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Flight Skill Proficiency Issues in Instrument Approach Accidents

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Abstract

Despite procedural modifications and advanced technology instrumentation, instrument approach phase accidents continue to be an issue in general aviation. This exploratory study details an analysis of instrument approach phase accidents that occurred between 2002 and 2012. Particular attention was focused on instrument proficiency check (IPC) currency for pilots involved in accidents during the approach phase of flight. An analysis suggests that more than half of instrument approach accidents evaluated during this study happened within three and half months of the last IPC. A leading cause of these accidents was failure to control the aircraft. Instrument training issues and potential follow-on studies are addressed.

Keywords: instrument approach accidents, flight skill proficiency

On September 8, 2010, at approximately 0926 EDT, an aircraft on an instrument approach to Helena, Georgia, crashed, killing the instrument-rated pilot and seriously injuring his passenger. Radar data indicated that after the aircraft was established on a GPS final approach course, the pilot did not appear to level off at the minimum descent altitude (MDA) and subsequently impacted the ground 2.74 miles short of the runway. Weather in the area at the time was reported as foggy with low ceilings and visibility. During the ten-year period ending in August 2012, this was just one of 170 instrument flight rules (IFR) approach-related accidents, highlighting the need for further investigation into trends and causal factors (ASI, 2012).

Introduction

In response to the wide variety of weather conditions and areas of concentrated air traffic, commercially certificated pilots usually operate in an IFR environment. Such operations are monitored by an extensive air traffic control network that

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depends primarily upon ground-based radar, and aural and data link communications. Despite such oversight, safe flight progress is still the responsibility of certified commercial pilots, who have been evaluated as proficient in all aspects of aircraft operation. This is particularly true during the descent and approach phases of flight conducted in actual instrument conditions, where weather obscures ground features. Under these circumstances, the skill level of the pilot in command is critical to the safe conclusion of the flight. Over the last two decades, evolving technology and changes in flight procedures seem key to a dramatic reduction in aviation accidents, particularly in the approach phase (FAA, 2010). However, approach phase accidents continue to be a concern, and further research is needed to address causes and remediation. The current exploratory study was conducted to better understand factors related to instrument approach accidents and the proficiency levels of instrument-rated general aviation (GA) pilots.

Literature Review

Instrument Flight Qualification

After initial qualification, Federal Aviation Regulations direct that instrument-rated pilots must complete holding procedures, six instrument approaches, and course interception and tracking within every six calendar months (FAA, 2012a). If the six-month period after formal certification expires without recurrent training in these instrument procedures, the pilot must complete an instrument proficiency check (IPC) to be recertified (unless currency is attained within the six-month period following the initial certification period). Although Part 121 airline pilots and Part 135 operators perform frequent instrument procedures during the course of monthly operations, many instrument-rated GA pilots may fly infrequently and, when they do fly, usually do so in a visual flight rules (VFR) environment. As a result, when such pilots operate using IFR procedures, especially in actual weather conditions, they are not well prepared procedurally and are unable to fly the close operational tolerances mandated in an instrument approach phase. Additionally, pilots who routinely fly instrument approaches, depending on advanced instrumentation and autopilot systems, may experience a deteriorated ability to manually control an aircraft when encountering actual IFR conditions.

Fanjoy and Young (2005) conducted a study of 100 airline pilots using a Level C flight simulator and found that experienced airline pilots who routinely fly automated instrument procedures had great difficulty maintaining acceptable airspeed, heading, and altitude tolerances when manually controlling an aircraft on final approach. Also, over half of the study participants reported a degradation of their manual flight skills due to the regular use of automated approach systems. Although this degradation could have been mitigated by periodic "hands-on" practice, such practice may not be practical due to company policies or infrequency of flight operations by a given pilot.

Flight Skill Degradation

Few empirical investigations specifically address flight skill degradation of pilots. Mengelkoch, Adams, and Gainer (1971) studied 33 non-pilot students, assigned to two groups, to determine skill degradation after academic instruction and training in a mock-up aircraft cockpit. One group completed five evaluated training sessions in a flight simulator, while the second group completed ten evaluated training sessions. Both groups were evaluated again after four months. The group with ten training sessions performed better than the five training session group on this final evaluation. However, findings suggest both groups experienced skill degradation, and in particular, there seemed to be a greater loss of procedural knowledge than loss of flight control motor skills. Of the flight motor skills, altitude and airspeed control seemed to show significant degradation for both groups over the training interval.

