perceive that he/she is flying into adverse weather [Goh and Wiegmann, 2002; Wiegmann et al., 2002], overconfidence in abilities, or inaccuracy in risk perception [Goh and Wiegmann, 2002; Wiegmann et al., 2002; Coyne et al., 2008; Pauley et al., 2008], and social pressure by passengers [Goh and Wiegmann, 2002], by company management, or self-induced [Shappell and Wiegmann, 2003; Bearman et al., 2009].

In Alaska, it was also identified that many areas of the state needed better weather information and that pilots were often having to fly without electronic, ground-based navigational aids [National Transportation Safety Board, 1995]. This limits the pilot's ability to plan flight into poor visibility using standard instrument procedures or to use navigational aids to confirm their location. While crashes involving VFR flight into IMC are often fatal, most aviation crashes do not result in fatalities [Aircraft Owners and Pilots Association Air Safety Foundation, 2007]. Risk factors for a crash being fatal include post-crash fire, location of crash away from an airport, IMC, and failure to use safety restraints [Li and Baker, 1993, 2007; Bensyl et al., 2001; Li et al., 2008].

Presented with surveillance data on injuries and fatalities, those involved in aviation and occupational safety in Alaska during the late 1990s began a multifaceted approach to improve aviation safety using the public health approach to injury prevention. Much of this work was encompassed in an initiative, the Alaska Interagency Aviation Safety Initiative (AIASI), which was funded by the US Congress in 2000 (Department of Transportation and Related Agencies Appropriations Act, 2000 Public Law 106–69) and focused on improving safety in commuter and air taxi operations [Berman et al., 2005]. This initiative was a multi-disciplinary partnership of several government agencies and the Alaskan aviation industry (Table I). The NIOSH Alaska Pacific Regional Office (formerly known as the Alaska Field Station) provided coordination and leadership for the AIASI, provided continued surveillance and risk factor identification, and conducted a statewide survey of commuter and air taxi operators and pilots [Conway et al., 2004]. The NTSB Alaska Regional Office provided investigative reports and accident investigation expertise for research and evaluation. The Federal Aviation Administration (FAA) Alaska Regional Office worked with the industry to install geographic information system-based navigational equipment on air taxi and commuter aircraft through the Capstone program addressing issues of pilot situational awareness and risk assessment [Herrick and Murphy, 2005]. The FAA also coordinated the passenger-focused Circle of Safety educational program to address issues of potential social pressure on pilots and educate passengers on issues of safety [Federal Aviation Administration, 2009]. With funding and support from the FAA, the National Oceanic and Atmospheric Administration's National Weather Service (NWS) Alaska Regional Office shared detailed climatic history data and undertook to increase the availability and accuracy of weather information through real-time weather cameras for mountain passes and remote locations available via the internet (http://akweathercams.faa.gov/). With the FAA, the NWS established the "mike-in-hand" program which provided near real-time aviation weather information to pilots via the radio [NTSB, 1999]. Additionally, in 2001 the Alaska Air Carriers Association helped create the Medallion Foundation, a nongovernmental voluntary program for commercial air carriers that awards stars for audited achievement in five critical areas of airline safety (http://www.medallionfoundation.org) and fosters a "culture of safety" for operators and pilots. Collectively these

TABLE I. Major Components of the Alaska Interagency Aviation Safety Initiative Described by Goals, Organization Responsible, Period of Implementation and Scope

Intervention	Goal	Organization responsible	Implementation	Scope
Weather cameras	Real-time mountain pass and remote location information	Federal Aviation Administration, National Weather Service	1997-Current	1999 = 4 stations
			Federally funded in 2004	2005 = 54 stations 2007 = 82 stations 2010 = 142 stations
Capstone safety program	Install advanced navigational equipment	Federal Aviation Administration	Phase I 1999–2003	I. Southwest Alaska
			Phase II 2003–2007	II. Southeast Alaska 2010 = approximately 485 aircraft equipped
Risk factor identification/survey	Information for interventions	National Institute for Occupational Safety and Health	Survey 2001–2002	Statewide
			Research summaries presented annually	
Mike-in-Hand	Real-time weather information	National Weather Service, Federal Aviation Administration	2001-current	3 Flight Service Stations
				14 Satellite Field Facility Flight Service Stations
Medallion Foundation	Promote higher industry standard of safety	Alaska Air Carriers Association	2001-current	Approximately 44 air carriers enrolled
Circle of Safety	Passenger safety information	Federal Aviation Administration	2002-current	Statewide

organizations undertook a multifaceted public health approach to aviation safety by employing technology, providing education to pilots and consumers, and by encouraging voluntary changes to improve safety within the aviation industry to reduce the incidence of aircraft crashes in Alaska.

Ten years after the launch of most of the initiative's activities, the question is if the AIASI has resulted in significant reductions in the number and rate of aviation fatalities in Alaska. The purpose of this study was to continue the public health approach and examine the effectiveness of this initiative by assessing several aspects of aviation safety before and after the implementation of the various safety interventions.

METHODS

Data

Since most of the programs were focused on air taxi and commuter operations, this evaluation has a similar focus. There were two parts to this effectiveness evaluation: The first part involved a comparison of the number and rate of crashes before (1990–1999) and after (2000–2009) the initiative was implemented, including all aviation operations in Alaska, air taxi/commuter operations in Alaska, and air taxi/commuter operations in the rest of the US. The second component of the study was an analysis of risk factors for CFIT crashes among air taxi and commuter operations after the start of the initiative (2000–2009). The public health interventions were not started at the same time and occurred over many years (Table I), but for this evaluation we conservatively chose the start of the congressionally funded initiative in January of 2000 as the beginning of the transition period.

