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A Human Factors Analysis of Fatal and Serious Injury Accidents in Alaska, 2004-2009

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16. Abstract

This report summarizes the analysis of 97 general aviation accidents in Alaska that resulted in a fatality or serious injury to one or more aircraft occupants for the years 2004-2009. The accidents were analyzed using the Human Factors Analysis and Classification System (HFACS) developed by Douglas Weigmann and Scott Shappell. As found in previous studies of this nature, Skill-Based Errors were found to be the most common accident causal factor, followed by Violation, Decision-Based Error, and Perceptual Error. Comparison of the findings to previous research finds both similarities and contrasts. Recommendations for preventing accidents are provided.

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INTRODUCTION

General aviation (GA) activity in Alaska has always been extremely vital to that state's economy and industry. GA accidents have a much greater effect on the Alaskan economy relative to other areas of the country. To get a clearer picture of accidents that have a major effect on pilots and passengers, there was a need to review accidents in which a fatality or serious injury (FSI) occurred. According to the National Transportation Safety Board (NTSB, Part 830.2, Definitions), a serious injury is any injury that:

1. Requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received;
2. Results in a fracture of any bone (except simple fractures of fingers, toes, or nose);
3. Causes severe hemorrhages, nerve, muscle, or tendon damage;
4. Involves any internal organ; or
5. Involves second- or third-degree burns, or any burns affecting more than 5% of the body surface.

In early 2010, a working group was formed with the intent of reviewing FSI GA aircraft accidents in Alaska. The goal of the review was to develop interventions and mitigation strategies to reduce the number of accidents or their severity. A total of 97 accidents were analyzed, covering all Alaska FSI accidents during the years 2004-2009.

The Code of Federal Regulations, Title 14 (14CFR), Part 91, covers operating requirements for GA flights within the U.S. Part 135 of the code further covers operating requirements for commuter and on-demand operations and rules governing persons onboard such aircraft. Both Part 135 and Part 91 accidents were included in the analysis. The primary difference between Part 91 and Part 135 operations is that Part 135 operations are for the purpose of conducting business with the public for compensation. Therefore, operational requirements are more stringent than operations conducted under Part 91. However, some Part 91 flights are conducted as incidental business, such as a hunting lodge. These operations are referred to in this dataset as Part 91 commercial (91c) operations. The dataset included 55 Part 91 accidents, 18 Part 91c accidents, and 24 Part 135 accidents.[1] In addition, accidents were characterized by whether there was at least one fatality or only a serious injury. Of the 97 accidents, 56 had at least one fatality, 41 had at least one serious injury (but no fatalities).

The FSI team reviewed each of the accidents and identified one or more causal factors. The causal factors used were based loosely on those found in the NTSB accident reports but included several ad hoc factors identified by the team. In all, 24 causal factors were established by the team. The reader is referred to an FAA review (FAA 2010) of those causal factors and accident summary. Because of the ad hoc nature of many of the factors, a separate effort was undertaken by the author to categorize the accidents using a well-established accident taxonomy, the Human Factors Analysis and Classification System (HFACS; Weigmann & Shappell, 2003). HFACS allows a comparison of the results to those of similar efforts (e.g., Detwiler et al., 2006). This report is a summary of the HFACS analysis of the Alaska FSI dataset.

SUMMARY OF THE ACCIDENT DATASET

Figure 1 shows the locations of the accidents in the dataset. Red (darker colored) pushpins denote fatal accidents, and yellow (lighter colored) pushpins denote serious injury accidents. As can be seen in the figure, the accident sites are distributed widely across the entire state. However, there is a higher concentration of accidents around the Anchorage area, which is located in the central southern portion of the state. This is to be expected, given that the majority of the population is located in this area, as well as the majority of flight operations. Likewise, both fatal and serious injury accidents are fairly evenly distributed across the state, with the exception of areas in southeast Alaska and central Alaska in the vicinity of Denali National Park. Both of these areas can be characterized as areas of extremely rugged mountainous terrain, which increases the probability of accidents being fatal.

Table 1 provides some basic demographic data regarding the accident dataset. The table breaks out the data in two separate ways: first, by Part (91, 91c, and 135), and

[1]Some of the accidents included as Part 135 were actually Part 133 – Rotorcraft external-load operations, but were included with Part 135 because the operation was similar in professionalism and requirements to Part 135.