Research by Childs, Spears, and Prophet (1983) supports significant psychomotor and cognitive skill degradation over time, if practice and reinforcement are irregular. Skill degradation can be attributed to either forgetting or confusing tasks that are required for safe flight. The results of this study suggested that perceptual and cognitive cues decay rapidly, while motor skills are retained significantly longer. Hendricks, Goldsmith, and Johnson (2006) studied flight performance data collected from airline pilots. One group was evaluated six months after training and a second group was evaluated after twelve months. Significant skill decay was found for the group evaluated twelve months after training, compared to those who were evaluated after six months. This skill degradation was noted for both frequently practiced maneuvers and less frequently practiced maneuvers, such as emergency procedures.

An empirical study by Ebbatson, Harris, Huddlestone, and Sears (2010) investigated the relationship between manual flying performance and recent flight experience of airline pilots. Study pilots, who flew more often in the previous week, showed less frequent pitch and yaw inputs during approach maneuvers. This suggests that pilots who have recent flight experience fly more smoothly. The longer the period of time between manually flown approaches, the poorer the pilot's performance.

Gillen (2010) evaluated the basic instrument flight skills of 30 certified Airline Transport Pilots (ATPs) and found them to be significantly below FAA standards. The evaluation took place in a Level D simulator, under the conditions of failed automation. Researchers also noted that the participant pilots perceived themselves proficient in handling the aircraft under conditions of failed automation, when questioned in a pretest survey. Study findings suggest that the participants were overconfident and not proficient in manual instrument flight skills.

In a study by Sohn and Doane (2004), 52 pilots were asked to complete three tasks that measured memory, recall, and situational tasks. Their findings indicate that memory plays a significant role in situational awareness. While a novice pilot's working memory can be overloaded, experienced pilots use stored information, which assists in decreasing their workload. These findings are consistent with previous studies that suggest cognitive abilities are more important for skill retention during initial training than practiced skills.

Causse, Dehais, and Pastor (2011) conducted an experiment to predict flight simulator performance based on personality traits. Twenty-four pilots were evaluated with neuropsychological tests to determine their tendencies in low-level executive functions of reasoning, inhibition, and updating. Once these executive functions were evaluated, the subjects' decision making under conditions of adverse weather were tested in a flight simulator. Findings suggested linkage between executive function tendencies and aeronautical decision making. For example, the executive function of updating was correlated with flight performance. Flying is a dynamic experience that requires memory functions to process and update information to maintain situational awareness. Another finding, focused on inhibition, revealed that subjects who were assessed as impulsive tended to inappropriately continue a landing in dangerous crosswinds. In response, the researchers recommended that executive functions should be evaluated during annual medical examinations to identify potential flight safety concerns.

O'Hare (2006) conducted a study to identify the perceptions of pilots who had accidents or incidents during flight operations. A questionnaire was sent to every licensed pilot with a current medical certificate in New Zealand. Over 1,000 respondents acknowledged they had been in an accident or incident and answered further questions. The questions pertained to factors that initiated the event, what hindered action to prevent the event, and the extent of pilot involvement in the evolving hazardous situation. The main finding of the study was that accidents reflected higher levels of cognitive disconnect of knowledge and strategy than did incidents. Additionally, incidents were caused primarily by events outside the pilot's control.

Shorrock (2005) interviewed 28 experienced air traffic controllers in London, UK. The point of the study was to gain insight on how controller memory lapses can lead to an operational incident. The second part of the study included an analysis of incident reports. Results led researchers to suggest errors could be attributed to lack of attention, fixation on other duties, lack of practice, and work overload.

Skill Retention Theory

Fitts and Posner (1967) proposed that learning, skill, and retention happen in three sequential stages: cognitive, associative, and autonomous. Cognitive learning degrades with lack of use, sometimes to the point of total skill memory loss. When associative learning degrades, errors occur. In the autonomous stage, a learner can still complete the task if the information is internalized and not lost over time.

Researchers suggest that closed looped task knowledge will decay at a greater rate than open looped tasks (Farr, 1987). An example of an open looped task is controlling an aircraft in straight and level flight, with the airplane trimmed for minimal pilot input. An example of a closed loop task is flying an instrument approach. That procedure requires constant feedback from the instruments to be performed precisely and safely.