Aviation operations included all nonmilitary fixed-wing and helicopter flights operating in the United States during 1990–2009. Crashes included all events classified by the NTSB as an "accident," defined as "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 all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage" (US Code of Federal Regulations (CFR) Title 49, 830.2). A fatal crash is defined as a crash that resulted in the death of at least one occupant within 30 days. Detailed aviation crash data came from the NTSB Aviation

Accident Database (www.ntsb/gov/ntsb/query.asp, accessed 17 Oct 2010).

Aviation operations and flights are regulated by the FAA through the Federal Aviation Regulations (FAR) CFR Title 14. These regulations are divided into ‘‘parts’’ dependent upon the type of operations. For the purpose of this study, we identified air taxi/commuter operations as those working under FAR Part 135 (Operating Requirements: Commuter and On Demand Operations and Rules). These flights include commuters, which operate with a regular schedule, or air taxi flights which do not have regular schedules and are available for on-demand trips. Aircraft used for commuter or air taxi flights have up to nine passenger seats and carry 7,500 pounds or less in cargo and/or passengers. Prior to March 20, 1997, aircraft with 10 to 30 passenger seats were also allowed to fly under Part 135. To enable comparisons to other published rates and because a separate study of the crash rate for aircraft with 10–30 seats operating under Part 135 during most of the baseline study period (1990–1997) was shown to be much lower than those with 9 or fewer seats [Baker et al., 2009] we use the prevailing Part 135 definition for each year.

Denominator data on the number of flights (departures) for the rate calculations were obtained from the FAA Terminal Area Forecast (TAF) system, which is the official measure and forecast of aviation activity at FAA facilities (http://aspm.faa.gov/main/taf.asp). The number of departures was used instead of flight hours, as number of departures reflects the more hazardous periods near or on the ground [Baker et al., 2008] and flight hours for Alaska were poorly sampled prior to 2004 [Federal Aviation Administration, 2007a]. TAF data have a different definition of commuter and air taxi operations than the FAR Parts (aircraft with 60 or fewer seats), but still represent smaller aircraft with either scheduled or unscheduled operations. Overall numbers of flights included all activity not classified as military. The number of departures is calculated as the activity (takeoffs + landings) divided by 2.

Enumeration of occupational fatalities associated with aviation crashes in Alaska was accomplished using the NIOSH Alaska Occupational Injury Surveillance System, as the NTSB aviation accident database lacked sufficient detail to determine the occupational status of each person in an aviation crash. For the occupational data summary, ‘‘pilots’’ included Standard Occupational Codes 53–2011 (Airline Pilots, Copilots and Flight Engineers) and 53–2012 (Commercial Pilots).

To determine risk factors for CFIT crashes among air taxi and commuter operations during 2000–2009 and facilitate comparisons, we used the same case definition as previously published results [Thomas et al., 2000]. All crashes in Alaska involving fixed-wing aircraft working for air taxi/commuter companies were included except for mid-air collisions. Companies were identified by their Part 135 certificate status so that crashes that occurred during both revenue (Part 135) and nonrevenue (Part 91) generating ‘‘positioning’’ flights by air taxi/commuter companies were included. Each operator’s certificate status was determined through the NTSB investigation data, FAA Certified Air Carrier Directories, or by contacting individual companies. Due to the difficulty in reliably establishing Part 135 certificate status for historical data, previously published results by Thomas et al. [2000] for 1991–1998 (before the initiative) served as a comparison to the recent data (2000–2009) analyzed in this study. The number of CFIT crashes to Part 135 certificate holders was also calculated for 1999 to examine trends over time.

Crashes identified as involving Part 135 certificate holders during 2000–2009 were evaluated for visibility, light conditions, number of people aboard, number of engines, pilot experience, and whether the cause of the crashes was CFIT. CFIT crashes were those that occurred during airborne phases of flight not related to takeoff and landing (i.e., climb, cruise, maneuvering, descent, or approach), in which the pilot had control of the aircraft but flew it into terrain or water. This definition required that the pilot had been in control of the aircraft, so crashes that involved emergency situations such as loss of control due to mechanical failure, fire, or pilot impairment were considered nonCFIT. If the cause of the crash could not be determined or the aircraft was not recovered, the crash was classified as nonCFIT.

Visibility was defined as the flight conditions at the time and location of the crash as noted in the dichotomous field on the NTSB report: either Visual Meteorological Conditions (VMC) when visibility allows for navigation by landmarks, or IMC, when visibility is limited and instruments are required for navigation. Another coded variable indicated if the pilot flew from an area of good visibility requiring only VFR into an area of poor visibility, or IMC. Pilot experience was dichotomized into whether or not the pilot in command had logged 6,000 or more flight hours at the time of the crash for comparison with previously published results [Thomas et al., 2000].

Analyses

Crash rates were calculated as the number of crashes over the time period divided by the total number of departures. To examine differences in the rate of crashes before and after the implementation of the initiative, the number of crashes and departures were analyzed using Poisson regression. This method was used due to the relatively low frequency of the events under study and the changing level of exposure by year [Agresti, 2002]. A dichotomous indicator variable representing the two time periods was included in the model and the significance of the corresponding coefficient was used to test the difference in rates before and after the implementation. Due to possible overdispersion for some of the rate data, a quasi-likelihood model was employed using the GENMOD procedure in SAS (SAS Institute, Inc., Cary, NC) version 9.2. Statistical significance was defined as the probability (P-value) of the test value being <0.05. This Poisson regression method was also used to examine the number of CFIT crashes relative to the total number of departures before and after the start of the initiative.