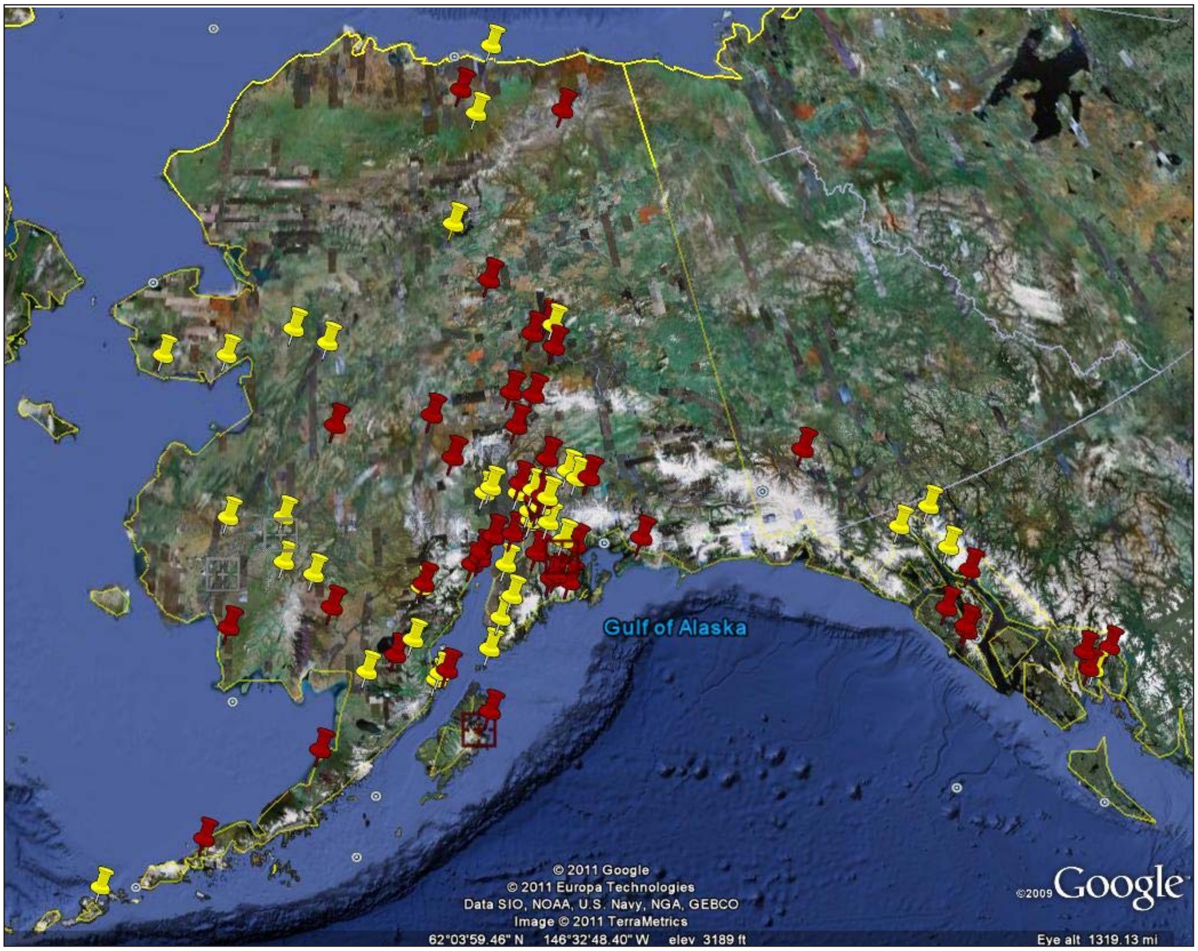

Figure 1. Dataset accident locations color coded by accident severity (yellow = serious injury, red = fatality).

Table 1. FSI accident set demographics.

	No. of Accidents	Mean Pilot Total Experience in Hours (range)	Mean Pilot Experience Last 90 Days (range)	Mean Pilot Age (range)
Part 91	55	4,168 (19-27,200)	52 (2-250)	53 (27-82)
Part 91 (Commercial)	18	6,396 (487-15,000)	126 (40-260)	52 (24-71)
Part 135	24	8,330 (1,280-24,850)	200 (22-467)	43 (25-66)
Serious Injury Accidents	41	5,964 (136-24,850)	125 (10-358)	50 (25-73)
Fatal Accidents	56	5,422 (19-27,200)	110 (2-467)	50 (24-82)
All Accidents	97	5,649 (19-27,200)	118(2-467)	50 (24-82)

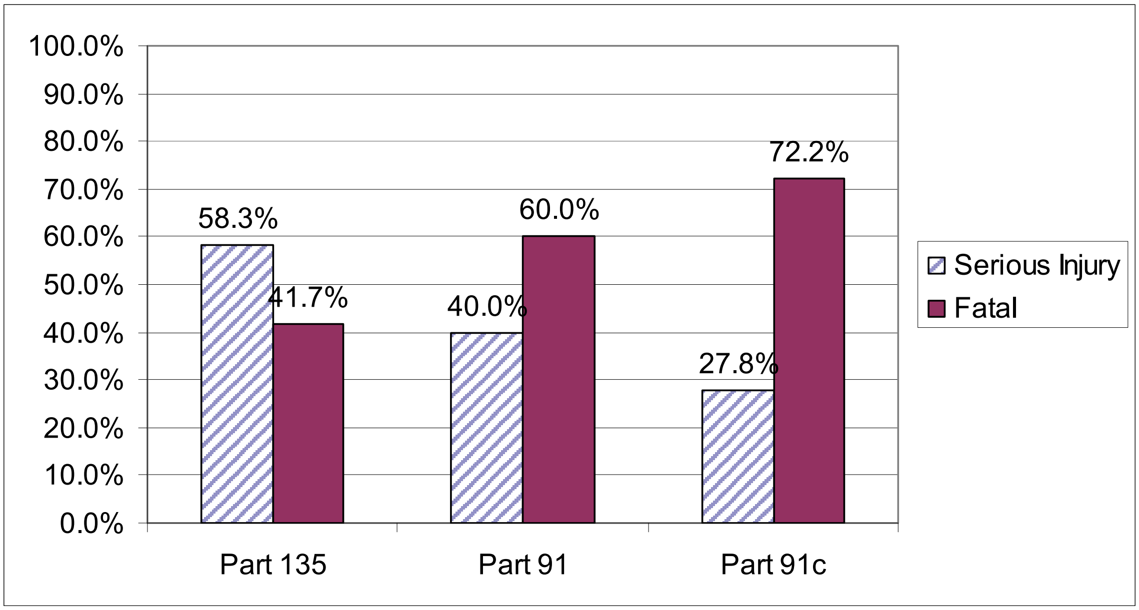

Figure 2. Comparing accident severity by type of operation (Part 135 vs. 91 vs. 91c).

second by accident severity (serious injury and fatality). Pilot demographics include the mean total flight experience of the pilot in hours, the mean flight experience in the last 90 days of flight before the accident, and the mean pilot age.

Looking at the table, we find that the average flight experience is fairly extensive, with a mean flight experience of over 5,600 hours across all of the accident pilots. When pilot statistics are divided according to accident severity (serious injury vs. fatal), we do not see much difference between the groups in terms of experience or age. However, when divided by operation (Part 91 vs. Part 91c vs. Part 135), we see that Part 135 pilots have greater than 4,000 hours more flight experience than Part 91 pilots and approximately 2,000 hours more flight experience, on average, than the Part 91c pilots, even though the average age of Part 135 pilots is 10 years younger than both the Part 91 and 91c pilots. In addition, they logged approximately 150 hours more flight time than the Part 91 pilots and 74 hours more than Part 91c pilots in the 90 days preceding the accident.

In addition to the difference in experience levels between Part 135, Part 91c, and Part 91 accident pilots, there was also a difference in accident severity. Figure 2 shows the breakout of serious injury and fatality accidents by type of operation.

As can be seen in the figure, the majority (60%) of Part 91 accidents in the dataset included at least one fatality. Part 91c accidents had an even higher percentage of fatal accidents at over 72%. On the other hand, the majority of Part 135 accidents were serious injury accidents (58.3%). There are potentially many reasons for this pattern, including stricter regulations governing Part 135 operations and higher levels of professionalism among those pilots. In addition, there are differences in the types of aircraft flown and in how they are maintained. There are also differences in the types of flight operations and the airports and/or off-airport landing sites used by pilots under the different operations. These differences will be referenced in later sections.

Another way to look at the dataset is by phase of flight in which the accident occurred. Figure 3 shows a breakout of the percentage of accidents that occurred during a specific phase of flight.

The phase listed on the right side of Figure 3, maneuvering, refers to a flight that was not traveling from point A to point B, as would occur during the en route phase of flight, but was engaged in some other activity such as looking at a particular point of interest (e.g., animals, campsite) or perhaps simply flying around for fun. They can include instructional flights as well. Also included in the maneuvering phase for this analysis were helicopters that were hovering over a location.