Müller and Pilzecker developed the memory consolidation theory 112 years ago. During that time, while testing human subjects, they discovered that recall of learned information might be interrupted by the learning of other information immediately following the original learning. Their findings indicated that new memories initially persevere in a delicate state and consolidate over time. Memory consolidation hypotheses are still used to guide researchers studying the time-dependent interaction and brain processes (McGaugh, 2000). During initial and recurrent instrument flight training, several distinct blocks of knowledge are mastered. In consideration of memory consolidation theory, mastery of initial or previously learned information can be interrupted.

Practicing or revisiting a learned skill can reduce skill degradation. This *spacing effect* describes how the longer a person waits to recall information, the more likely information will be forgotten (Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006). Optimal spacing of recurrent training depends on how long the information needs to be retained. Research suggests that 10 to 20 percent of a retention interval is an ideal time period for recurrent training (Rohrer & Pashler, 2007). This theory and related research have provided organizations and regulatory agencies with guidelines for appropriate retraining intervals.

Contemporary theories suggest that motor skill proficiency is related to practicing an action. Improved motor skill performance can happen over time if the practiced skill repeatedly meets the demands of a given task. The relationship between physical movement and the outcome of action should be the focus for increasing levels of proficiency (Newell, 1991). Motor skill learning is an active process, interrelated with cognition (Gallahue & Cleland, 2003). As a pilot gains more flight experience, his/her motor skills and cognitive functions are likely to improve.

Causes of Accidents in IFR Conditions

An FAA study (2012) evaluated 26 interviews from pilots who declared an emergency, requested assistance, or made a deviation while facing adverse weather conditions.

Researchers also analyzed weather conditions at the incident location in question. Their findings indicated deficiencies in pilot education and training, when tasked with deciphering weather information. The study recommended that all pilots receive a designated number of weather training sessions from a Certified Flight Instructor (CFI). Researchers felt that a home study course would not provide valid training, if used for that purpose.

Wiegmann et al. (2005) conducted an analysis of aircraft accidents using the Human Factors Analysis and Classification System (HFACS). That analysis focused on human error in general aviation accidents. The researchers categorized errors as decision, skill-based, and perceptual. Errors that led to the largest segment of the investigated accidents were skill-based, followed by decision and perception errors. In response, researchers recommended more use of aircraft automation, improved checklists, and workload management training to mitigate the likelihood and nature of future accidents. It was noted that problems with cost, feasibility, and acceptance are potential roadblocks to implementation of accident mitigation elements.

An FAA study (2010) further supported the categorization of weather-related accidents as resulting from perceptual, skill-based, and decision errors. Skill-based errors are the hardest to understand because pilots who do not survive cannot report on what happened, and pilots who live often misrepresent their own abilities. Additionally, pilots have a tendency to alter the facts associated with an accident if they feel their testimony may cause a repercussion or trigger punishment by authorities. FAA researchers also found that instrument-rated pilots were often prone to getting into weather conditions that were beyond their limit. A tendency to be overconfident, in that regard, was prevalent. Study findings suggest that there is a common tendency in the decision-making process to elect to fly into adverse weather instead of diverting around it.

The United States has over 300,000 general aviation aircraft, making it the largest general aviation fleet in the world. Approximately 80 percent of general aviation accidents are caused by human error (Wiegmann & Shappell, 2000). Over the past 10 years, 170 accidents have occurred during instrument approaches (FAA, 2012b). The purpose of the current study is to examine general aviation accidents during instrument approach and identify common themes, as well as any correlation between such accidents and the interval after initial or recurring IPC.

Methodology

This study evaluated general aviation accident data from the AOPA Air Safety Institute (ASI) database. This data-filtered search was performed to investigate all fixed wing aircraft accidents over the past ten years that occurred during IFR approaches. The resulting database filter identified 170 accident reports for analysis. This data was further sorted to identify 31 accident reports with recorded IPC dates. Those accident reports were analyzed to identify correlations and common themes. The data collected from individual accident reports included: NTSB report number, year of accident, primary cause, engine type, type of approach flown, total time of pilot flying, pilot flight time in accident aircraft, date pilot was IFR rated, date of last reported evaluation (IPC), aircraft type, weather condition, and type of instrument display. Researchers used only information from the official reports and did not attempt to make personal conclusions on primary or secondary causes of the accident.