Linear trends in the numbers of crashes over time were assessed through linear regression using the GLM procedure in SAS. A dichotomous indicator variable representing the two time periods was included in the model and the significance of the corresponding interaction coefficient with time (year) was used to test if the trend in crash numbers (linear slope) changed between the two time periods. This same method was used to assess linear trends in the number of occupational fatalities and the number of CFIT crashes between the two time periods. When comparing slopes estimated from separate regression analyses (Alaska vs. the rest of the US), pooled variance t-tests [Zar, 1996] were employed to test for equality.

Previous work by NIOSH examined the lethality of CFIT crashes and identified several important risk factors. In order to examine changes in the risk factors associated with CFIT crashes, the authors performed an analysis similar to the Thomas study [Thomas et al., 2000] for data during 2000–2009. Odds ratios (OR) and 95% confidence intervals (CI) were calculated for each variable to determine what factors were significantly associated with an increased risk for a CFIT crash compared to other types of crashes. Odds were also calculated for the likelihood that a CFIT crash resulted in a fatal crash. Odds ratios were calculated separately, unadjusted for other factors so that the risks associated with known correlated factors (e.g., visibility at the crash site and flying into areas with poor visibility) could be assessed individually. Confounding variables, those strongly correlated with the risk factor and the outcome, can bias the unadjusted odds ratios, although adjusting for some variables does not necessarily eliminate this problem. OR were calculated using SAS (SAS Institute, Inc.) version 9.2. Statistical significance was defined as the probability (P-value) of the test value being <0.05.

RESULTS

During 1990–2009 there were 2,807 aviation crashes in Alaska, mostly in general aviation (Part 91; 76%). Of these total crashes, 568 (20%) involved aircraft flying under Part 135 regulations, meaning they were revenue generating air taxi or commuter flights (Fig. 1) and 81 of these Part 135 crashes resulted in a fatal crash. While overall aircraft crashes in Alaska accounted for only 7% of all crashes in the US during this time, approximately one out of every three Part 135 crashes in the US (35%) occurred in Alaska. There was a general decrease in the number of Part 135 crashes during the study period in both Alaska and the rest of the US (Fig. 1). Departures for Alaska commuter flights were the highest during 1996–2004. In the rest of the US, commuter departures showed

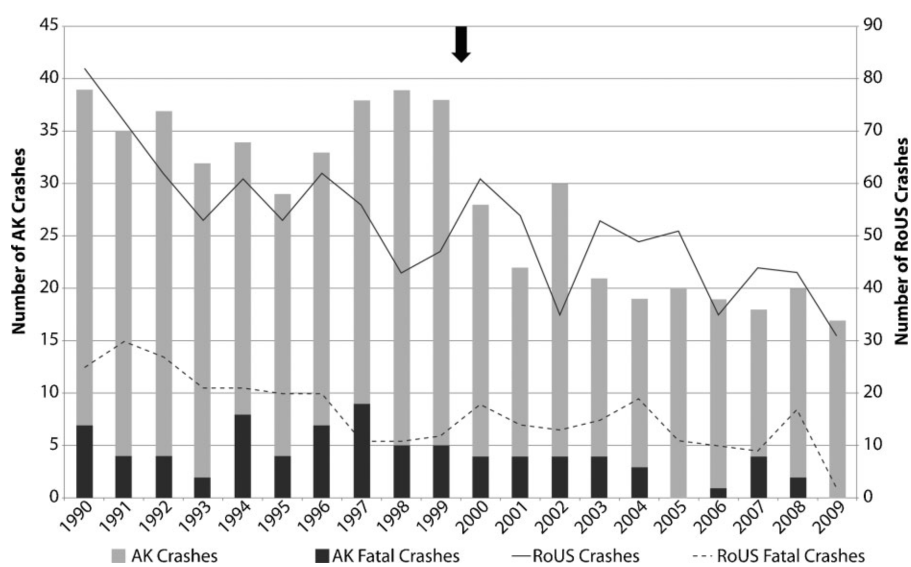

FIGURE 1. Number of air taxi and commuter aviation (Part 135) crashes in Alaska and the rest of the US before (1990–1999) and after (2000–2009) the start of the Alaska Interagency Aviation Safety Initiative (arrow). Bars show the number of Part 135 crashes in Alaska with fatal crashes in a darker color. Numbers of Part 135 crashes in the rest of the US (RoUS) are indicated as a solid line and fatal crashes as a dashed line.

a general increase from 1990 to 2005, followed by a decrease in departures through 2009. Alaska also showed an overall statistically significant decrease in the number of occupational deaths attributable to aircraft crash (Fig. 2; $P < 0.001$) although the average annual decrease in crashes did not differ significantly between the two time periods (slope test, $P = 0.853$). There were a higher number of occupational deaths due to aircraft crashes in 2000 and 2001 (17/year) compared with the rest of the decade (average of 6/year), including the two deadliest nonmilitary occupational crashes in Alaska during the time period which resulted in five and nine occupational fatalities, respectively. The overall decrease in Alaska occupational deaths due to aircraft crash was especially evident for commercial pilots. During 1990–1999 there was an average of 10 commercial pilot deaths in aviation crashes in Alaska per year. This declined by 50%, to an average of 5 per year during 2000–2009. There were a total of 46 occupational pilots deaths during 2000–2009 which corresponds to an annual pilot fatality rate of 177 deaths per 100,000 pilots (estimated annual population of 2,600 air taxi and commuter pilots in Alaska [Conway et al., 2004]).