As can be seen in the figure, the takeoff and en route phases account for the most accidents. The maneuvering phase is third, followed by approach, and then landing. It is interesting to note that the landing phase accounts for only 5.2% of the accidents in the dataset. Other reviews of accidents have shown a much higher percentage. For example, in Detwiler et al. (2006), almost 40% of the accidents occurred during landing. One major difference between the Detwiler dataset and the current dataset is that Detwiler included all accident severity levels, not just those resulting in a fatality or serious injury. In addition, Detwiler et al. looked at only Part 91 operations and did not include Part 135 operations.

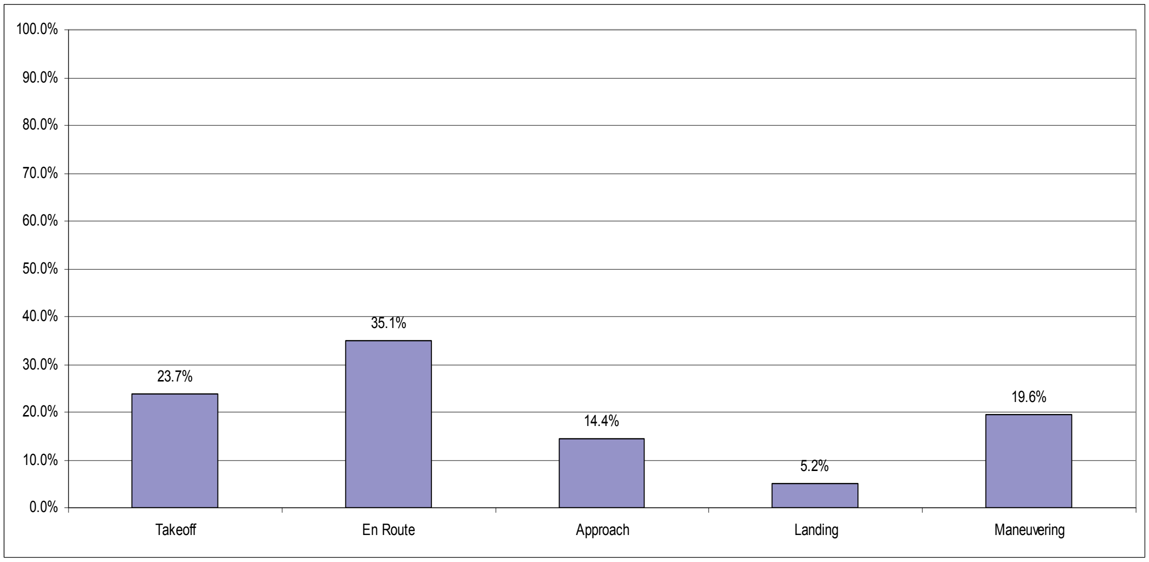

Figure 3. Accident percentage by phase of flight.

If we separate the FSI accidents by type of operation (Part 91 vs. Part 135 vs. Part 91c), we see slightly different patterns in the percentage of accidents associated with a phase of flight. Figure 4 shows the percentage of accidents within each flight phase by type of operation.

Whereas the pattern across phases of flight is similar to the overall dataset, especially for Part 91 accidents, there are some interesting differences. There were no accidents during the landing phase for Part 135 operations. In addition, there were more accidents during the approach phase than during the maneuvering phase. Looking at the actual number of accidents, given that there were a lot more Part 91 accidents than Part 135 accidents, we find that there were far more Part 91 maneuvering phase accidents (16) than Part 135 maneuvering phase accidents (3). If we look at these accidents individually, we find that all three of the Part 135 maneuvering phase accidents involved a rotary wing aircraft. On the other hand, for the Part 91 maneuvering phase accidents, 15 involved fixed wing aircraft, and only one involved a rotary wing aircraft.

In addition to type of operation, we can also look at the percentage of accidents across phases of flight as they relate to accident severity (serious injury vs. fatality). Figure 5 shows these results.

If the accident occurred during takeoff or landing it was more likely to involve a serious injury, but no fatality. Most likely this was because of the lower energies associated with those phases of flight. However, if the accident occurred during the en route phase, it was more likely to involve a fatality. Approach phase accidents were divided equally, while maneuvering accidents slightly favored fatalities.

HUMAN FACTORS CAUSAL ANALYSIS

Only 10 of the 97 accidents, or approximately 10%, did not have an error by the flight crew associated with it. In fact, several of those accidents had errors associated with the maintenance or inspection of the aircraft, which involves a definite human factors component, but these errors were not examined for this analysis. To determine the root human factors causes of these accidents, each accident was reviewed and assigned one or more causal factor based on the HFACS taxonomy (Weigmann & Shappell, 2003). The full HFACS taxonomy uses four levels of causal categories. The highest levels are "Organizational Influences" and "Unsafe Supervision." Because the accidents included Part 91 operations, these levels were of little use in the analysis and so were not included. The third level of categories is "Preconditions for Unsafe Acts." While potentially useful, the limited time frame for conducting the analysis led to the elimination of this level from the analysis as well. Only the lowest level of categorization, "Unsafe Acts," was used. Unsafe acts are divided into five factors: skill-based error, perceptual error, decision error, routine violation, and exceptional violation. A brief description of each of these factors is as follows (from Weigmann & Shappell, 2003):

- Skill-Based Error – occurs with little or no conscious thought and is particularly susceptible to attention and/or memory failures. Examples include the breakdown in visual scan patterns, inadvertent activation/deactivation of switches, forgotten intentions, and omitted items in checklists. Even the manner in (or skill) which one flies an aircraft (aggressive, tentative, or controlled) can affect safety.

