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Mary Johnson, Ph.D., Associate Editor

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No juried publication can excel, unless experts in the field serve as anonymous reviewers. Indeed, the ultimate guarantors of quality and appropriateness of scholarly materials for a professional journal are the knowledge, integrity, and thoroughness of those who serve in this capacity. The thoughtful, careful, and timely work of the Editorial Board and each of the following professionals added substantively to the quality of the journal, and made the editor's task much easier. Thanks are extended to each reviewer for performing this critically important work. In addition to the members of the Editorial Board, the other reviewers for this issue include:

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STATEMENT OF OBJECTIVES

The *Collegiate Aviation Review* is published semi-annually by the University Aviation Association. Papers published in this volume were selected from submissions that were subjected to a blind peer review process, for presentation at the 2014 Fall Education Conference of the Association in Daytona Beach, Florida.

The University Aviation Association is the only professional organization representing all levels of the non-engineering/technology element in collegiate aviation education. Working through its officers, trustees, committees and professional staff, the University Aviation Association plays a vital role in collegiate aviation and in the aviation industry.

The University Aviation Association accomplishes its goals through a number of objectives:

> To encourage and promote the attainment of the highest standards in aviation education at the college level.
>
> To provide a means of developing a cadre of aviation experts who make themselves available for such activities as consultation, aviation program evaluation, speaking assignments, and other professional contributions that stimulate and develop aviation education.
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Call for Papers

The Collegiate Aviation Review (CAR) is the refereed journal of the University Aviation Association (UAA). Both qualitative and quantitative research manuscripts relevant to aviation are acceptable. The CAR review process incorporates a blind peer review by a panel of individuals who are active in the focus area of each manuscript. Additional recommendations are also provided by the editors of the CAR. A list of all reviewers is published in each edition of the CAR and is available from the CAR editor.

Authors should e-mail their manuscript, in Microsoft Word format, to the editor at CARjournal@uaa.aero no later than July 1 (Fall 2014 issue) or January 15 (Spring 2015 issue).

Previous editions of the CAR should also be consulted for formatting guidance. Manuscripts must conform to the guidelines contained in the Publication Manual of the American Psychological Association, 6th edition. Specifically, this means that submissions should follow the formatting found in the manual, e.g. proper use of the headings, seriation, and in-text citations. The references section must be complete and in proper APA format. Submissions that include tables and figures should use the guidelines outlined in the APA manual. In order to better align the CAR with the general research community, submissions using quantitative analysis should take into account the recommendations of the APA Task Force on Statistical Inference. Papers that do not meet these expectations will be returned to the author for reformatting.

All submissions must be accompanied by a statement that the manuscript has not been previously published and is not under consideration for publication elsewhere. Further, all submissions will be evaluated with plagiarism detection software. Instances of self-plagiarism will be considered the same as traditional plagiarism. Submissions that include plagiarized passages will not be considered for publication.

If the manuscript is accepted for publication, the author(s) will be required to submit a final version of the manuscript via e-mail, in “camera-ready” Microsoft Word format, by the prescribed deadline. All authors will be required to sign a “Transfer of Copyright and Agreement to Present” statement in which (1) the copyright to any submitted paper which is subsequently published in the CAR will be assigned to the UAA and in which (2) the authors agree to present any accepted paper at a UAA conference to be selected by the UAA, if requested. Students are encouraged to submit manuscripts to the CAR. A travel stipend for conference attendance up to $500 may be available for successful student submissions. Please contact the editor or UAA for additional information.

Questions regarding the submission or publication process may be directed to the editor at (727) 403-9903, or may be sent by email to: CARjournal@uaa.aero.

Editor’s Commentary

"It isn't often that a writer of superlative skills knows enough about flying to write well about it." – Samuel Hynes

It is hard to write. It is even harder to write well. But as scholars we are expected to produce not only writing, and not only good writing, but text that gives the research community insight into areas yet to be discovered. I am often asked what it takes to get something published. My answer always is “quality research.” But what exactly is considered to be “publishable” research?

Whilst the definition of this milestone varies among scholars, generally we are looking for something that provides original material that builds upon the existing body of knowledge. Although a thorough literature review can and often does provide insights, it is the presentation of existing ideas. Without some sort of analysis or synthesis, the product does not provide what is necessary to receive favorable reviews from our dedicated researchers who volunteer to peruse such works. Alternatively, the author can involve some qualitative research methods to extract new connections or findings within the literature – then you would have something novel to offer.

But the point to remember is you can never publish unless you write. And the first step to writing is sitting down, perhaps with your favorite beverage of choice, and start tapping away. Read other studies to lubricate the mind. Of course, the *CAR* is a great source for places to start. I am looking forward to reading your future studies.

As a reminder, the *CAR* now accepts book reviews (non-peer reviewed), methodological papers, reviews of statistical analysis, pilot studies, and more – basically, we are now more flexible about submissions. Please send me a query about any ideas you have for submission. We can chat about what works and what does not.

Lastly, thank you to all who have continued their support of the *CAR*. As of this issue, I will be handing the reigns over to Mary Johnson as I am obligated to manage the new scholarly journal at Embry-Riddle Worldwide. Please welcome her as the new editor!

Cheers – David Ison, PhD, Editor

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The Relationship between Part 121 Pilots' Age and Accident Rates

Michael A. Gallo and Arthur Clauter
Florida Institute of Technology

Abstract

This *ex post facto* study examined the relationship between Part 121 pilots' age and accident rate per 1000 flight hours using data from Aviation Safety Information Analysis and Sharing(ASIAS) for the 14-year period 1998–2011. Of the 970 aviation events reported, 267 met our definition of an accident, which followed the FAA's definition but also included a more restrictive requirement that the accident had to be related to pilot error. Of the 267 aviation accidents, 97 (36%) had missing age or flight hours data, which reduced the sample size to $N = 170$. Regression analyses confirmed neither a significant bivariate linear relationship, $r^2 = .007$, $F(1, 35) = 0.26$, $p = .6127$, nor a quadratic relationship, $R^2 = .102$, $F(2, 34) = 1.93$, $p = .1601$,between pilot age and accident rate. Furthermore, although the increment in explained variance (sr^2) between the linear and quadratic models was .095, this increment was not significant, $F(1, 35) = 3.687$, $p = .0630$. Findings indicate that pilot age was not a significant predictor of aviation accident rates with respect to accidents that involved pilot error. A recommendation for practice is for the FAA to reconsider the age restriction for Part 121 pilots, and for the NTSB to strive for data completeness and integrity by ensuring that all the data are collected and included in their investigation reports.