Several comparisons were performed on the number and rates of crashes before and after start of the public health effort in 2000. There were statistically significant decreases in the rates of crashes between the two time periods for all operation types (Table II). Numbers of fatal crashes decreased more than all crashes combined with a 53% decrease in the number of Part 135 fatal crashes in Alaska compared to a 40% decrease in the number of all Alaska Part 135 crashes. Of the 568 air taxi and commuter crashes (Part 135) in Alaska during 1990–2009, there was an average of 35 per year during 1990–1999 and 21 per year during 2000–2009. As a comparison for Alaska, the number and rate of crashes involving Part 135 flights for the rest of the US (excluding Alaska) were examined during both time periods (Table II). Rates of both fatal and all crashes for Part 135 flights in the rest of the US decreased significantly. The numbers of Part 135 fatal crashes in the rest of the US decreased by 35% between the time periods, while all Part 135 crashes showed a 23% decrease.

Significant differences in rates between the two time periods could be due to a steady annual decrease in the number of crashes. Linear regression was used to assess this possibility. Analysis of the total number of Part 135 crashes for the rest of the US (excluding Alaska) failed to find a difference in the decrease in the number of crashes per year between the two time periods ($P = 0.357$) and thus supported a constant decrease per year over the 20 years. For the fatal Part 135 crashes for the rest of the US the difference in the change in the number of crashes per year was also not significant ($P = 0.091$), supporting a constant decrease per year over the 20 years.

Analysis of the total number of Part 135 crashes for Alaska indicated a significant and downward change in the number of crashes per year between the two time periods ($P = 0.029$). The number of fatal Part 135 crashes for Alaska also showed a downward change between the time periods, but the difference was not statistically significant ($P = 0.087$). Since the difference in the change in number of crashes per year for the Part 135 crashes for the rest of the US was nonsignificant, the overall decrease per year (slope) was estimated for the entire 20-year period using linear regression. This value was compared to the estimated decrease per year (slope) for the Part 135 Alaska crashes to determine if there was a steeper decline in Alaska than the decline experienced in the rest of the US (data in Fig. 1). During 1990–1999, before the start of the

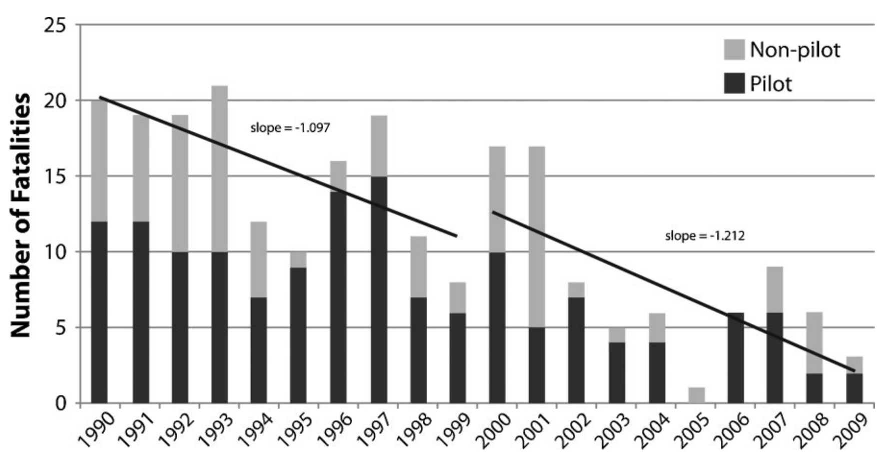

FIGURE 2. Number of occupational fatalities in Alaska due to aviation crashes for commercial pilots and all other workers. Regression lines represent linear trends before (1990–1999) and after (2000–2009) the start of the Alaska Interagency Aviation Safety Initiative. The slopes between the two periods are not significantly different ($P = 0.853$). Does not include active military.

TABLE II. Number and Rate of Aviation Crashes in Alaska and the Rest of the United States During the Two 10-Year Periods Before and After the Start of the Initiative Aimed at Reducing Alaska Air Taxi and Commuter (Part 135) Aviation Crashes

			1990–1999	2000–2009	Test of change in rates*
Region	**Operation type**	**Crashes included**	**Number (Rate[a])**	**Number (Rate[a])**	***P*-value**
Alaska	Part 135	Fatal	55 (13.8)	26 (6.0)	<0.001
		All	354 (88.5)	214 (49.1)	<0.001
	All	Fatal	187 (17.9)	102 (9.4)	<0.001
		All	1663 (159.0)	1144 (105.8)	<0.001
RoUS[b]	Part 135	Fatal	198 (3.3)	128 (1.9)	0.003
		All	591 (9.7)	456 (6.7)	<0.001

*Significant difference in rates between time periods based on Poisson regression quasi-likelihood test.
[a]Rate per 1 million air taxi and commuter departures based on Terminal Area Forecast data available from http://aspm.faa.gov/main/taf.asp.
[b]RoUS, rest of the United States, excludes Alaska.

initiative, Alaska did not show any decline in the number of Part 135 crashes and the estimated slope was significantly larger than that estimated for the rest of the US (t-test of slopes, $P = 0.007$). After the start of the initiative, 2000–2009, there was no significant difference between the rate of decline observed in the rest of the US and that observed in Alaska (t-test of slopes, $P = 0.171$); both indicated decreasing numbers of crashes over the time period. Thus, while the rest of the US showed a downward trend in the total number of Part 135 crashes during 1990–2009, Alaska did not show any decline during 1990–1999, but did show an annual decline similar to the rest of the US during 2000–2009.