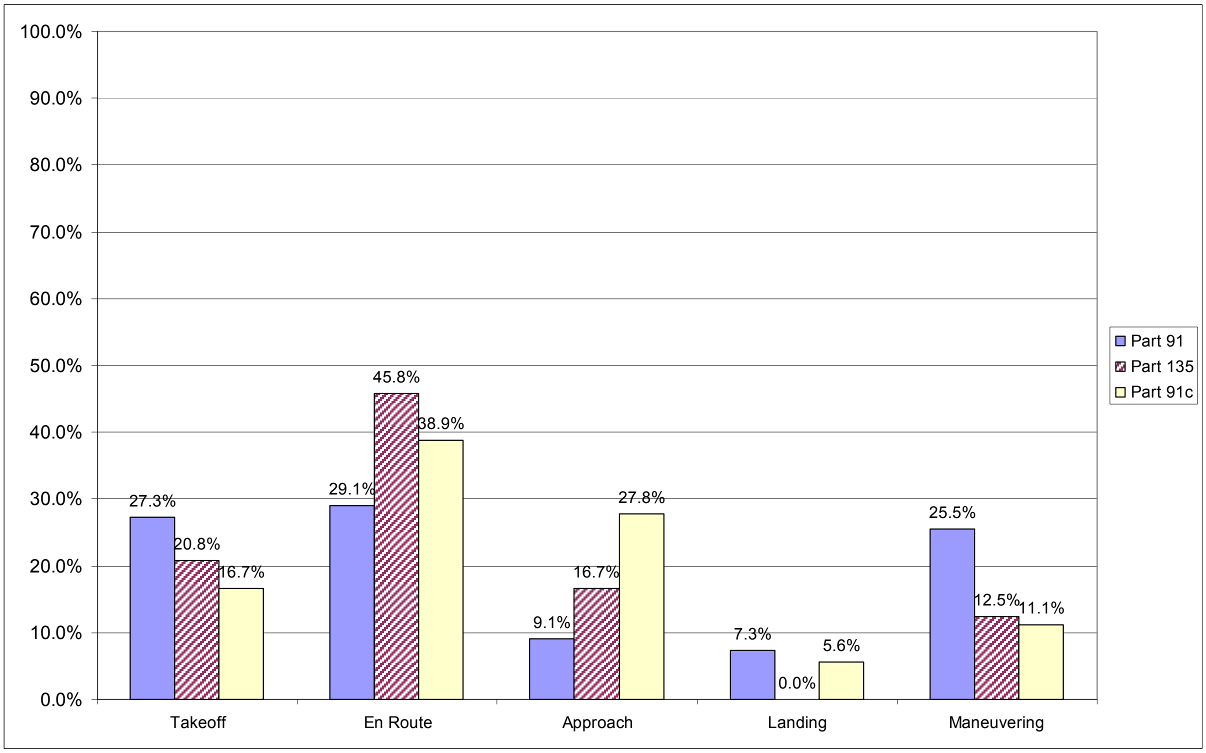

Figure 4. Accident percentage across phase of flight by type of operation.

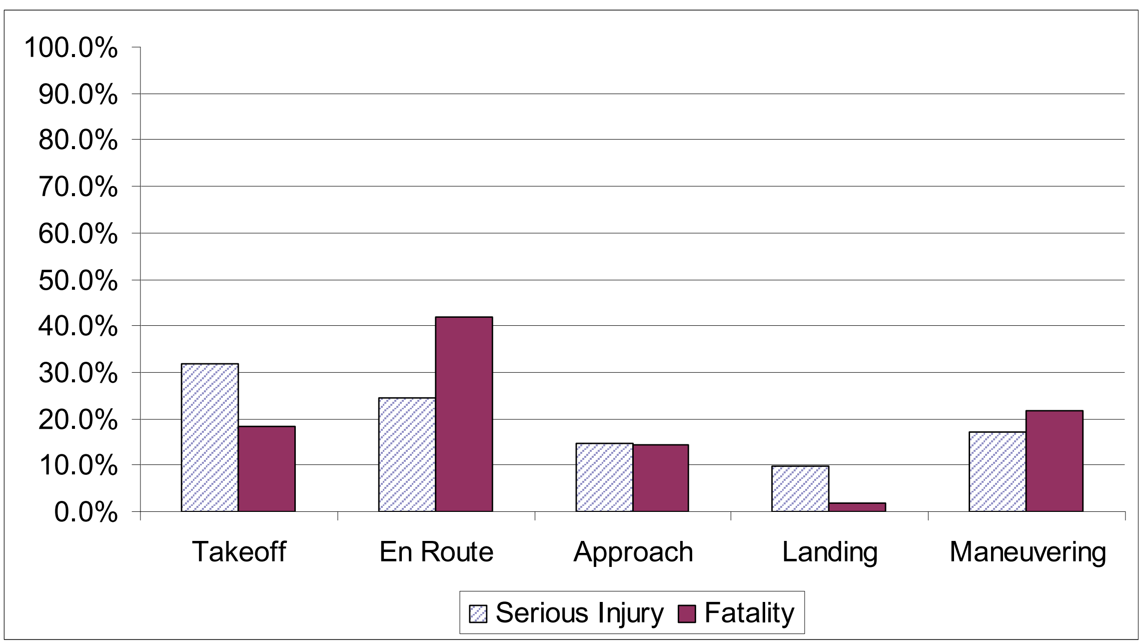

Figure 5. Percentage of accidents across phase of flight by accident severity.

- Perceptual Error – occurs when sensory input is degraded, or "unusual," as is often the case when flying at night, in the weather, or in other visually impoverished environments, causing misjudging distances, altitude, and descent rates, as well as responding incorrectly to a variety of visual/vestibular illusions.
- Decision Error – represents conscious, goal-intended behavior that proceeds as designed, yet the plan proves inadequate or inappropriate for the situation. They manifest as poorly executed procedures, improper choices, or simply the misinterpretation or misuse of relevant information.
- Routine Violation – tends to be habitual by nature and is often enabled by a system of supervision and management that tolerates such departures from the rules. Often referred to as "bending the rules," the classic example is that of the individual who drives his/her automobile consistently 5-10 mph faster than allowed by law.
- Exceptional Violation – is an isolated departure from authority, neither typical of the individual nor condoned by management. For example, driving 105 mph in a 55 mph zone would not be typical of drivers in general and would not be condoned by authorities.

Previous studies using the HFACS taxonomy (notably Detwiler et al., 2006) have grouped all of the violations into a single category. This was done in the current study for comparison with these other studies. While the categorization of the accidents using the HFACS taxonomy was performed solely by the author, there was an attempt to reach a consensus from the other members of the working group. This was accomplished by cross-referencing some of the categories used by the working group against the results of the HFACS categorization. For example, the working group created a category that was referred to as "willful violation." All accidents where "willful violation" was identified as a contributing factor were also given an HFACS label of "violation." The other HFACS factors did not have directly analogous categories from the working group. However, there were categories that at least partially overlapped the HFACS factors. Thus, the working group created a category called "flat light/whiteout." This category was cross-referenced to the HFACS perceptual error factor. In all but one accident, if the accident had been attributed at least partially to "flat light/whiteout," it was also identified as a perceptual error in the HFACS categorization. Likewise, the working group category of "fuel mismanagement" was cross-referenced to the HFACS skill-based error factor. Every fuel mismanagement accident also appeared as a skill-based error accident. So, while there was no direct effort to reach a consensus with the HFACS categorization among the members of the working group, this indirect approach ensured a high level of consensus among the members.

Figure 6 shows the percentage of accidents that have a particular HFACS causal factor. Keep in mind that each accident could have more than one causal factor associated with it, so the percentages will not add up to 100% across all causal factors.

