Improving Flight Safety through Aircraft Simulation Instruction

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Abstract - *Flight safety is a measure that is most preemptive in pilot training. There has been a forty-year history in the utilization of flight simulators for pilot training and certification. The utilization of flight simulation is predominantly that of training and checking pilots, recreating experiences for the pilots which are indistinguishable from actual flying. If pilots learn, in a flight simulator, the required tasks and maneuvers involved in flight safety when they encounter precarious flying conditions, then they are likely to perform similarly when actually flying. A survey study was done sampling perceptions of certifying examiners and flight instructors regarding whether flight safety is promoted through flight simulator utilization by pilots. The study methodology and results are presented. The results suggest that current flight safety is perceived favorably due in large part to existing guidelines and regulations regarding simulator flight training.*

Keywords: Aircraft simulation, flight safety, general aviation, very light jets, flight simulator.

1 Introduction

Federal Aviation Administration (FAA) divides general aviation activities into the following categories: air taxi (10.6%); business (12%); corporate (11%); instructional (14%); personal (34%); and other uses (18% per government-owned or municipal-leased). In 2005, there were 234,352 active general aviation aircraft flying about 27 million hours. According to Alan Klapmeir, co-founder and CEO of Cirrus Design, which produces four-seat piston airplanes (price $189,000 to $379,000): “With greater affluence, progress in personal aviation must be made in performance with small-plane travel at least three times faster than car travel; comfort; user-friendliness; and safety.” Very light jets (VLJs) offer speed and safety of airline travel at a cost far below that of today’s private jets. Personal aviation has become a viable alternative to commercial airline travel.

Two years later in 2007, the U.S. Government Accountability Office (GAO) forecasted 3,016 VLJ deliveries in 2016 and 7,649 VLJ deliveries in 2025 [1]. The new aircraft models include Diamond D-Jet, Adam A 700, Cessna Citation Mustang, Eclipse 500 Embraer Phenom 100, and Honda Jet. By definition, a VLJ is an aircraft with a maximum takeoff weight below 19,000 pounds and certified for single-pilot operations. VLJs cost between $1 million and about $3 million. Most VLJs provide cruise speed (357 mph) and twice the cruise altitude (41,000 ft) of lightweight piston aircrafts.

The Mustang was the first entry-level jet to be certified and enter service without restrictions and has attracted a large number of owner-pilots for whom the old types of rating courses were not likely to produce the kind of proficiency necessary. Many pilots will be transitioning to jet aircraft, as the sole pilot-owner, from older and slower turboprops or single-piston powered aircraft. There are two main challenges: instruction in the ways of a modern digital cockpit and instruction in flying a high-performance aircraft. For every aircraft manufactured, a matching flight simulator is produced to train and certify pilot-owners. A flight simulator creates a virtual flight environment wherein pilot behavior is observed. As an example, consider the Diamond D-Jet VLJ, which is primarily designed for the owner-flown market, with simplicity of operation, safety and affordability being the main objectives. The D-Jet is Diamond's vision of the ultimate private aircraft. Figure 1 shows the Diamond D-Jet VLJ and Figure 2 shows its matching simulator.

Figure 1. Picture of Diamond D-Jet VLJ.

The continuous improvements in general aviation safety, over nearly 25 years, have finally reached a plateau. Commercial airlines neither dominate American civil air fleet nor manage more than a fifth of the certificated pilots

in the national airspace [2]. General aviation pilots, in comparison, are minimally certificated with a private pilot license after a minimal amount of instruction at a flight training school, and are not required to undergo recurrent training or license renewal.

(a)

(b)

(c)

Figure 2. D-Jet Simulator: (a) prototype "flying;" (b) interior much like the aircraft's planned interior for more realism; and (c) flight simulator training class.

FAA regulates minimum initial qualifications and recurrent training for airline pilots. They are licensed for each type of aircraft flown. Training needs as well as renewal requirements for pilots in commercial aviation differ from those in general aviation. Yet, they both share the same national airspace and are vulnerable to the same precarious flying conditions.

2 Aircraft Simulation Instruction

About 3% of flying mishaps are reported compared to an estimated 10% which go unreported [3]. This has caused concern that pilots perform differently when flying alone, unsupervised or unmonitored in an actual aircraft. In 2005, there were 224,352 active general aviation aircraft flying about 27 million hours. According to the 2007 GAO study, the forecast of a large presence of very light jets in the near future will only exacerbate the safety concerns of general aviation. VLJ owners are not covered under the current FAA standards and regulations. The advantages of simulator training and checking include lower costs and increased safety [4]. With an increase of private VLJ pilots, recurrent training in Level D simulators will be important.