Introduction and Background

The Age 60 Rule

One of the most controversial issues within the airline safety community is the relationship between pilots' age and airline accidents. This issue first emerged more than 50 years ago and led to the "Age 60 Rule," which was enacted in December 1959 and became effective March 1960 by the Federal Aviation Administration (FAA). The Age 60 Rule prohibited air carriers "from using the services of any person as a pilot, and prohibits any person from serving as a pilot, on an airplane engaged in operations under part 121 if that person has reached his or her 60th birthday" (FAA, 2009, p. 34229). Part 121 operations include large commercial passenger aircraft, smaller propeller aircraft with 10 or more passenger seats, and common carriage operations of all-cargo aircraft with a payload capacity of 7500 pounds.

The Age 60 Rule was enacted without the benefit of medical or scientific studies and without public comment. Since then, it was expanded from part 121 to include part 135 operations based mostly on studies conducted by Broach (1999), Golaszewski (1983, 1991, &1993), and Kay et al. (1994). Although there is considerable evidence that age is neither a valid nor reliable predictor of a part 121 pilot's ability to fly an aircraft safely, the FAA has reasoned there is a greater likelihood of accidents occurring for older pilots because of the association between declining cognitive ability and age (International Brotherhood of Teamsters, 2005). The rule also "has been the focus of numerous inconclusive studies, several subsequent rulemaking proceedings, many court battles, and occasional legislative attempts to overturn or modify it" (International Brotherhood of Teamsters, 2005, p. 2).

Studies Refuting the Age Effect

Mohler, Bedell, Ross, and Veregge (1967) conducted one of the earliest studies on this topic by examining the relationship between accident rate and pilot age. Mohler et al. separated the data into different levels of pilot certification—student, private, commercial, and air transport—and partitioned the accidents by age groups of 16–29, 30–44, 45–59, and 60 and over, respectively, for 450,494 certified aviation pilots in all categories mid-year 1965. They then calculated accident rate using the number of pilots in each age group and category with respect to the number of accidents per 10,000 pilots. Mohler et al. reported that the overall accident rate of the age 60 and older group was 110 accidents per 10,000 pilots 60 years old or older. By comparison, the accident rate of the other age groups was 106 for the 16–29 group, 121 for the 30–44group, and 100 for the 45–59 group. When focused strictly on the air transport category of pilots, Mohler et al. reported the following accident rates: 298for the 16–29 group, 118 for the 30–44group, 104for the 45–59 group, and 104 for the 60 and over group. Based on the results of a Chi-square analysis, Mohler et al. indicated that pilots over 60 years old "were essentially as safe as their younger colleagues" (p.6).

Broach (2000) re-analyzed the data from the 1999 *Chicago Tribute* study, which reported that "older pilots were '…among the safest in the skies'" (p. 2) based on an analysis of 450 "incidents" between January 1, 1990 and June 11, 1999. According to Broach (p. 4), "the original *Tribune* analysis underestimated the actual ATP population across the 9.5 years by almost 250,000 pilots." Based on his re-analysis, Broach concluded there were no significant differences in the accident/incident rates among different age groups.

Despite the arguments put forth claiming pilots' likelihood for sudden incapacitation after the age of 60 years was greater than their younger counterparts, Li et al. (2003) uncovered the opposite based on 3,306 commuter air carrier and air taxi pilots aged 45–54 years in 1987. A follow up study conducted 10 years later revealed that of 12.9 million aggregate flight hours, there were 66 crashes, or about 5.1 crashes per 1 million flight hours. According to Li et al., "Crash risk remained fairly stable as the pilots aged from their late forties to their late fifties. Flight experience, as measured by total flight time at baseline, showed a significant protective effect against the risk of crash involvement" (p. 874). Li et al.'s findings were consistent with Broach's (2000) findings. Both studies showed the youngest and less-experienced pilots having the greatest risk or accident rate.

The second age group and experience level had the lowest risk, and the third age group or experience level was slightly higher than the second. Finally, the eldest pilots (those who were 50–59 years of age or had more than 15,000 flight hours) had a slightly lower risk or accident rate than those in the third eldest group.

Studies Supporting the Age Effect

In a series of four reports, Broach, Joseph, and Schroeder (2003) purposely focused on pilot age and accident rates based on accident data provided by the National Transportation Safety Board (NTSB) for the period 1988 through 1997. They defined accident rate as the ratio of the total number of accidents (fatal and nonfatal) to annual hours flown by air transport pilots (ATP), which included part 121 and part 135 pilots. Broach et al. estimated the number of annual hours from medical examination records, which were extracted from the FAA Comprehensive Airman Information System.

Broach et al. (2003) conducted three separate analyses based on different age categories. The most relevant to the current study involved non-overlapping age groups for 5-year periods: LE29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, and 60–63. Broach et al. reported a U-shaped distribution between accident rate and age groups: For the younger and older year’s age groups, accident rates were higher than for the middle year’s age groups. They also indicated that the accident rate for the 60–63 age groups was statistically greater than that for 55- or 56–59-year-old pilots, and that age was statistically significant. Broach et al. concluded that their findings suggested part 121 and part 135 accidents based on annual flight hours were related to age.

Recent Developments

In a review of U.S. civil aviation accidents from January 1, 2007 to December 31, 2009, the National Transportation Safety Board (2011) reported there were 4,958 aviation accidents that resulted in 1,641 fatalities. Of these totals, though, there were 86, or 1.7%, accidents that resulted in 56, or 3.4%, fatalities involving part 121 pilots. The vast majority of accidents and fatalities were attributed to part 91, general aviation pilots. According to NTSB, “Part 121 accident rates … have declined from 2000 to 2009 (and) between 2007 and 2009, turbulence encounters during the en route phase of flight was the most common defining event for Part 121 accidents, followed by on-ground collisions between aircraft” (p. 1).