As with the previous study by Detwiler et al. (2006), skill-based errors were the most prevalent, followed by decision errors. Violations were third, followed by perceptual errors. Each of these four categories is discussed in more detail below.

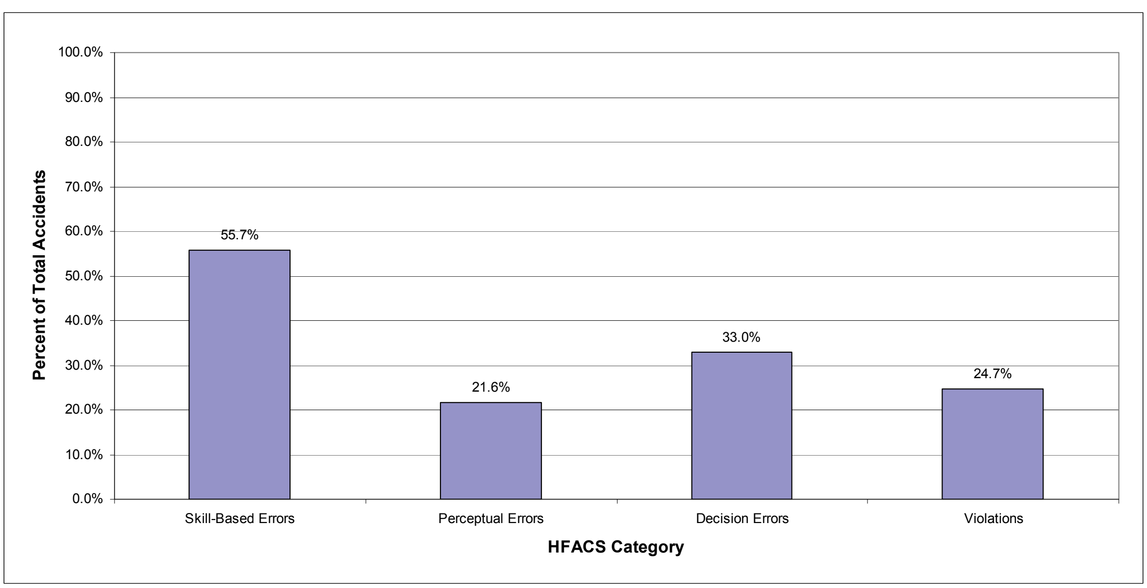

Figure 6. Percentage of accidents across human factors causal factors.

Skill-Based Error Accidents

There were 54 accidents (55.7% of the total number of accidents) in which a skill-based error by the pilot occurred. When we take a closer look at the accidents involving skill-based errors, we find three general types: 1) critical error accidents; 2) beyond ability accidents; and 3) distraction accidents. We will look at each of these types below.

Critical error accidents. The first type is an accident in which a single critical skill-based error led to the failure of the flight. There were 11 critical error accidents, accounting for approximately 21% of the total skill-based accidents. The nature of these accidents varied. However, most of them included the improper performance of a flight or preflight procedure. One accident occurred when the pilot failed to switch fuel tanks, leading to fuel starvation. Seven of the accidents were related to an improper preflight procedure: failing to place a control switch in the proper position (1), not removing the gust locks (2), not checking the fuel correctly (1), not deicing the aircraft sufficiently (1), not verifying correct control surface movement (1), and incorrect hand-propping of the aircraft (1), which resulted in the propeller striking the pilot on the leg. Finally, three critical error accidents occurred when the pilot failed to maintain proper situation awareness. One of these was a helicopter flight in which the pilot did not remember that he was hovering underneath a power line. A second pilot failed to continue monitoring the position of a truck crossing the end of the runway. The last pilot failed to monitor aircraft altitude during landing and misperceived the distance to the surface of the water.

Beyond ability accidents. The second type of skill-based error can be characterized as a situation that is beyond the ability of the pilot to maintain flight control. Thirty-one accidents, or approximately 57% of those involving a skill-based error, were classified as a "beyond ability" accident. The reason that a particular flight situation was beyond the flight ability of the pilot varied from accident to accident. However, there were five factors that were specifically identified as contributory: 1) overloading the aircraft (three accidents); 2) encountering unexpected wind conditions (12 accidents); 3) a mechanical malfunction with the aircraft that led to either a pilot distraction or change in aerodynamics of the aircraft or both (five accidents); 4) a training flight task that proved to be beyond the ability of the student pilot and beyond the ability of the instructor pilot to monitor or correct (five accidents); and 5) an adverse medical condition for the pilot (four accidents). For a few accidents, more than one adverse condition was present. For several other "beyond ability" accidents, no adverse condition could be identified for certain, but the outcome of the accident suggested that the pilot's flying ability was exceeded. One pilot was attempting to perform an aerobatic maneuver and stalled the aircraft. One accident was a mid-air impact. This accident was classified as "beyond ability" in the sense that the pilots were unable to see each other and/or unable to maneuver the aircraft in such a way as to avoid impact. Two accidents occurred during approach to a difficult landing area. Both of these ended with the aircraft stalling at too high an altitude above the ground. The final two "beyond ability" accidents involved a pilot that was unable to complete an instrument approach procedure. In the entire dataset, there were four accidents involving a failed instrument approach. However, it was unclear for two of them whether they involved a lack of skill or simply poor decision-making.

It should be noted that, for some of these accidents, the decision to categorize the accident as "skill-based" has a strong subjective component. For example, an aircraft that is landing at an unimproved runway and encounters a wind gust that pushes the aircraft into some trees can be categorized as a "skill-based" accident if the assumption is made that a different pilot, under the same conditions, would have been able to prevent the accident. There is no way to test this assumption since the event could never be duplicated exactly. Given this caveat, one suggestion for preventing pilots from flying beyond their ability would be to improve training. However, the problem for improving training is how to train for extreme conditions that are rarely encountered during actual flight. Simulator training might be of some use, but there is a question about the realism of simulator training for extreme conditions, especially simulations of smaller GA aircraft.

Pilots at airlines receive almost no hands-on training in how to recover from full aerodynamic stalls and other extreme scenarios, according to the National Transportation Safety Board (NTSB). The reason is that current flight simulators cannot accurately reproduce such conditions. A USA Today review of NTSB accident reports over the past decade found that 317 of the 433 airline fatalities on U.S. carriers since 2000 – or 73% – could have been prevented with better simulator training (Levin, 2010). However, this conclusion is based on an assumption that it is possible to simulate the "extreme scenarios" that might be encountered. Motion-based simulators cannot provide sustained acceleration cues like those encountered in actual aircraft, so the assumption that better simulator training is possible or economically feasible is tenuous.