Findings

A filtered search of the ASI database resulted in data from 170 general aviation aircraft accidents over the last ten years. Seven incomplete datasets were removed from the ensuing analysis. The next step in the analysis was to extract primary accident causes from the ASI database. For the 163 accidents considered, the primary causes were: failure to control (29.4%), failure to follow instrument approach procedures (29.4%), flight below published minimum (16.6%), inadequate airspeed (11.7%), spatial disorientation (8%), controlled flight into terrain or water (2.5%), failure to initiate missed (2.5%), and other causes (3.1%). These percentages are graphically shown in Figure 1. In some accident reports, secondary causes were identified but not considered as part of the current study.

The study dataset was further filtered to identify accidents with a listed IPC date to investigate potential correlations between accident causes and time since last IPC. Although limiting data to those accident pilots without a listed IPC date may affect generalization of study results, the researchers felt this data was still useful in providing insight for follow-on studies. For the current analysis, 31 accidents were identified with listed IPC dates. Primary accident causes associated with these accidents included: failure to control (29.0%), flight below published minimums (25.8%), inadequate airspeed (22.6%), failure to follow instrument approach procedures (9.7%), spatial disorientation (6.5%), failure to initiate missed approach (3.2%), and other causes (3.2%). See Figure 2 for the primary causes of the accident subset with a listed IPC date.

Primary Causes of Instrument Approach Accidents

1. Failure to control
2. Failure to follow instrument approach procedures
3. Flight below published minimums
4. Inadequate airspeed
5. Spatial disorientation
6. Controlled flight into terrain/water
7. Failure to initiate missed
8. Other

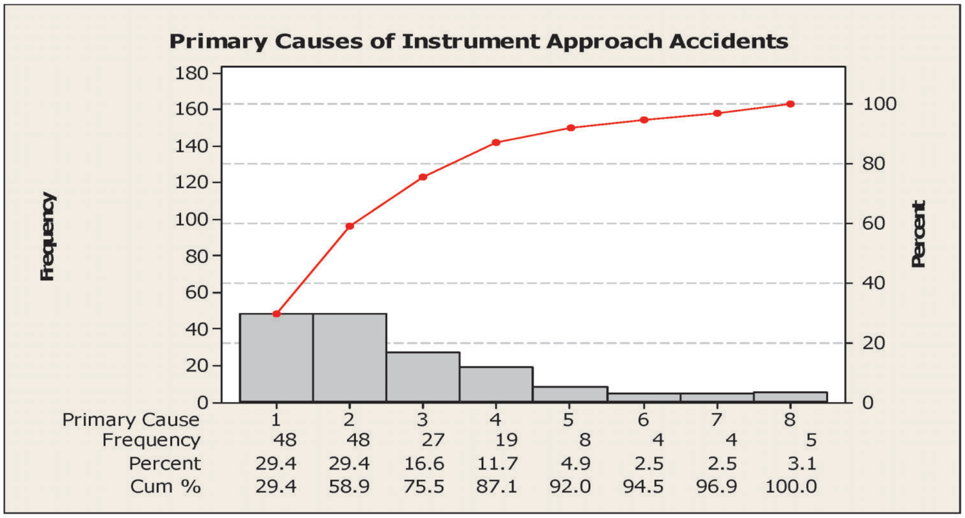

Figure 1. Primary causes of instrument approach accidents.

Next, a graphical summary was created to better understand when accidents typically occur after the IPC. The data shows that most of the accidents in the targeted subset occur within three and half months following IPC. After this time period, the number of accidents begins to decrease. The lower quartile of the chart, which represents the 25th percentile, is 50 days. The upper quartile, or the 75th percentile, is 156 days. Relative frequency is shown by the height of the bars. Skewness is > 0, which indicates a positive skewed distribution and accidents were less likely to happen later in the period after an IPC (see Figure 3).

Finally, researchers separated primary causes of instrument approach accidents (with IPC noted) into intervals of time after the last noted IPC. These intervals were 0–100, 101–200, 201–300, and 301–500 days. The researcher extended the last interval to 301–500 days because of the lengthy time period over which the remaining few accidents occurred. Table 1 depicts the primary causes of accidents during those blocks of time. Thirty-six percent of the accidents that occurred between 0–100 days after IPC listed flight below published minimums as the primary cause. Other primary causes during this same block of time included: inadequate airspeed (29%), failure to control (21%), failure to initiate missed approach (7%), and spatial disorientation (7%).