In December 2007, then-President Bush signed the “Fair Treatment for Experienced Pilots Act,” which increased the mandatory retirement age for part 121 pilots to 65. It has now been 5 years since this Act took effect and the first wave of part 121 pilots who were 60 years old in 2007 began mandatory retirement. Independent of this event, there have been no studies that have examined pilot age and accident rates since Broach et al. (2003), which examined data from 1988 to 1997.

Summary of Past Studies

The literature reviewed here shows a mix of findings with respect to pilot age and aviation accidents. Some studies such as Mohler et al. (1967), Broach (2000), and Li et al. (2003) indicate that older pilots are not more likely to be involved in accidents whereas other studies such as Broach et al. (2003) refute this claim. One of the concerns with all of these studies is they are not always focusing on data involving part 121 pilots, which is the only group targeted by FAA for the Age 60 Rule. One of the biggest concerns, though, is the data being used for these analyses are neither necessarily accurate nor complete. For example, Broach et al. estimated pilots' annual flight hours, combined part 121 and 135 pilot data, and commented on the limited availability of data. Furthermore, the last fully reported study involving Part 121 pilots' age and accident rates was Broach et al., which involved data that was collected more than 15 years ago.

Purpose Statement and Operational Definitions

The purpose of the current study was to address some of the issues from past studies and to extend the current discussion of the Age 60 Rule by including more recent data. The current study augmented Broach et al. (2003) by examining part 121 U.S. airlines pilots' age and accident statistics for the 14-year period January 1, 1998 to December 31, 2011. This targeted period also included data from 2008–2011, which for the first time since the Age 60 Rule took effect includes part 121 pilots older than 60. Because the scope of this study involved aviation accidents, the following definitions are provided from the Federal Aviation Administration (see FAA Transportation Definitions, 1988):

> *Aircraft accident* means 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.
>
> *Fatal injury* means any injury that results in death within 30 days of the accident.
>
> *Serious injury* means any injury which: (1) Requires hospitalization for more than 48 hours, commencing within 7 days from the date of 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 percent of the body surface.
>
> *Substantial damage* means damage or failure which adversely affects the structural strength, performance, or flight characteristics of the aircraft, and which would normally require major repair or replacement of the affected component.

> Engine failure or damage limited to an engine if only one engine fails or is damaged, bent fairings or cowling, dented skin, small punctured holes in the skin or fabric, ground damage to rotor or propeller blades, and damage to landing gear, wheels, tires, flaps, engine accessories, brakes, or wingtips are not considered "substantial damage" for the purpose of this part.
>
> *Incident* means an occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations.

For the current study, we used a more restrictive definition of an aircraft accident by including only those accidents that were the result of pilot error and could have been prevented by the pilots. To make the distinction between the FAA's definition and our more restrictive definition, we used the NTSB's assessment of the probable cause(s) of an accident. For example, in event record 20040319X00351, the NTSB determined the probable cause to be: "The captain's improper decision due to his attempt to taxi back onto the runway after coming to a stop in the grass, and the resulting collapse of nose landing gear" (NTSB, 2004, "NTSB Identification: CHI04LA086"). As a result, this event was considered an accident by our more restrictive definition and was included in our analysis. On the other hand, in event record 20001212X20714, the NTSB determined the probable cause to be "The tug operator's inadequate visual lookout" (NTSB, 2000, "NTSB Identification: NYC00LA086"), which was not pilot-related, and therefore this event was not included in our analysis.

Methodology

The population for this study was all aviation events (incidents and accidents) involving Part 121 operations between January 1, 1998 and December 31, 2011. We targeted this population because the last full study that examined the relationship between Part 121 pilots and accident rate (Broach et al., 2003) used data between 1988 and 1997. Our sampling strategy was purposive: We selected only those events that were consistent with the FAA's definition of an accident but also met our additional criterion where the accident was a consequence of pilot error. This sampling strategy was appropriate because we were seeking a sample that would be typical, or representative, of Part 121 pilots who were involved in aircraft accidents judged to be due to pilot error.

To acquire the data set, we submitted an e-mail request to an Aviation Safety Information Analysis and Sharing (ASIAS) analyst at ASIAS@faa.gov. The initial data set we received consisted of 970 events. We then reviewed each event by entering the event ID in a Google search and reading the descriptions. As noted earlier, we focused on what the NTSB determined to be the probable cause of the event. Of the 970 events, 267 satisfied our restrictive definition of an accident, but only 170 contained complete data for pilots' age and aggregate flight hours. Thus, the final sample size was $N = 170$. When we inquired about the missing data, we received the following reply from J. Werner, aviation safety analyst for the FAA (personal communications, October 19, 2012):

"Those data are missing either because they were not known at the time of investigation or the investigator did not enter the data into the fields."

The primary research question that guided the study was: "What is the relationship between pilot age and accident rate under FAA part 121 operations?" Depending on the context, accident rate was defined as either per 1,000 or 10,000 flight hours. The corresponding research hypothesis was that pilot age is not related to aviation accident rates. We used a correlational research methodology because the sample consisted of a single group (part 121 pilots) and multiple measures (pilots' age, total flight hours, accident rate). Because correlational studies examine relationships among variables without any manipulation or control, the reader is cautioned not to infer any cause-and-effect relationship from the findings.

Data Analysis

Descriptive Statistics

A summary of the number of events and number of accidents organized by year is provided in Table 1 and pictorially illustrated in Figure 1. As noted earlier and illustrated in Table 1, there were 970 events during the 14-year period 1998–2011 of which 267 were considered accidents by our more restrictive definition. With the exception of 2002, the number of events during each year increased steadily from 1998 to 2003, and peaked at 106. There was no consistent pattern, though, in the number of events from 2004 to 2011. Overall, the mean number of events for the 14-year period was $M = 69.3$ ($SD = 17.98$, *Range*: 53 to 106). It is interesting to note that the fewest number of events occurred in 2011.

The number of accidents that were extracted from the events data for their respected year showed a different picture. Of the 54 events that occurred in 1998, none were considered accidents by our restrictive definition. Unlike the number of events, which increased steadily from 1998 to 2003, the number of accidents essentially decreased from 1999 to 2004. From 2005 to 2011, though, there was no consistent pattern between year and number of accidents. Nevertheless, the accident frequency for this latter period was relatively low. Overall, the mean number of accidents for the 14-year period was $M = 19.1$ ($SD = 10.1$, *Range*: 0 to 31), with the fewest number of accidents occurring in 2010 and 2011.