Distraction Accidents. The third type of skill-based error occurred when a distraction, either inside or outside of the aircraft, led to the pilot failing to "fly the aircraft," or maintain control. Twelve of the 53 accidents (22%) involved the pilot not flying the aircraft first. During the analysis, these were sometimes referred to as "moose stalls." All but one of these accidents ended when the aircraft stalled and struck the ground. Most of them occurred as the pilot was distracted from flying because of something happening outside of the aircraft, although to be fair, moose-watching was not the only distraction. Several of these accidents did involve looking at wildlife (sheep, wolves, a whale bone, as well as moose). For some of the accidents, pilots were looking at a campsite, or investigating a potential landing area. As with the "beyond ability" accidents, some of them involved exacerbating factors such as being over gross weight (three accidents), a mechanical problem (one accident), or a medical problem (one accident). However, the primary cause was the failure of the pilot to first fly the aircraft.

The one accident that was not a stall accident involved a pilot with an unreported case of diabetes. The pilot, while flying on a perfectly clear day, impacted a hill along the route of flight. Toxicological analysis did not find evidence that the diabetes was a contributing factor, but it is impossible to say whether it was or was not. The NTSB investigation concluded that the plane was being flown on autopilot at the time of the accident, leading to speculation that the pilot was simply not monitoring where the aircraft was flying. Whether the pilot was sightseeing, incapacitated, sleeping, or engaged in some other activity is unknown and unknowable because the lone pilot was killed in the accident.

Decision Error Accidents

Thirty-two accidents, approximately 33% of the dataset, involved a decision error on the part of the pilot. Twenty-five of these decision errors were faulty judgments regarding the weather. Twenty-four of the weather-related accidents can be separated into two basic categories, those involving an inadvertent visual-flight-rules flight into instrument meteorological conditions (VFR into IMC), which accounted for 14 accidents, and those involving unexpected wind conditions (10 accidents). The remaining weather-related accident could be considered a VFR into IMC accident, except that the pilot had filed an instrument flight rules (IFR) flight plan. In this accident, the pilot attempted an inappropriate instrument approach procedure at the destination airport, which suggests that he was unprepared for actual IMC conditions.

The accidents involving unexpected wind conditions occurred either during takeoff (7), landing (1), or while flying over mountainous terrain (2). Five of the seven takeoff accidents were float planes taking off from a lake. One aircraft took off from a sandbar. The other aircraft took off from an unimproved grass runway. The sole landing accident also occurred off-airport.

The other seven decision-error accidents had a variety of factors associated with them. Two of the accidents were instructional flights in which it was determined that poor decision-making on the part of the instructor contributed to the accident. Engine failure was a contributing factor to two other accidents, but in both cases there were indications of potential engine problems before the accident flight was initiated. For the final three accidents, one occurred during preflight when the pilot was injured trying to hand-start the aircraft, one was a flight through a mountain pass in which the pilot initiated a climb through the pass too late, and the final accident was a fuel-starvation accident where the pilot made a decision to continue toward an airport that was beyond the range of the aircraft.

As with some of the skill-based error accidents, there is a subjective component in the categorization process. Particularly in regard to wind-related takeoff accidents, there is a question about whether the decision to take off was made using all available sources or whether some information (e.g., the size of swells on the water, the movement of trees, etc.) was overlooked. Takeoffs from lakes and unimproved runways do not usually leave room for error. It often requires that the aircraft be positioned over trees or other objects at relatively low altitudes, compared to taking off from a normal runway and any loss of lift can lead to an inability to avoid hitting these objects.

VFR Into IMC Accidents

Accidents involving VFR flights into IMC have been of major interest to aircraft accident investigators and researchers for a number of years. One reason is that, while such accidents account for a small number of the total accident count, a large percentage of these accidents are usually fatal to the aircraft occupants. Statistics over the last 30 years have placed the percentage of VFR into IMC accidents that resulted in a fatality between 70% and 80% (ASF, 2009; NTSB, 1989; Weigmann & Goh, 2000). In the current accident database, the number of fatal and serious injury accidents attributed to VFR into IMC was 19, or approximately 20% of the total. The majority of these were classified as a decision-error accident. However, some were classified as violation accidents. Of those 19 accidents, 15 (79%) incurred at least one fatality.

Previous analyses of VFR into IMC accidents have focused on faulty pilot decision-making as a major contributor to the accident (O'Hare & Smitheram, 1995; Weigmann & Goh, 2000). The current dataset supports this notion, with all of the accidents involving either poor decision-making or a willful violation (which is a special type of poor decision-making) or both. In only a single accident from the database was it likely that the pilot was totally unaware of the presence of dangerous weather conditions along the route of flight.

Weigmann and Goh (2000) list four factors associated with poor pilot decision-making in VFR into IMC accidents. The first factor is poor situation assessment. The pilot lacks experience in interpreting changing weather conditions, especially slowly changing weather. Tiredness, fatigue, and increased workload, or some combination of these, can also increase the likelihood of an inaccurate assessment of the weather.

The second factor associated with poor pilot decision-making is faulty risk perception of the dangers involved in flying in marginal weather conditions. Recent research by Shappell et al. (2010) supports the notion that many pilots have a poor understanding and appreciation of the hazards associated with adverse weather conditions. Contributing to this perception, many pilots might have successfully navigated during marginal conditions in the past and so have gained confidence in their ability to succeed again in similar circumstances. While we have accident statistics regarding unsuccessful flights in marginal conditions, we do not have statistics on the success rate of flights in these types of conditions. Even if pilots have no experience in marginal weather conditions, it is likely that their risk perception is faulty. Previous research has demonstrated that pilots usually tend to exhibit low levels of risk awareness and a high perception of their skill and judgment in flying (O'Hare, 1990).

The third factor associated with poor pilot decision-making is inappropriate motivations that bias the decision making process. The term "get-home-itis" refers to the motivation of the pilot to complete the journey. In addition, commercial pilots have financial and professional pressures that motivate their decisions (Bailey, Peterson, Williams, & Thompson, 2000; Conway, et al., 2004). Such motivations can sometimes outweigh weather considerations when deciding when and where to fly.

The fourth factor associated with poor pilot decision-making is called "decision framing." Decision framing refers to the idea that a person's choice between a risky or safe course of action depends on whether the choice is framed in terms of a gain or a loss. When the safer course of action is framed in terms of a loss, the decision tends to be risk-seeking. When framed in terms of a gain, the decision tends to be risk-averse. In the case of VFR flight into IMC, research has shown that framing the decision to not fly into marginal weather conditions as a loss (i.e., wasted time, money, and effort) leads to a greater likelihood of continuing the flight, but framing the decision to not fly as a gain (i.e., it is safer) leads to a greater likelihood of diverting the flight (O'Hare & Smitheram, 1995).