Utilization of flight simulation is predominantly that of training and checking pilots, re-creating experiences for the pilots that are indistinguishable from actual flying. Generally, pilots behave the same in both a flight simulator and an actual aircraft. Pilots learn in a flight simulator, specifically the required tasks and maneuvers involved in flight safety when they encounter precarious flying conditions (e.g., aircraft malfunction, dangerous airspace congestion or hazardous weather conditions). Current aviation practice is a stimulus/response learning approach. The stimulus is the situation, system malfunction or failure, being scripted. The response is the execution of the established procedure. Scenario-based training, as it is known, focuses on conditioning responses in contrast to developing higher-order thinking skills. In a recent study [5], the FAA investigated the problem of pilot error due to continuing bad judgments, which lies in the pilot's inability to use judgment to resolve problems not specifically trained for. In all instances, the pilot's actions will relate to the complete situation.

The problem is the perception, that is, whether flight simulator training is widely acceptable as a viable means of training pilots with an increase in flight safety. Many of the pilots' tasks in actual flight operations are difficult to test and demonstrate. To mitigate the exposure to harm, the alternative is to test the pilot in a safe, controlled environment. The environmental hazards confronting the pilot cannot be predicted under normal conditions. When such hazards are mimicked in the simulator, proper maneuvering response techniques can be taught. Apart from the commercial airlines, pilots are not trained in flight simulators. Hence, the perception is that flight simulator

training is inferior to training in an actual aircraft. The null hypothesis and research hypothesis are stated as follows:

- $H1_0$: Perception of flight safety *is not* significantly associated with utilization of flight simulators in pilot training and certification.

- H1a: Perception of flight safety *is* significantly associated with utilization of flight simulators in pilot training and certification.

FITS, or Federal Aviation Administration/Industry Training Standards, has evolved into one of the most important safety initiatives undertaken in the general aviation community. The FITS program is designed to address the changes introduced by the global positioning system (GPS) and the data inputting functions. Recent evaluations of accidents in technical advanced aircraft (TAA) and training accidents identified (1) a lack of situational awareness, (2) decision-making, and (3) inadequate risk management, as major causal factors. Hence, general aviation training and testing will change to address these leading accident causes and further reduce the number of general aviation fatal accidents. The new changes will include teaching high-order decision making and critical thinking skills to enhance pilot judgment [6].

Those most knowledgeable of the pilots' real proficiency in flying include FAA certifying examiners and flight instructors. This paper investigates their perception on whether flight safety is promoted through aircraft simulation instruction.

3 Methodology

A researcher-designed survey was constructed for the sole purpose of gathering information for this study. It consisted of an introduction, a demographics section, a hypothesis testing section and a couple of open-ended questions. Questions in the hypothesis testing section covered perceived changes in flight simulators, whether simulator certification/training prepares pilots for safe piloting, effects of cockpit automation and FITS, fidelity of simulator performance tasks relative to actual flying, pilot response to simulator versus actual aircraft conditions, pilot judgment, and influences to improvements in flight safety.

The survey was developed to collect data for summarization and analysis. Null and research hypotheses were formulated in terms that could be measured using the Likert Scale [7, 8]. The Likert Scale is a common interval-based multiple-choice type of scale from which respondents choose one option that best aligns with their view, and it is often used in questionnaires. Data were entered into and were summarized using several Microsoft Excel spreadsheets, where descriptive statistics were applied. The t-test was the data analysis tool used to accept or reject the null hypothesis.

The survey population consisted of personnel operating over 500 FAA-qualified simulators throughout the United States. The sample represented a wide range of sectors in aviation, including air cargo, commercial airlines, aviation centers, federal agencies, simulation centers, flight training centers and universities. The non-federal respondents worked mostly at flight training centers. Their students prepare to fly commercially or, more commonly, in general aviation with privately owned aircraft. In contrast, the FAA respondents worked at FAA's Federal Standards District Offices (FSDOs) logistically located at or near commercial airline facilities. They certified pilots to operate designated aircraft.

The respondents at each simulator work location typically had lots of work as well as simulator experience. Many had long tenure, hence representing an aging workforce. Their aggregate experience represents a knowledge base that is not easily transferred to their replacements. Yet, their aggregate experience is a way of validating the study results. In addition, many of the respondents had extensive pilot training and piloting experience, which allows for a better assessment of the flight safety.