Table 1

Summary of Number of Events and Accidents

Year of Event	**Number of Events**	**Number of Accidents**[a]
1998	54	0
1999	56	31
2000	70	31
2001	101	26
2002	87	27
2003	106	23
2004	59	20
2005	82	30
2006	72	13
2007	59	15
2008	61	20
2009	54	20
2010	56	5
2011	53	6
Total	970	267

Note.[a]An accident was defined by FAA Transportation Definitions (1988), but was restricted to those events where there was a chance it could have been prevented by the pilots. (See also Figure 1.)

Table 2 provides a summary of the accident data by age and includes the number of accidents overall, the number of accident cases that had complete data (pilot age and total flight hours), the aggregate pilot hours by age, and the accident rate per 1,000 hours. The accident rate was based on the ratio of “the number of accident cases with complete data” and “aggregate pilot hours per age.” This quotient was then multiplied by 1000. From Table 2, note that although there were 267 accidents, only 170 (64%) cases included both pilot age and total number of flight hours, which were needed to calculate accident rates. There also were 48 cases (18%) with incomplete data because age and/or flight hours were not reported.

Overall, with the exception of two outliers (ages 25 and 62), the accident rates per 1000 flight hours ranged from .06 (age 39) to .26 (age 45), and the ages with the highest rates involved pilots in their 40s (ages 41, 42, 45, 46, 47, 49). Of the 267 cases examined, there were only three accidents that involved pilots older than 60 years old. As for the two outliers, both were easily explained. There were two accidents involving 25-year-old pilots, but neither case included the pilots’ total flight hours and therefore the corresponding accident rate was 0. Similarly, there was one accident involving a 62-year-old pilot. This pilot had a total of 2,000 flight hours, which is unusual for older pilots, and the combination of a single case with a small number of flight hours inflated the corresponding accident rate for this age group.

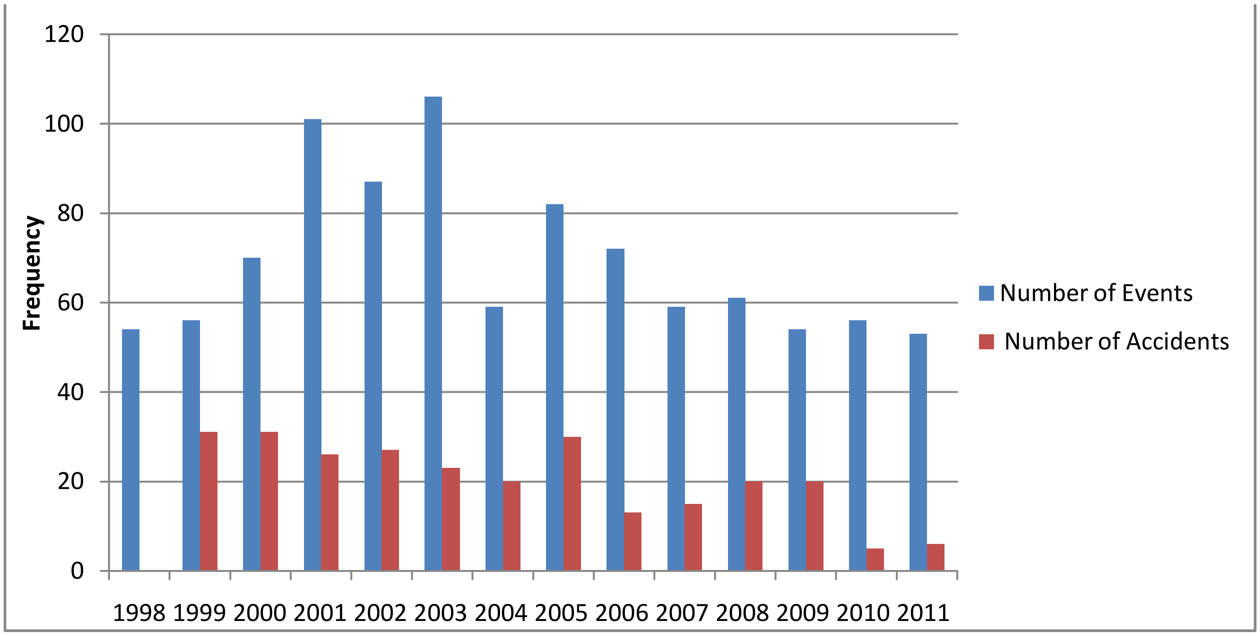

Figure 1. Number of events and accidents by year.

Table 3 compresses the data from Table 2 by summarizing the accident data by age group, which were partitioned into the following categories: less than or equal to 29 (LE29), 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, and Not Reported. These data also are pictorially displayed in Figure 2. An important attribute of Table 3 is the high percentage of incomplete data from the initial data set provided by ASIAS. For example, of the 267 accident cases that occurred during the targeted time period, 97 cases (36.3%) did not include the pilot’s age and/or the total number of flight hours.

The accident rates reported in Table 3 were calculated based on 10,000 pilot hours derived from the total flight hours. The accident rate ranged from 0.97 for the 50–54 age group to 1.86 for the 60–64 age group. It should be noted, though, there were only three pilots in this latter group with an aggregate of 16,138 total flight hours. The accident rate steadily increased beginning with the 30–34 age group until the 45–49 age group where it peaked at 1.58. A dramatic drop was then observed with the 50–54 group and then increased again for the 60–64 age group.

Table 4 contains a summary of the number of accident cases involving pilots for which the initial ASIAS data set included corresponding ages. As reported in Table 4, pilots who were 26, 40, 42, 44, 48, 52, 54, and 59 years old were involved in at least nine accidents during the 14-year period between 1998 and 2011; pilots of all other ages younger than 60 were involved in seven or fewer accidents. Pilots 60 years or older, though, were involved in two or fewer accidents during this time period.

Preliminary Data Analyses

Prior to testing our research hypothesis that pilot age is not related to aviation accident rates, we first conducted several preliminary analyses, including an outlier analysis, a check for multicollinearity, and a check for compliance with regression assumptions using the data set for accidents with complete cases reported in Table 2. This data set consisted of 39 cases involving 170 accidents. A brief description of each follows.