A fifth factor, one that is not discussed by Weigmann and Goh, is what is referred to as problem-solving set (Gick & Holyoak, 1979), which is the tendency to repeat a solution process that has been previously successful. In addition to altering one's perception of risk, successfully conducting a flight in marginal conditions by using a specific strategy (e.g., following a river while flying underneath the clouds) will increase the likelihood that the strategy will be used again under similar circumstances. Memory plays a crucial role in problem-solving, and repetition plays a crucial role in memory. So when faced with a problem (how do I make it through this weather?), humans tend to adopt a strategy that has been used successfully in the past, even if the current situation does not quite match previous events.

While it is not known whether these pilots had previously flown in similarly marginal weather conditions, it does seem likely, because the average flight hours for these pilots was 7,604, and the average flight hours in the 90 days preceding the accident was 137. In addition, eight of the flights (42%) were conducted as Part 135 operations, which tend to fly more regularly than Part 91 flights.

One question that can be asked in regard to these accidents is whether the pilots actually intended to fly into instrument meteorological conditions or if they were hoping to fly under (scud run) or around the clouds while maintaining a visual reference to the ground. While we cannot know for sure, analysis of the accident reports and other available information suggests that in only one of the 19 accidents did the pilot fully intend to fly into IMC. In that accident, the pilot was apparently using a handheld GPS (Garmin 295) to fly through the IMC. Unfortunately, there was an island that did not appear in the Garmin database. The aircraft collided with the island, killing all of the aircraft occupants. For the other 18 accidents, it is believed that the pilots thought they could avoid flying into IMC but were unsuccessful.

It might easily be concluded that pilots under these circumstances try to avoid flying into IMC as long as possible because they lack the skills to fly in instrument conditions. This may be true for some of the pilots. However, 12 (63%) of the pilots in the dataset were instrument-rated, which means that at least at some point in the past, they could competently fly in IMC.

Another question that must be asked is why some of these pilots did not simply transition to IFR flight when it seemed obvious that they would no longer be able to avoid IMC. Reasons probably vary; however, some possibilities include the potential that those that were not instrument rated felt they might get into trouble with the FAA, or the time between losing ground reference and actual impact was too short to make a decision, or they lacked the skills to fly in IMC, or they simply never thought about doing so. This last possibility is a reference to problem-solving set discussed above.

Given these possibilities, there are several potential ways to reduce the number of VFR into IMC accidents. They all involve getting the pilot to make better decisions regarding the flight both before and during the flight. Improving pilot awareness of changing weather conditions would allow better go/no go decisions before the flight. Preflight planning by the pilot could include specific locations along the route of flight to assess weather conditions. These locations should also be accompanied by specific plans for diverting. For example, if the pilot chooses to turn around and come back at a specific point, the pilot needs to be aware of all potential obstructions to be avoided during the turn. Training programs such as the Medallion Foundation's Cue-Based Weather Training program would be useful for selecting locations and planning divert procedures (Medallion Foundation Newsletter, 2010).

Another approach is to seek ways to allow a non-punitive entry into IFR under certain circumstances. The lack of ability for flying in IMC could be addressed with training. The training would need to include training for transitioning from VFR into IMC during the flight. This training would help to overcome problem-solving set by providing the pilot an alternative solution to safely completing the flight. Such a transition could be assisted through the use of a terrain display similar to those used in the Alaska Capstone Program (Williams, Yost, Holland & Tyler, 2002).

Reducing VFR into IMC accidents requires that pilots make better decisions both before and during a flight. Assisting the pilot in making those decisions requires a combination of policy changes, technology, and training. The challenges are great, but the payoff would be a reduction in the number of fatal aircraft accidents.

Violation Accidents

Twenty-four accidents in the dataset were classified as involving at least one rule violation on the part of the pilot. Unlike the other HFACS categories, accidents involving violations are much more likely to result in a fatality. Figure 7 illustrates this finding.

As can be seen in the figure, within each HFACS category there are more fatal accidents than serious-injury accidents. This reflects that there are more fatality accidents in the database. However, for skill-based error and decision-error accidents, the number of fatal accidents and serious-injury accidents was nearly identical. We see a larger ratio of fatal accidents for those associated with perceptual errors. But the ratio of fatal to serious-injury accidents among the violation accidents was 7 to 1 (21 fatal vs. 3 serious-injury). This result is very close to the findings of Detwiler et al. (2006) who found that 90% of the violation accidents in Alaska resulted in a fatality. The current study found that 87.5% of the violation accidents resulted in a fatality.

Breaking down the violation accidents, the most common violation was overloading the aircraft. While it might be argued that the pilots might have overloaded the

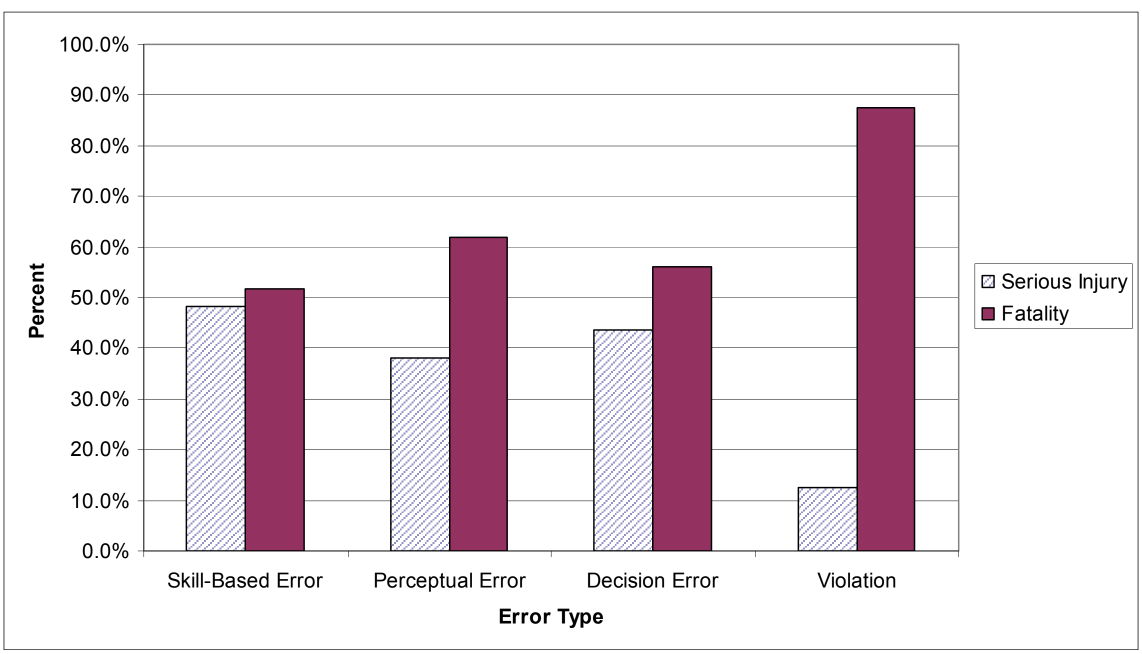

Figure 7. Accident severity within each HFACS category.

aircraft unintentionally, weight and balance calculations are a standard part of the preflight routine, especially for smaller aircraft. Seven accidents included loading the aircraft significantly beyond its maximum gross weight capacity. All of these flights ended when the aircraft stalled unexpectedly at low altitude.