The analysis of risk factors for CFIT crashes in Alaska during 2000–2009 included review of 265 crashes to fixed-wing aircraft operated by companies with active Part 135 certificates. Of these, 28 crashes were fatal, resulting in the death of 24 pilots and 64 passengers. In 26 (10%) of the 265 crashes, the pilot had inadvertently flown the aircraft into terrain or water (CFIT crash, Fig. 3, 2000–2009). Only one such crash occurred per year during 2005–2008. While accounting for a small number of the total crashes, CFIT events accounted for 39% (11) of the fatal crashes and 35% (31) of all fatalities. When examining crashes, CFIT crashes were 9.6 times more likely to have resulted in a fatality than a nonCFIT crash (95% CI: 3.8, 24.1). The majority of CFIT crashes (62%) and fatalities (77%) occurred after the pilot had flown from areas of good visibility permitting VFR into areas of reduced visibility (IMC). Based on previous findings several variables were examined for their relationship with the likelihood of a CFIT crash (Table III). Weather and visibility were strong risk factors. CFIT crashes were 85 times more likely to have occurred in IMC than VMC. A related variable indicated that CFIT crashes were 62 times more likely to have occurred as a result of flying VFR into IMC. Twenty (77%) of the 26 CFIT crashes occurred in IMC, and in 16 of these the pilot had flown from an area of good visibility

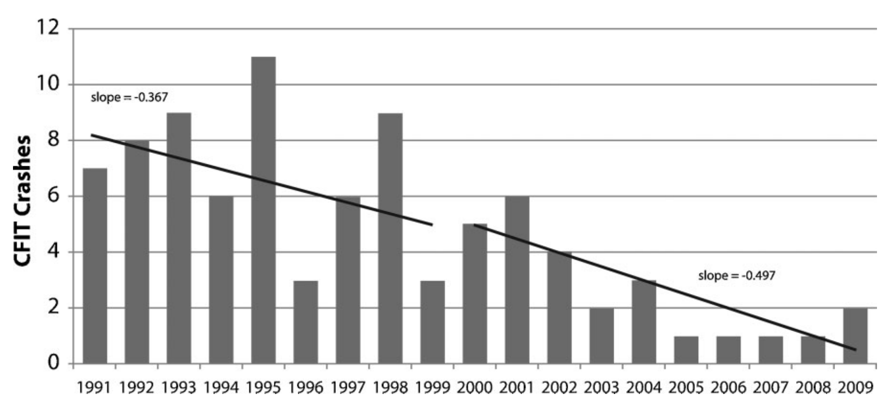

FIGURE 3. Number of fixed-wing aviation crashes in Alaska (fatal and nonfatal) for air taxi and commuter operations (Part 135 and Part 91) which resulted from controlled flight into terrain (CFIT). Regression lines represent linear trends before (1991–1999) and after (2000–2009) the start of the Alaska Interagency Aviation Safety Initiative. The slopes between the two periods are not significantly different ($P = 0.708$). Data for 1991–1998 are from Thomas et al. (2000) and use the same case definition.

TABLE III. Risk Factors for Odds of a Controlled Flight Into Terrain (CFIT) Crash by a Fixed-Wing Commuter or Air Taxi Aircraft in Alaska, 2000–2009

Risk factor	CFIT	NonCFIT	Odds ratio (95% CI)	Crashes ($n = 265$)
IMC	20	9	85.19*	265
vs. VMC	6	230	(27.53–263.58)	
VFR into IMC	16	6	62.13*	265
vs. other condition	10	233	(20.04–192.69)	
Night	3	8	3.89	261[a]
vs. daylight	22	228	(0.96–15.72)	
1 Person on board	10	90	1.03	265
vs. more than one	16	149	(0.45–2.38)	
Total pilot hours $\leq$6,000	14	128	1.01	265
vs. >6,000	12	111	(0.45–2.28)	
Multiple engines	8	50	1.66	263[a]
vs. single engine	18	187	(0.68–4.05)	

IMC, instrument meteorological conditions; VMC, visual meteorological conditions; VFR, visual flight rules; CI, confidence interval.
*$P < 0.05$.
[a]Some records lacked complete daylight and engine count information.

allowing for VFR. CFIT crashes were more likely to have occurred at night than during daylight although the variable was not significant. While the majority of all crashes occurred during daylight, 14% of the CFIT crashes occurred at night, while only 4% of the nonCFIT crashes occurred in those conditions. The variables indicating presence of other people on board, total pilot hours, and number of engines were not significant risk factors.

Including the data from Thomas et al. [2000] and taking into account the number of departures in Alaska, there was a significant difference in the rate of CFIT crashes between 1991–1999 and 2000–2009 (Poisson regression, $P < 0.001$) The average annual number of CFIT crashes among Part 135 operators decreased from 7 per year during the 1990s to an average of 3 a year during 2000–2009, with over half of these occurring in the first 3 years (Fig. 3). During 2005–2008 there was only one CFIT crash per year in Alaska involving a Part 135 operator. To assess whether the difference in rates was due to an overall decline, linear regression of the number of CFIT crashes was employed. The analysis indicated that there was an overall decrease ($P < 0.001$) but did not support a statistically significant more rapid decline in the numbers of CFIT crashes during 2000–2009 relative to the 1990s ($P = 0.708$).