Regarding the time interval 101–200 days after IPC, 38% of accidents were caused by failure to maintain control. Other causes in that interval were: flight below published minimums (23%), failure to follow instrument approach procedures (23%), spatial disorientation (8%), and improper decision to abort a landing (8%).

In the time interval 201–300 days after IPC, one of the accidents was caused by failure to control and the other by inadequate airspeed. In the 301–500 day time interval, both accidents were caused by inadequate airspeed. It should be noted that 29 of the 31 accidents used in this sample were conducted in instrument meteorological conditions. This means there was not an external reference to the horizon, which provides pilots with a natural attitude indication.

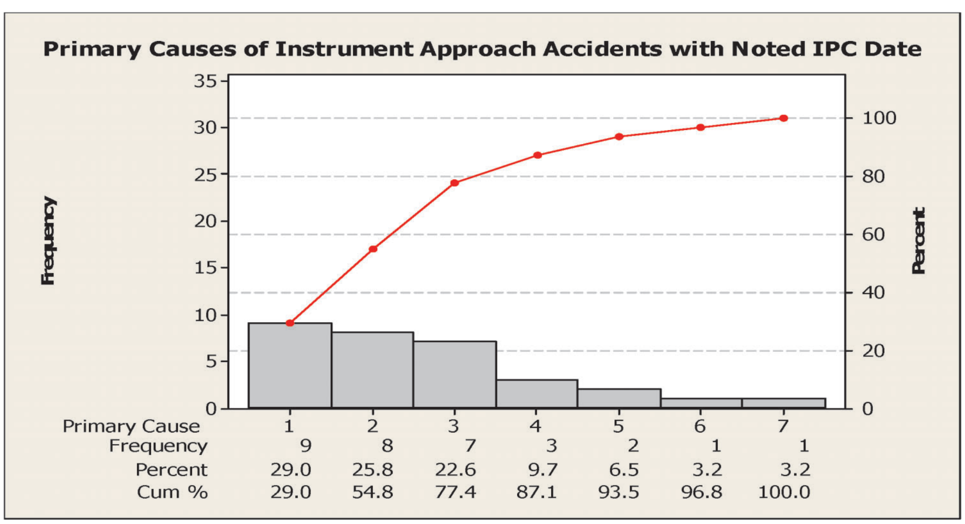

Figure 2. Primary causes of instrument approach accidents with noted IPC date.

Primary Causes with Noted IPC
1. Failure to control
2. Flight below published minimums
3. Inadequate airspeed
4. Failure to follow instrument approach procedures
5. Spatial disorientation
6. Failure to initiate missed approach
7. Other

Discussion and Conclusions

Conventional wisdom within the aviation community is that pilots who have not demonstrated proficiency in instrument flight procedures for more than six months are unsafe in instrument flight operations. Previous research into skill degradation suggests that without regular performance of complex tasks, procedural and motor skills degrade over a fairly short time frame, and procedural knowledge tends to decay more quickly than motor skills. Current FAA regulations reflect such findings by mandating training if more than six months have elapsed without instrument flight since the last IPC. The current regulations do not mandate what training is *required* for IPCs. However, there is a *recommendation* of one and one-half hours of ground instruction and a two-hour flight.

The results of the current research suggest that more than half of the instrument approach accidents in the target dataset were caused by failure to control the aircraft or failure to follow procedures. In addition, the number of individuals in the subject dataset who had accidents after an IPC seems to peak at 111 days after being signed off. Any generalization of these findings is not possible, as the pilots of many accident aircraft in the original 170 accident dataset may have had an IPC that was not reported in the accident findings. Also, the data addressing the recency or number of instrument procedures completed by accident pilots was not available in many of the reports.

Accidents in the dataset with listed IPC dates occurred over a wide time interval. Literature seems to suggest that primary accident causes would reflect procedural shortcomings or motor skill deficiencies. In the current study, accidents that reflect procedural shortcomings (failure to follow procedures, flight below minimums, failure to initiate missed approach, improper abort decision) seem to increase over the first 200 days following IPC. That finding would agree with earlier research. The rate of accident causes, which reflect motor skill aspects (failure to control, inadequate airspeed, and spatial disorientation), seem to remain fairly constant over the 200-day period after IPC. That finding is consistent with limited "stick and rudder" practice.