Five of the violations involved the use of illegal drugs (cocaine, marijuana) or unapproved medications (anti-depressants). Four of the accidents involved a problem with the medical certification of the pilot. In one case the pilot had actually been denied a medical (because of a heart condition) but was still flying. Two of the accidents involved an unreported medical condition (diabetes). One involved a pilot flying with an expired medical certificate.

Of the remaining violations, there were a variety of different circumstances. These included not following a published IFR approach procedure (two accidents), flying below the minimum altitude (six accidents), improper or undocumented maintenance procedures (three accidents), flying without an authorized flight certificate (two accidents), and improperly (and illegally) securing an external load to the aircraft (one accident). Keep in mind that some accidents involved multiple violations, so the numbers cited will not sum to 24.

For many of these violation accidents, the violation involved multiple incidences over a long period of time. For others, the violation seemed to be an isolated event. Preventing such accidents, especially those involving multiple incidences, is difficult because the pilot is already performing an action that is "not allowed." Focusing on pilot decision-making seems ineffective because they already know they are making a bad decision. One suggestion for changing pilot attitudes is to present the potential consequences of these violations in a dramatic format. These "dramatic re-enactments," which could be presented online, or in video format, would reconstruct actual accidents, such as the pilot who consistently engaged in scud-running until he crashed into a lake, trapping his three daughters in the back seat of the aircraft while he and his wife managed to free themselves and swim to safety. If this appeal to emotions is successful, it might lead to an adjustment of pilots' attitudes toward engaging in flight violations.

Perceptual Error Accidents

The final HFACS category is the perceptual error. Twenty-one accidents had an associated perceptual error. Of these, the large majority (16 accidents) involved VFR into IMC flight. Other HFACS studies (notably, Detwiler et al., 2006) have not categorized VFR into IMC accidents as including a perceptual error on the part of the pilot. However, if we look at the description of a perceptual error (provided above), it states that it "occurs when sensory input is degraded, or 'unusual,' as is often the case when flying at night, in the weather, or in other visually impoverished environments, causing misjudging distances, altitude, and descent rates, as well as responding incorrectly to a variety of visual/vestibular illusions." This description seems to fit VFR into IMC events.

The other five perceptual-error accidents included a mid-air accident, two "flat-light" accidents involving flight over a glacier, one collision with a powerline, and one accident during an attempt to land on a lake when the pilot misjudged the surface of the water.

As with the other accident types, one strategy for preventing perceptual error accidents would be to encourage better decision-making, as was discussed above regarding VFR into IMC accidents. However, if we focus on the lack of or misinterpretation of perceptual stimuli associated with these accidents, then a potential strategy for prevention would be to provide a technological improvement to pilot vision in the form of enhanced and/or synthetic vision displays. Such displays would improve awareness of both hazardous terrain and other aircraft in the vicinity of the aircraft. As with all technological solutions, though, cost is a significant driver, especially for private aircraft owners.

CONCLUSIONS AND RECOMMENDATIONS

This HFACS analysis of FSI accidents in Alaska that occurred from 2004-2009 revealed a pattern of causal categories that is very similar to an earlier study (Detwiler et al., 2006). Skill-based error accidents were the most prevalent, followed by decision-error accidents, violation accidents, then perceptual-error accidents. The analysis also found that violation accidents were more likely to result in a fatality than other causal factors, again, as was found in Detwiler et al. This similarity to the Detwiler study was somewhat surprising given that the earlier study did not include Part 135 accidents and was not restricted to FSI accidents. However, the similarity in findings does suggest that the pattern is robust across a variety of conditions.

Given the prevalence of skill-based and decision-error accidents in the database, training recommendations immediately come to mind. Improving piloting skills and decision-making abilities seems a logical approach to reducing these types of accidents. Breaking down the skill-based accidents into critical-error, beyond-ability, and distraction accidents suggests different types of training approaches. Critical-error accidents suggest the need to focus more on the use of checklists and the establishment of standard procedures for typical preflight and flight tasks. Distraction accidents suggest the need for emphasizing flying the aircraft first before other flight requirements. Training in pilot decision-making has often been suggested (e.g., Brecke, 1982; Jensen & Benel, 1977; O'Hare, 1992) and it is still a useful strategy to consider.

In addition to training solutions, technological solutions might also help to prevent these types of accidents. Critical-error accidents quite often suggest the need for a redesign of the human/machine interface. Beyond-ability accident pilots might benefit from technology that would improve awareness of wind conditions. They might also benefit from flight simulators that could accurately model various wind and other environmental conditions. Distraction-accident pilots could benefit from improved stall warning capabilities. Decision-error accident pilots also could benefit from improved weather awareness technologies.

Violation accidents are probably the most difficult for which to find solutions because the pilot has made a conscious decision to not adhere to established regulations. Emotional appeals that highlight potential consequences might be of some benefit for reducing the number of violation accidents, as was suggested with the dramatic re-enactments. Perhaps technological solutions that improve pilots' awareness of flight variables (e.g., weight and balance, weather) would help reduce these types of accidents. But the assumption here is that pilots are not aware that a violation is occurring, or they are not aware of the magnitude of the violation.

Finally, perceptual-error accidents could benefit from technology that provides better awareness of height above ground, both below and in front of the aircraft. For VFR into IMC accidents, improved pilot decision-making could also be emphasized.

The implementation of solutions is more problematic for pilots flying only Part 91 operations compared to Part 135 operations. Training requirements for Part 91 pilots is not as strict or imposing as for Part 135. Biennial reviews are required for all pilots, but other types of training would have to be done voluntarily by the pilots flying only Part 91 operations. Technological solutions are also easier for Part 135 operations, given the higher availability of revenue compared to private individuals.

For a full set of interventions, as well as mitigation strategies in the event of an accident, the reader is referred to the FAA FSI review document (FAA, 2010). Whatever interventions and mitigations are proposed, it should be kept in mind that pilots are influenced by issues of cost, time, and other factors. If the solutions are too expensive and/or time consuming, they will not be implemented and the flight will occur as long as both pilot and passengers feel the flight is worth the risk involved.

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