Outlier analysis. To check for outliers, we ran a Jackknife distance analysis involving pilots' age, total flight hours, and accident rate. This analysis flagged one outlier, which was the single case involving a 62-year-old pilot with an accident rate of 0.5 per 1000 flight hours. We removed this case, which left the data set consisting of 38 cases involving a total of 169 accidents.

Multicollinearity. We checked for multicollinearity by examining the variable inflation factors (VIFs) for the corresponding regression coefficients. According to Cohen, Cohen, West, and Aiken (2003), VIFs greater than 10 indicate the presence of multicollinearity. The VIFs obtained were 1.0.

Regression assumptions. We also examined the data set with respect to regression assumptions. According to Cohen et al. (2003), a given data set should be compliant with six regression assumptions: linearity, correct specification of the independent variables, measurement reliability, homoscedasticity of the residuals, independence of the residuals, and normality of the residuals. Because we were considering only one factor, namely, pilot age, we did not examine the data set for correct specification of the independent variables or for measurement error.

Table 2

Summary of Accident Data by Individual Ages

Pilot Age	**Number of Accident Cases**[a]	**Number of Accident Cases with Complete Data**[b]	**Total Flight Hours per Age**	**Accident Rate per 1,000 Hours**[c]
23	1	1	8,000	0.125
24	2	1	12,518	0.0798849656
25	2	0	0	0.0
26	11	9	69,334	0.1298064442
27	3	2	15,850	0.1261829653
28	3	2	15,865	0.1260636621
29	4	4	41,103	0.0973164976
30	7	5	39,885	0.1253604112
31	3	3	37,943	0.0790659674
32	3	1	12,500	0.08
33	2	2	14,850	0.1346801347
34	4	3	22,785	0.1316655695
35	7	7	32,678	0.214211396
36	5	5	35,795	0.1396843135
37	7	6	52,162	0.1150262643
38	3	2	21,783	0.0918147179
39	4	3	51,400	0.0583657588
40	10	8	57,813	0.1383771816
41	5	3	15,014	0.1998135074
42	10	8	42,749	0.1871388804
43	6	5	57,281	0.0872889789
44	11	9	75,623	0.1190114119
45	5	4	15,284	0.2617115938
46	7	6	33,111	0.1812086618
47	7	5	30,811	0.1622797053
48	11	9	69,887	0.1287793152
49	6	6	38,334	0.1565190171
50	7	5	38,781	0.1289291148
51	4	4	28,917	0.1383269357
52	9	4	46,285	0.0864210867
53	5	4	36,225	0.11042098
54	12	8	70,301	0.1137963898
55	6	6	39,696	0.1511487304
56	5	5	43,854	0.1140146851
57	5	1	9,145	0.1093493712
58	5	5	46,446	0.1076518968
59	9	6	63,882	0.0939231708
61	2	2	14,138	0.1414627246
62	1	1	2,000	0.5
Not Reported	48			
Total	267	170	1,362,578	

Note.[a]An accident was defined by FAA Transportation Definitions (1988), but was restricted to those cases where there was a chance it could have been prevented by the pilots. [b]This includes only cases in which pilot age and total number of flight hours were reported. [c]Accident rate was calculated as ("Number of Accident Cases with Complete Data" divided by "Total Flight Hours per Age") × 1000.

Table 3

Summary of Accident Data by Age Groups

Age Group	**Number of Accident Cases**[a]	**Number of Accident Cases with Complete Data**[b]	**% Cases with Incomplete Data**	**Total Flight Hours per Age Group**	**Accident Rate per 10,000 Hours**[c]
LE29	26	19	26.9%	162,670	1.17
30–34	19	14	26.3%	127,693	1.10
35–39	26	23	11.5%	193,818	1.19
40–44	42	33	21.4%	248,480	1.33
45–49	36	30	16.7%	189,977	1.58
50–54	37	25	32.4%	257,205	0.97
55–59	30	23	23.3%	203,023	1.13
60–64	3	3	0%	16,138	1.86
Not Reported	48				
Total	267	170	36.3%	1,399,004	

Note.[a] An accident was defined by FAA Transportation Definitions (1988), but was restricted to those cases where there was a chance it could have been prevented by the pilots. [b] This includes only cases in which pilot age and total number of flight hours were reported. [c] Accident rate was calculated as ("Number of Accident Cases with Complete Data" divided by "Total Flight Hours per Age Group") × 10000.

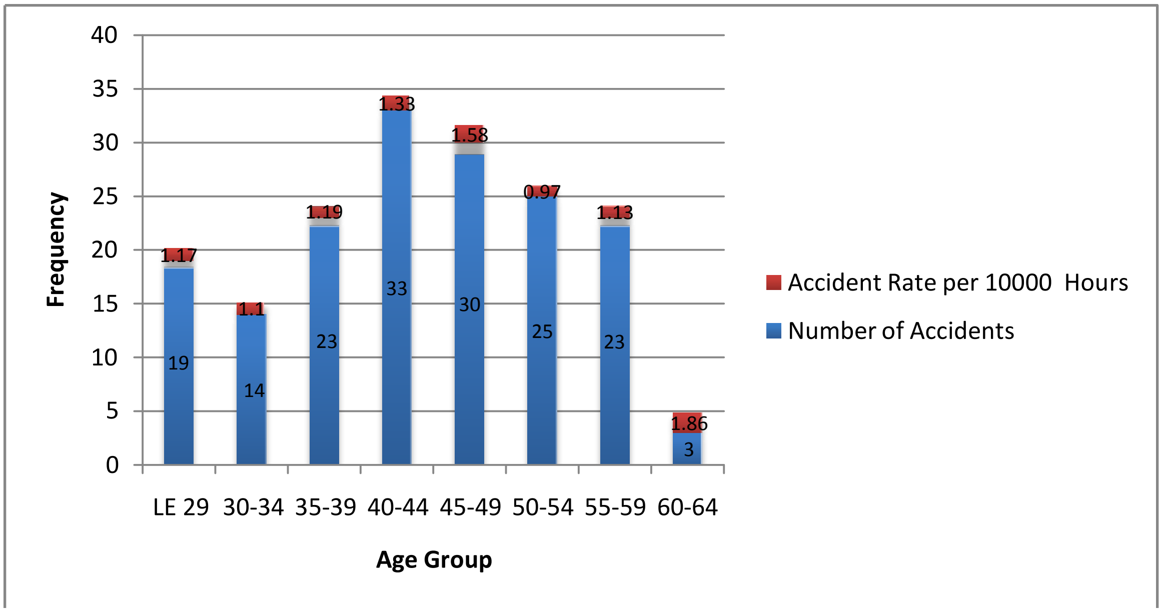

Figure 2. Number of pilots in each group vs. accident rate per 10,000 flight hours.