It is important to note the exploratory nature of this study and the relatively small dataset considered. Additionally, missing aspects of the original dataset relating to IPC dates and actual instrument currency limit the utility of these findings. However, findings do suggest interesting follow-on studies with a larger and more detailed dataset to pin

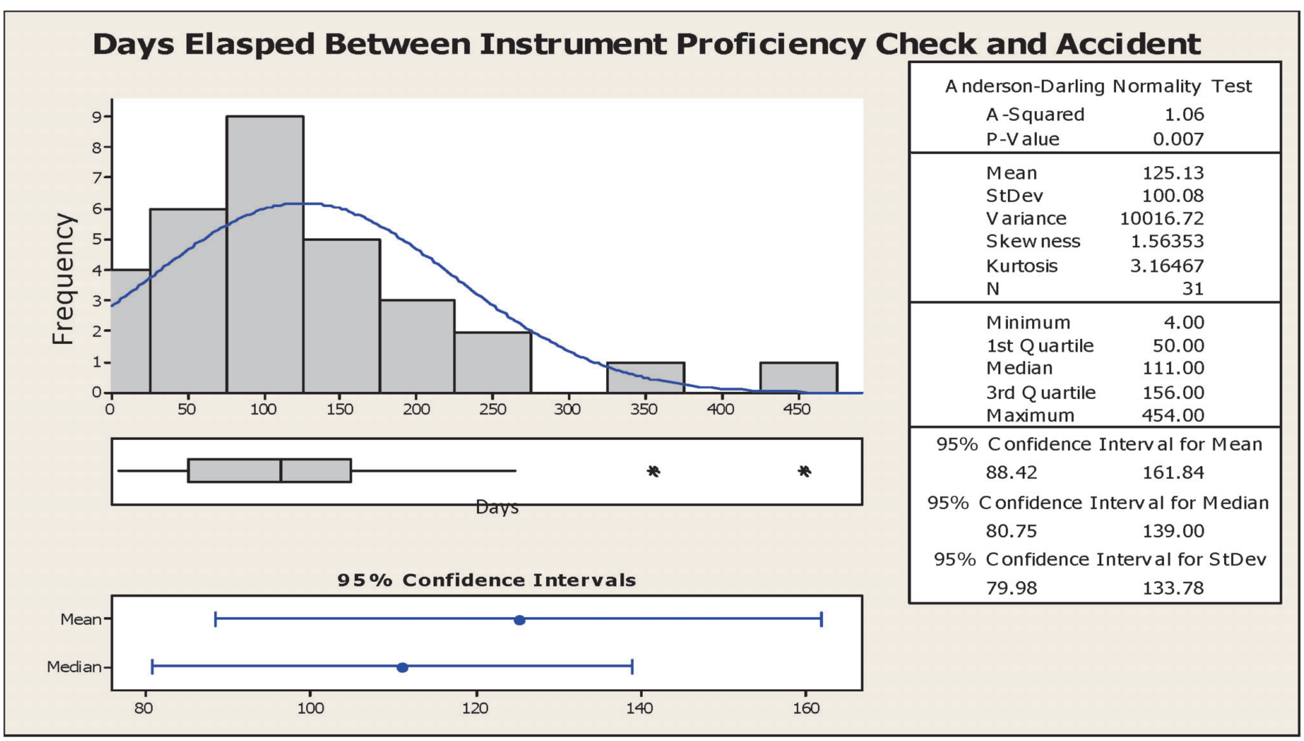

Figure 3. Summary of days elapsed between instrument proficiency check and accident.

Table 1.
Primary causes of accidents after IPC in time intervals.

0–100 Days (14 Accidents)	101–200 Days (13 Accidents)	201–300 Days (2 Accidents)	301–500 Days (2 Accidents)
Flight Below Published Minimums 36% (5)	Failure to Maintain Control 38% (5)	Failure to Maintain Control 50% (1)	Inadequate Airspeed 100% (2)
Inadequate Airspeed 29% (4)	Flight Below Published Minimums 23% (3)	Inadequate Airspeed 50% (1)	N/A
Failure to Maintain Control 21% (3)	Failure to Follow Instrument Approach Procedures 23% (3)	N/A	N/A
Failure to Initiate Missed 7% (1)	Improper Decision to Abort Landing 8% (1)	N/A	N/A
Spatial Disorientation 7% (1)	Spatial Disorientation 8% (1)	N/A	N/A

down degradation aspects of instrument flight proficiency. Findings from such studies should offer insight and opportunities for mitigation strategies to improve aircraft operations in an instrument environment, particularly for the general aviation pilot population.

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