DISCUSSION

Alaska experienced fewer aviation crashes and a lower crash rate during 2000–2009 compared to the previous 10-year period. Although all nonmilitary aviation operations in Alaska showed a significant rate decrease, the greatest improvements were seen in fatal air taxi/commuter (Part 135) crashes with a 57% decrease in rates and 53% decrease in numbers. Part 135 operations in the rest of the US also showed a significant percent decrease in the rate of crashes between the two time periods for fatal crashes and the total overall. Although the general trend in the data was one of increased safety over the 20-year time period, Alaska Part 135 crashes were not decreasing during the 1990s, and only after the start of the initiative, during 2000–2009, did the number of Part 135 crashes decline.

Reductions in the numbers and rates of Part 135 fatal and nonfatal crashes in both Alaska and the rest of the US indicate a trend of improved safety in this segment of the aviation industry and agree with the recent findings of Baker et al. [2009]. Enhanced safety in Part 135 operations may be due to development and installation of better safety equipment in aircraft, implementation of safety management systems, crew resource management training, advanced technology in simulators used for training, and an industry focus on safety [FAA, 2010].

Efforts of the AIASI were focused on air taxi/commuter operations and on preventing the most injurious events, CFIT crashes and continuation into adverse weather. While our results did not identify a significantly sharper decline in CFIT crashes compared to the prior decade, there was a marked decline during the intervention and the decrease in rates between the two periods and low frequency of CFIT crashes during 2000–2009 support the effectiveness of these efforts. One factor in this statistical outcome may have been our conservative approach of setting the cutpoint at the beginning of the AIASI funding, while many of the interventions were not implemented until 2001 or later. Also, as the number and rate of crashes approach zero, it becomes more difficult to detect statistically significant differences. Unfortunately, CFIT crashes in Alaska continue to be more likely to result in a fatality than other types of crashes. Flight into adverse weather may increase the risk of fatality due to high impact forces when pilots crash into unseen terrain, as well as hamper search and rescue efforts; cold temperatures may limit survivability of injured persons while waiting for rescue [Baker et al., 2008]. Compared to the Thomas et al. study, those CFIT crashes which occurred after the start of the AIASI were even more likely to occur in IMC (85 times more likely vs. 47 times more likely), and as a result of flying VFR into IMC (62 times more likely vs. 46 times more likely). These results may suggest that these rare, but even more lethal events may now occur in circumstances wherein not all pilots have appropriate information and decision making abilities to avoid IMC, or other human factor issues still need to be addressed. A human factors analysis of general aviation accidents in Alaska compared with the rest of the US identified several important "unsafe acts" [Detwiler et al., 2006]. Overall skill-based errors were the most prevalent error noted in accident data, although in Alaska there were more decision errors and fewer skill-based errors than in the rest of the US [Detwiler et al., 2006]. Accidents in Alaska were more likely to include intentional flight from VFR into IMC or into adverse weather conditions, and accounted for 47% of the accidents included in the general aviation study. Clearly more work on possible interventions needs to be done to identify training, infrastructure, information, or cultural changes to dissuade pilots from flying into adverse weather.

The AIASI may have also contributed to the reduction of accidents due to other causes and for other types of flying. For instance, the Medallion Foundation's Five Star Program included an Operational Control Program and Maintenance and Ground Program, as well as a CFIT Avoidance Program. The "mike-in-hand" program could be used to obtain wind direction and velocity information as well as visibility and ceiling conditions during en route flight. Internet access to weather cameras is publicly available, and the Capstone program's navigational equipment was available for installation in general aviation and public use aircraft.

Some of the reduction in CFIT crashes may also have been the result of implementation of the Single-Engine Instrument Flight Rules in 1998, which was not part of the initiative. This rule allowed commercial, passenger-carrying Part 135 operations using instrument flight rules (regulations and procedures for flying aircraft by reference only to the aircraft instrument panel for navigation) in single-engine airplanes; planned flight under instrument flight rules into IMC by appropriately equipped aircraft may reduce the number of VFR flights conducted in marginal weather and in IMC. Planned flight under IFR into IMC might prevent crashes as pilots may have an option to avoid flights low to the ground in order to avoid clouds, in addition new technology pairing satellite-based signals with ground reference stations may allow navigation, approaches and landings to airports where none existed previously. Operators' equipage of aircraft and pilot and controller training are required to take full advantage of the new capabilities [Federal Aviation Administration, 2011].

The AIASI was a multifaceted approach and therefore it is difficult to pinpoint how much any one-intervention strategy contributed to the overall success. The Capstone project has been reviewed as very successful; in 2000–2004 an estimated 44% of preventable navigation and CFIT accidents in the targeted area of Western Alaska were avoided as a result of Capstone [Herrick and Murphy, 2005]. This estimate was based on the number of flight operations equipped with the avionics and the average effectiveness of pilots using them [Herrick and Murphy, 2005; pg. 57]. This project also paved the way for a national deployment of Automatic Dependent Surveillance-Broadcast (ADS-B) technology. This technology is a critical component of the Next Generation Air Transportation System, which will be made operational throughout the US national airspace system [Federal Aviation Administration, 2007b]. An early analysis of the AIASI found that Medallion Foundation's activities were associated with safe flying, although it was difficult to determine whether the Foundation caused the changes or merely identified them [Berman et al., 2005]. This study found that after accounting for the type of flying, region of operations, and company size, companies with Medallion stars were more likely to have lower fatal crash rates than those without.