Table 4

Summary of Accident Cases by Number of Pilots with Respect to Age

Age in Years	Number of Pilots	Age in Years	Number of Pilots
23	1	43	6
24	2	44	11
25	2	45	5
26	11	46	7
27	3	47	7
28	3	48	11
29	4	49	6
30	7	50	7
31	3	51	4
32	3	52	9
33	2	53	5
34	4	54	11
35	7	55	6
36	5	56	5
37	7	57	5
38	3	58	5
39	4	59	9
40	10	60	0
41	5	61	2
42	10	62	1

Note.N = 267. Of these 267 accident cases, 48 cases had missing age data.

Linearity and homoscedasticity of the residuals. To check for these two assumptions, we regressed accident rate on pilot age and examined a scatter plot of the residuals against the predicted values and included the zero-line. The result showed little systematic pattern in the plot. Although the corresponding lowess line did not converge exactly to the zero line, we judged it to be close enough to conclude there was constant variance of the residuals. Nevertheless, we were still concerned about the possible presence of a nonlinear relationship between the variables as cited in the literature. For example, Golaszewski (1983) reported a U-shaped relationship and Kay et al. (1994) reported a quadratic trend across age groups for aviation and automobile accident rates. Broach et al. (2003) also reported that a U-shaped function “best described the trend in mean accident rate across age group” (p. 29). As a result, we decided to run two separate regression analyses—bivariate linear and polynomial—with accident rate being regressed on age as well as on age-squared.

Independence of the residuals. To check for this assumption, we regressed accident rate on pilot age and examined a scatter plot of the residuals against the case numbers and included the zero-line. The result showed little systematic pattern in the plot. Although the corresponding lowess line did not converge exactly to the zero line, we judged it to be close enough to conclude there was no relationship among the residuals for any subset of cases in the analysis.

Normality of the residuals. To check for this assumption, we examined a normal q-q plot of the residuals. In a normal q-q plot, if the residuals ape a normal distribution, then they should appear to be close to the straight line that is superimposed. This was indeed the case, and all of the points were enclosed within a 95% confidence band.

Primary Data Analyses

Working with a data set that consisted of 38 complete cases involving 169 accidents (see Table 2), we first conducted a bivariate linear analysis in which accident rate per 1000 hours was regressed on pilot age. This analysis yielded a nonsignificant model, $r^2 = .007$, $F(1, 35) = 0.26$, $p = .6127$ (see Table 5). Thus, based on the sample data, we failed to reject the corresponding null hypothesis: There is no significant linear relationship between pilot age and accident rate.

Table 5

Parameter Estimates for Linear Model of Accident Rate vs. Age

Term	Estimate	*SE*	*t*	95% CI	*p*
Intercept	0.1155	0.0272	4.24	[0.060, 0.171]	.0002
Pilot Age	0.0003	0.0006	0.51	[-0.001, 0.002]	.6127

Note. $N = 169$ accidents with complete data involving 38 different pilot ages ranging from 29 to 61 years old (see Table 2). Overall $r^2 = .0074$, $F(1, 35) = 0.26$, $p = .6127$.

We next conducted a quadratic analysis in which accident rate per 1000 hours was regressed on pilot age and age-squared. This yielded a nonsignificant overall model, $R^2 = .102$, $F(2, 34) = 1.93$, $p = .1601$ (see Table 6). Although the increment in explained variance (sr^2) between the linear and quadratic models was $.102 - .007 = .095$, this increment also was not significant, $F(1, 35) = 3.687$, $p = .0630$. Thus, based on sample data, there is no significant quadratic relationship between pilot age and accident rate.

Table 6

Parameter Estimates for Quadratic Model of Accident Rate vs. Age

Term	Estimate	*SE*	*t*	95% CI	*p*
Intercept	0.1296	0.0273	4.74	[0.074, 0.185]	< .0001
Pilot Age	0.0003	0.0006	0.50	[-0.001, 0.001]	.6127
$(\text{Pilot Age})^2$	- 0.0001	6.8×10^{-5}	-1.89	[-0.000, 0.000]	.0667

Note. N = 169 accidents with complete data involving 38 different pilot ages ranging from 29 to 61 years old (see Table 2). Overall R^2 = .1021, $F(2, 34)$ = 1.93, p = .1601.

In addition to the previous analyses, we also examined the differences in accident rates among the nonoverlapping age groups used by Broach et al. (2003) as shown in Table 3. The results of a one-way ANOVA confirmed there were no significant differences in accident rates with respect to any of the targeted age groups, R^2 = .3121, $F(7, 29)$ = 1.88, p = .1097 (see Table 7). Thus, although the different age groups collectively accounted for 31.21% of the variance in accident rates, the overall model was not significant at the preset alpha level of .05.

Table 7

Mean Accident Tae per 1000 Hours by Age Group

Age Group	**N^a**	**M^b**	**SE^c**	**95% CI**
LE29	6	.11	0.015	[.08, .14]
30–34	5	.11	0.017	[.08, .14]
35–39	5	.12	0.017	[.09, .16]
40–44	5	.14	0.017	[.11, .18]
45–49	5	.18	0.017	[.14, .21]
50–54	5	.12	0.017	[.08, .15]
55–59	5	.12	0.017	[.08, .15]
60–64	1	.14	0.037	[.06, .22]

Note. N = 169 accidents with complete data involving 38 different pilot ages ranging from 29 to 61 years old (see Table 2).
[a] N = total number of accident cases with complete data for each age group. [b] M = mean accident rate per 1000 flight hours. [c] SE = standard error based on pooled estimate of error variance. Overall R^2 = .3121, $F(7, 29)$ = 1.88, p = .1097.