4 Results

FAA respondents had almost five times the total piloting experience than the non-federal respondents at airline facilities but slightly less at flight training centers. The mean piloting experience for FAA group was 11,160 hours compared to about 1,800 for the non-federal respondents working at airline facilities. FAA respondents had a mean of 31 years simulator work experience at airline facilities compared to 17 years for non-federal. In contrast, non-federal respondents at flight training centers had almost five times the total simulator work experience, with a mean of 36 years, than FAA respondents with a mean of 20 years.

Both groups agreed that flight simulators have changed very much during their careers, as described by their Likert means, 3.7 and 2.8 (on a Likert Scale ranging from 0-4). Clearly, there was reason to reject the null hypothesis. However the difference between the two means was significant. With a pre-selected probability level of 0.05, the researcher showed a difference between the two groups responding. The mean of FAA respondents indicated a stronger perception that simulators have changed.

Regarding the main focus of this paper on improving flight safety through simulation instruction, survey questions that directly addressed whether simulator certification/training improved flight safety in the past decade, prepares pilots for safe piloting, or would provide

scientific data sufficient to improve flight safety yielded the following results. Both groups agreed that utilization of flight simulators would improve flight safety, as shown by the sample means in Table 1. There is no difference in the perception of the respondents as the theoretical t-value (2.131) exceeded the statistical t-value of 1.3309.

Table 1. t-Test: Paired Two Sample Means – Flight Simulation/Certification Improvement to Flight Safety.

Statistic	All	FAA	non-Federal
Mean	3.001	3.1529	2.8529
Variance	0.3664	0.3064	0.4014
Median	3		
Mode	3		
Observations		16	16
Hypothesized Mean Difference		0	
Degs. of freedom		15	
t Stat		1.3309	
P(T=t) one-tail		0.1009	
P(T=t) two-tail		0.7459	

Both groups agreed that simulator training/certification prepares the pilot for safe piloting, and by inference flight safety. There was less similarity among the FAA and non-federal respondents regarding correlation between the recent decade of improved flight safety (per National Transportation Safety Board accident statistics) and flight simulation/training. Both groups shared the perception that more scientific investigation on flight simulator training/certification would improve flight safety.

The perception of the respondents was that there is a transfer of knowledge in pilot training from simulator to actual aircraft. There was no difference between the respondent groups as they both perceived FITS' utilization of simulators would improve flight safety. The perception of FAA was much stronger than the non-federal respondents that FITS would improve flight safety. No respondents perceived a FITS program not utilizing simulators.

5 Conclusion

As mentioned before, flight simulators have changed much over the years. The high degree of cockpit automation may be the cause. After all, when a new aircraft model is designed and manufactured, the identical prototype is used to construct a simulator, as well. Cockpit automation has created computer programmers out of today's pilots. Autopilot with all of its sophistication has taken the pilot out of the *inner loop of control*. As a result, pilot training has had to keep pace with the highly automated TAAs, which include general aviation aircraft that combine design features such as advanced cockpit automation systems, automated engine and systems management, and integrated auto flight/autopilot systems. Incorrect programming or other computer problems as they rarely occur in TAAs, still require a pilot who can quickly transition to a manual mode of piloting.

Cockpit automation of TAAs was perceived to improve flight safety. However skilled the pilot may be, his/her judgment is sometimes called into question. The high automation of TAAs requires greater pilot judgment, not less, during flight operations. Traditional pilot training emphasizes learning pilot skills. With the popularity of TAAs, training is addressing the issue of *heads down piloting* and teaching scripted scenarios for various flying conditions, instead. Response procedures taught to pilots entail judgment during most events. Hence, judgment is a process of recalling training and experience under present circumstances and conditions. FITS attempts to integrate the interaction of cockpit, air traffic control, and crew management to yield good decision-making strategies.

The implication of this study is that current flight safety is perceived favorably and that much of this is due to the guidelines and regulations of FAA, regarding simulator flight training. The study revealed the disparity of expertise and piloting experience among the aviation sectors sampled, reflective of the variation in flight safety perception. This was significant in that the non-federal respondents were more aligned with general aviation and FAA respondents were more aligned with commercial airlines. When scientific investigation describes the real issues and needs to be addressed regarding flight safety, it becomes a public service. More scientific investigation is suggested on flight simulator training as it improves flight safety.

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