Fewer fatal crashes translate into a safer work environment for commercial pilots and other workers in Alaska. The annual occupational fatality rate for pilots in Alaska decreased substantially from 410 fatalities per 100,000 workers in the 1990s [Conway et al., 2002] to 177 fatalities per 100,000 workers during 2000–2009. Previous research has identified limited experience, lower pilot ratings [Li et al., 2001], later initial licensing [Groff and Price, 2006], and older age [Groff and Price, 2006] of pilots as risk factors for crashes, although there is evidence against the simple association of age and increased risk [Li et al., 2001, 2006; Rebok et al., 2009]. Our CFIT results did not find a relationship between flight experience and the likelihood of a CFIT crash, but this could be due to the simplified design of the variable, using only two categories. The analysis of a statewide survey conducted by NIOSH as part of the AIASI revealed that air taxi/commuter operators in Alaska with high crash rates had pilots who worked on average 10 hr more a week than those working for operators without high crash rates, and their pilots had on average less career flight experience [Conway et al., 2005]. The pilots of high crash rate air taxi/commuter operators were also three times as likely as other pilots to fly daily into unknown weather conditions.

Future research should focus on the interaction of real-time weather information and pilot decision making so that CFIT crashes can be minimized. Also, while fatigue has been identified as an important risk factor for short-haul operations [Conway et al., 2005; Goode, 2003; Powell et al., 2007] the specific effect fatigue plays in decision making for pilots should be explored further. Some of the interventions applied in Alaska are being expanded to the rest of the US, most notably the use of ADS-B. Research of how this expansion affects local crash rates might help to identify the individual role of this technology in reducing crashes.

The AIASI is an example of the public health approach which can be applied to other broad-reaching injury prevention programs. This approach includes an ever-refining cycle of surveillance, risk factor identification, development and implementation of prevention strategies, evaluation and repetition/refinement until the injuries are reduced or eliminated. The effectiveness of this program was likely improved through the cooperation of government agencies, industry, and individual workers and the availability of complete injury data through the NTSB and NIOSH Alaska Pacific Regional Office was critical in the ability to evaluate the initiative.

This coordinated application of several intervention activities to address a significant public health problem was successful in reducing fatalities, crashes, and CFIT crashes in the air taxi/commuter industry in Alaska. In this example the programs were diverse, focused on the critical risk factors and most injurious events, and involved many segments of the aviation industry including pilots, operators, passengers, regulators, and governmental and nongovernmental agencies. This successful multifaceted approach might be applied to reduce occupational fatalities and injuries in other industries.

REFERENCES

Agresti A. 2002. Categorical data analysis. 2nd edition. New Jersey: John Wiley & Sons, p. 710.

Aircraft Owners and Pilots Association Air Safety Foundation. 2007. 2007 Nall report: Accident trends and factors for 2006. Frederick, MD: AOPA Air Safety Foundation.

Alaska Department of Health and Social Services. 2010. Section 10. Occupational Safety & Health. Health Alaskans 2010, Volume 1: Targets for improved health Juneau. AK: State of Alaska.

Baker SP, Qiang YD, Rebok GW, Li GH. 2008. Pilot error in air carrier mishaps: Longitudinal trends among 558 reports, 1983–2002. Aviat Space Environ Med 79:2–6.

Baker SP, Groff L, Haaland W, Qiang YD, Rebok GW, Li G. 2009. Crash rates of scheduled commuter and air carrier flights before and after a regulatory change. Aviat Space Environ Med 80:381–385.

Bearman C, Paletz SBF, Orasanu J. 2009. Situational pressures on aviation decision making: Goal seduction and situation aversion. Aviat Space Environ Med 80:556–560.

Bensyl DM, Moran K, Conway GA. 2001. Factors associated with pilot fatality in work-related aircraft crashes, Alaska, 1990–1999. Am J Epidemiol 154:1037–1042.

Berman M, Martin S, Hill A. 2005. Evaluation of the Alaska Interagency Aviation Safety Initiative Anchorage. AK: University of Alaska Anchorage, Institute of Social and Economic Research.

Boeing. 2010. Statistical Summary of Commercial Jet Airplane Accidents: Worldwide Operations 1959–2009. http://www.boeing.com/news/techissues/pdf/statsum.pdf, Accessed on: 9 Dec 2010.

Conway GA, Lincoln JM, Husberg BJ, Manwaring JC, Klatt ML, Thomas TK. 1999. Alaska's model program for surveillance and prevention of occupational injury deaths. Public Health Rep 114:550–558.

Conway GA, Lincoln JM, Hudson DS, Bensyl DB, Husberg BJ, Manwaring JC. 2002. Surveillance and Prevention of Occupational Injuries in Alaska: A Decade of Progress, 1990–1999. Cincinnati, OH: Department of Health and Human Services, Centers for Disease Control and. Prevention National Institute for Occupational Safety and Health.

Conway GA, Hill A, Martin S, Mode NA, Berman M, Bensyl D, Manwaring JC, Moran K. 2004. Alaska air carrier operator and pilot safety practices and attitudes: A statewide survey. Aviat Space Environ Med 75:984–991.

Conway GA, Mode NA, Berman MD, Martin S, Hill A. 2005. Flight safety in Alaska: Comparing attitudes and practices of high- and low-risk air carriers. Aviat Space Environ Med 76:52–57.

Coyne JT, Baldwin CL, Latorella KA. 2008. Pilot weather assessment: Implications for visual flight rules flight into instrument meteorological conditions. Int J Aviat Psychol 18:153–166.