Discussion

The results of the current study are consistent with those reported by Mohler et al. (1967), Broach (2000), and Li et al. (2003). There was no significant linear or quadratic relationship between pilot age and accident rate, and it appears that the accident rate of senior U.S. part 121 air carrier pilots is not statistically different than the accident rate of their younger counter parts. The results of the study are not consistent with those reported by Broach et al. (2003), however, who reported a significant quadratic relationship between age and accident rate. A plausible explanation for this inconsistency is that Broach et al.'s findings were based on data from 1988 to 1997, whereas the current study's findings were based on data from 1998 to 2011. A second plausible explanation is that the data set of the current study was incomplete. This also was a problem for Broach et al. who commented on the "limits of available data" (p. 13). It is conceivable that if we had a more complete data set, then the results might have been more consistent with those of Broach et al. It also is conceivable that if more data were available to Broach et al., then their findings might have been more consistent with ours. A third plausible explanation is that our analysis was based on a very restrictive definition of an "accident." It is possible that if we had examined all the event data and used FAA's definition of an accident without imposing an additional restriction on this definition that focused on only accidents that were due to pilot error, then we might have had similar results to those reported by Broach et al.

In conclusion, age does not appear to be a significant predictor of accident rates involving part 121 pilots for U.S. air carriers. Based on these results, a recommendation to the FAA is to remove the age 65 mandatory retirement regulation so part 121 U.S. air carrier pilots may operate an aircraft as pilots beyond the age of 65 as long as they can hold a valid class I or II medical certificate.

A final comment about the amount of missing data also is warranted. The number of missing data in the data set ASIAS provided surprised us. Because not all the cases reported by the NTSB included total flight hours and pilot age, any analysis that examines the relationship between pilot age and accident rate measured per flight hours is going to be problematic, which will make it difficult to compare results from different studies. Therefore, a recommendation is for the NTSB and FAA to strive for data completeness and integrity by ensuring that all the data are collected and included in their investigation reports.

Limitations and Delimitations

A limitation refers to circumstances or events that are beyond the control of the researcher. In the current study, one limitation was with respect to the data set. Because ASIA provided the data, we had no control over its integrity or accuracy. As noted above, second limitation is the amount of missing data.

A delimitation refers to circumstances or events that the researcher imposes on the study that further limits the generalizability of the results. One delimitation of the current study is that we only considered accident reports with respect to part 121 operations as defined by FAA Transportation Definitions (1988).Thus, a similar study to the current one that involves populations other than part 121 pilots such as general aviation pilots might not get the same results. A second delimitation is that we used a more restrictive definition of an accident than the FAA's definition. Accidents that are compliant with the criteria of C.F.R §830.2 but could not be prevented by the pilots (i.e., were not the result of pilot error) were not included. As a result, similar studies to the current one that removes the restriction we imposed might not get the same results. A third delimitation is that we chose to delete all cases with missing data. Therefore, another study that uses this data set but opts to use a data imputation method for missing data might not get the same results.

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The Relationship Between 2011 METAR and TAF Data at Chicago-Midway and Seattle-Tacoma Airports

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Abstract

This study examined the relationship between expected meteorological conditions as specified by TAF reports and actual ground conditions as specified by hourly METAR reports for Chicago-Midway (MDW) and Seattle-Tacoma (SEA) airports for the period September–December 2011. MDW and SEA were targeted because they had the highest and lowest percentage of delays, respectively, for 2011. The rationale was to determine if one of the contributing factors for the difference in percentage delays was because of the relationship between TAF and METAR reports. The primary hypothesis was that the relationship between the forecasts and actual ground conditions at MDW would be weaker than the corresponding relationship at SEA. TAF and METAR data were acquired from the respective TAF and METAR products pages at "Aviation Weather Charts Archive" (2012). Descriptive statistics revealed that MDW had less total departures than SEA (86,834 vs. 100,133) for all of 2011, but it also had nearly five times as many weather-related departure delays than SEA. Chi square analyses indicated that although the relationship between TAF and METAR at each airport was statistically significant, the corresponding Kappa agreement coefficients showed that this relationship was nearly twice as strong at MDW (.60) than at SEA (.35). Plausible explanations include that 70% of the weather conditions at MDW were VFR as opposed to only 56% at SEA, MDW had one-third the number of special METARS than SEA (374 vs. 917), and MDW had approximately one-fifth the number of LIFR conditions than SEA (70 vs. 337). The analysis also revealed that SEA had difficulty correctly forecasting IFR and LIFR conditions, especially under rapidly changing conditions. Based on the study's findings, it appears that the relationship between TAF and METAR was not a contributing factor to departure delays at both MDW and SEA during the September–December 2011 period.

Introduction and Background

Airport delays are a common and often expected occurrence within the airline industry. The Bureau of Transportation Statistics (BTS), which collects aviation data, organizes the reason for airport delays into five main categories: carrier, weather, National Airspace System (NAS), security, and late aircraft arrival. Of these, "weather has been identified as the most important causal factor for NAS delays" (Sridhar & Kulkarni, 2008, p. 1) and has the greatest impact on airports.

“According to FAA statistics, weather is the cause of approximately 70% of the delays in the National Airspace System” (Kulesa, N.D., p. 1). Kulesa also reported “weather continues to play a significant role in a number of aviation accidents and incidents,” contributing to 23% “of all aviation accidents” (p. 1). Kulesa indicated that the total impact of weather “is an estimated national cost of $3 billion for accident damage and injuries, delays, and unexpected operating costs” (p. 1). Some of the weather-related delays cited by Kulesa (N.D.) included thunderstorms and other convective weather, in-flight icing, turbulence, ceiling and visibility, ground de-icing, and volcanic ash.

Klein, Craun, and Lee (2010) reported “understanding airport delays, their causes and their relationship with inclement weather has been the subject of research for many years, especially since the late 90’s” (p. 1). This research has benefited from the combined efforts of federal organizations such as the National Weather Service (NWS), Federal Aviation Administration (FAA), Department of Defense (DOD) and NASA, private organizations such as MITRE, MIT Lincoln Lab, and academic institutions such as MIT, University of Maryland, and George Mason University (Klein et al., 2010).