Detwiler C, Hackworth C, Holcomb K, Boquet A, Pfleiderer E, Wiegmann D, Shappell S. 2006. Beneath the tip of the iceberg: A human factors analysis of general aviation accidents in alaska versus the rest of the United States. Washington, DC: Federal Aviation Administration. p 14.

FAA. 2010. Testimony of Peggy Gilligan, Associate Administrator for Aviation Safety. Subcommittee on Aviation on FAA's Oversight of On-Demand Aircraft Operations, House Committee on Transportation and Infrastructure, US House of Representatives: Federal Aviation Administration.

Federal Aviation Administration. 2007. Appendix A: Methodology for the 2007 General Aviation and Part 135 Activity Survey. Washington, DC: Federal Aviation Administration. http://www.faa.gov/data_research/aviation_data_statistics/general_aviation/CY2007/media/FAA%202007%20Appendix%20A%20Methodology.doc, Accessed on: 29 Sept 2009.

Federal Aviation Administration. 2007. Fact Sheet—Next Generation Air Transportation System 2006 Progress Report. October 10, 2007. http://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=8336.

Federal Aviation Administration. 2009. Circle of Safety—Information for Passengers: Alaska Region Flight Standards, Federal Aviation Administration. http://www.faa.gov/about/office_org/headquarters_offices/avs/offices/afs/divisions/alaskan_region/circleofsafety/, Accessed on: 20 December 2010.

Federal Aviation Administration. 2011. FAA's NextGen implementation plan. Washington, DC: Federal Aviation Administration.

Goh J, Wiegmann D. 2002. Human factors analysis of accidents involving visual flight rules flight into adverse weather. Aviat Space Environ Med 73:817–822.

Goode JH. 2003. Are pilots at risk of accidents due to fatigue? J Safety Res 34:309–313.

Groff LS, Price JM. 2006. General aviation accidents in degraded visibility: A case control study of 72 accidents. Aviat Space Environ Med 77:1062–1067.

Herrick P, Murphy P. editors. 2005. The impact of capstone phase I program: Final report. Anchorage, AK: University of Alaska Anchorage and MITRE.

Kobelnyk G. 2004. A review of accidents involving Alaskan air taxi commercial flight operations 1983–2000. Anchorage, AK: Federal Aviation Administration.

Li G, Baker SP. 1993. Crashes of commuter aircraft and air taxi crashes: What determines pilot survival? J Occup Med 35:1244–1249.

Li GH, Baker SP. 2007. Crash risk in general aviation. JAMA 297:1596–1598.

Li GH, Baker SP, Grabowski JG, Rebok GW. 2001. Factors associated with pilot error in aviation crashes. Aviat Space Environ Med 72:52–58.

Li GH, Gebrekristos HT, Baker SP. 2008. FIA score: A simple risk index for predicting fatality in aviation crashes. J Trauma Injury Infect Crit Care 65:1278–1283.

Li GH, Grabowski JG, Baker SP, Rebok GW. 2006. Pilot error in air carrier accidents: Does age matter? Aviat Space Environ Med 77:737–741.

Mercy JA, Rosenberg ML, Powell KE, Broome CV, Roper WL. 1993. Public-health policy for preventing violence. Health Affairs 12:7–29.

National Transportation Safety Board. 1989. Safety report: General aviation accidents involving visual flight rules into instrument meteorological conditions. Washington, DC: National Transportation Safety Board.

National Transportation Safety Board. 1995. Aviation safety in Alaska: Safety study. Washington, DC: National Transportation Safety Board.

NTSB. 1999. Testimony of James LaBelle, Chief of the Northwest Field Office, NTSB. Transportation Subcommittee, Committee on Appropriations, US Senate: National Transportation Safety Board.

Pauley KA, O'Hare D, Mullen NW, Wiggins M. 2008. Implicit perceptions of risk and anxiety and pilot involvement in hazardous events. Hum Factors 50:723–733.

Powell DMC, Spencer MB, Holland D, Broadbent E, Petrie KJ. 2007. Pilot fatigue in short-haul operations: Effects of number of sectors, duty length, and time of day. Aviat Space Environ Med 78: 698–701.

Rebok GW, Qiang YD, Baker SP, Li GH. 2009. Pilot age and error in air taxi crashes. Aviat Space Environ Med 80:647–651.

Shappell SA, Wiegmann DA. 2003. A human error analysis of general aviation controlled flight into terrain accidents occurring between 1990–1998. Washington, DC: Office of Aerospace Medicine. p 25.

Smith GS. 2001. Public health approaches to occupational injury prevention: Do they work? Injury Prev 7:i3–i10.

Stout NA. 2008. The public health approach to occupational injury research: From surveillance to prevention. Safety Sci 46:230–233.

Stout N, Linn H. 2001. From strategy to reality: 25 Years of planning and progress in occupational injury research. Injury Prev 7:i11–i14.

Stout NA, Linn HI. 2002. Occupational injury prevention research: Progress and priorities. Injury Prev 8:IV9–IV14.

Thomas TK, Bensyl DM, Manwaring JC, Conway GA. 2000. Controlled flight into terrain accidents among commuter and air taxi operators in Alaska. Aviat Space Environ Med 71:1098–1103.

Wiegmann DA, Goh J, O'Hare D. 2002. The role of situation assessment and flight experience in pilots' decisions to continue visual flight rules flight into adverse weather. Hum Factors 44:189–197.

Zar JH. 1996. Biostatistical analysis. 3rd edition. New Jersey: Prentice Hall.