Most of the research focus has been on developing models of delay. For example, using data from BTS and an open-source package called Weka (Hall et al., 2009), which is a collection of machine learning algorithms for data mining purposes, Stefanski (2009) developed models for predicting flight delays based on various attributes of a particular flight. Because of the voluminous amount of data, Stefanski limited his analysis to departing flights during the month of February 2008, and focused on seven attributes: day of week, airport origin, carrier, departure time, departure delay time, and distance the flight must travel after departure. As part of his findings, Stefanski reported that “airports and carriers may play a key role in determining whether a flight will be delayed or not” (p. 4), and “it is possible to make fairly good predictions on the basis of a few key attributes, such as carrier, departure time, date, and airport” (p. 7). A drawback to Stefanski’s study, though, is that the data were limited to a single month and he did not include weather as one of his attributes.

At the 26th International Congress of the Aeronautical Sciences, Sridhar and Kulkarni (2008) reported on their research, which involved developing models relating national delay, center level delays, and weather. They developed their models using the Weather Impacted Traffic Index (WITI), which is a metric of the number of aircraft affected by weather at a given instant of time. WITI uses National Convective Weather Diagnostic reports as well as METAR, which is “the primary observation code used in the U.S. to satisfy World Meteorological Organization (WMO) and International Civil Aviation Organization (ICAO) requirements for reporting surface meteorological data” (Aviation Weather Services, 2010, p. 3-1). Sridhar and Kulkarni restricted their analysis to traffic data for the 5-month period between April and August for the years 2004–2006, inclusive. The centers Sridhar and Kulkarni targeted were the 20 FAA Air Route Traffic Control Centers (ARTCC) within the continental U.S.

Sridhar and Kulkarni (2008) found mostly small correlations (< .30) between national WITI and center delays, which indicate that the national WITI is not a good predictor of weather delays at these centers. The centers with the lowest correlations (− .02 to .03) included Seattle (ZSE), Oakland (ZOA), Salt Lake City (ZLC), Albuquerque (ZAB), and Minneapolis (ZMP). The center with the largest correlation was New York (ZNY) at .40, which indicates that national WITI may be a good predictor of weather delays at the New York center. When Sridhar and Kulkarni examined the relationship between each center's respective WITI and center delays, they found that all centers except Seattle (− .02) had a positive correlation that ranged between .17 (Jacksonville, ZJX) and .72 (Houston, ZHU). This finding suggests that the Seattle center, which covers Washington, most of Oregon, and parts of California and Idaho, is unique because the weather delays at the center were related to neither the national WITI nor the center's own WITI.

Sridhar and Kulkarni (2008) also examined the impact of weather in each center on NAS delays. They found that the Oakland and Seattle centers had the lowest average daily WITI, 79 and 83, respectively, which indicates that these regions had the fewest number of aircraft affected by weather at a given instant of time. Among the 20 centers, though, the Seattle center was the only one with a zero average daily contribution to national delays. On the other hand, the center with the highest average daily contribution to national delays was the Chicago (ZAU) center, with an average WITI of 1,476. This center covers the northern half of Illinois, the southern Wisconsin, the eastern Iowa, and parts of Indiana and Michigan.

Instead of focusing on ARTCC as Sridhar and Kulkarni (2008) did, Klein et al. (2010) used WITI for predicting airport delays. Klein et al. initially used a 3-component WITI that included en route component (E-WITI), the terminal component (T-WITI), and the queuing delay component (Q-DELAY). E-WITI "reflects the impact of convective weather on routes connecting major airports," T-WITI "captures capacity degradation resulting from surface weather impact, proportional to the number of operations at an airport," and Q-DELAY "measures the cumulative effect of traffic demand in excess of capacity" (Klein et al., p. 2). They found that this 3-component WITI was insufficient to identify the weather's impact on individual airports.

As a result, Klein et al. (2010) modified this model and developed a 12-component airport WITI that included: E-WITI, which does not depend on the airport's terminal weather; volume WITI, which is based only on traffic; local convective weather; wind; snow; IMC data, which includes ceiling or visibility below airport specific minima, fog, and heavy rain; and other, which includes "minor impacts due to light/moderate rain or drizzle but ceilings/visibility above VFR minima (and) unfavorable RWY configuration usually due to light-to-moderate winds (15-20 Kt or even 10 Kt) that prevent optimum-capacity runway configurations from being used" (p. 3). These latter five components were then converted into T-WITI (linear) and Q-DELAY (nonlinear). Kelin et al. (2010)

tested their model comparing predicted delays “for several major airports and for two different seasons (summer, winter)” (p. 7) to actual delays for specific dates in 2008 and 2009. They found the model to be robust and “sufficiently sensitive to weather forecast inaccuracies (and therefore) […] can be used for convective and non-convective forecast product evaluation” (p. 12).

Pearson (2002) reported that among the fatal general aviation aircraft accidents that occurred between 1995 and 2000, two significant factors in 63% of the accidents were low ceilings and visibilities, which means the accidents occurred during Instrument Flight Rules (IFR) conditions. In an effort to shed light on the importance of IFR conditions in Terminal Aerodrome Forecasts (TAFs), Thompson and Baumgardt (2009) examined hourly METARs from 1961–2009 “to achieve climatological averages and percentiles for IFR conditions for two airports: La Crosse, WI (LSE) and Rochester, MN (RST). In contrast to a METAR, which contains the current meteorological conditions, a TAF contains the forecasted conditions. It is a “concise statement of the expected meteorological conditions significant to aviation for a specified time period within 5 statute miles of the center of the airport’s runway complex (terminal)” (Aviation Weather Services, 2010, p. 7-19).

Thompson and Baumgardt (2009) found that “IFR conditions have the highest frequency of occurrence in the Upper Mississippi Valley during the winter months, November through March, with fog being the major weather contributor” and that snow also contributes about 30% to IFR conditions in cool season (p. 4). Thompson and Baumgardt also reported that METAR data from 1961–1990, showed that “measurable snow events have a direct correlation to IFR conditions and approximately 90% of IFR visibilities occur rapidly, or within 2 hours of snow onset with little difference between the two airports investigated” (p. 4).

Thompson and Baumgardt’s (2009) findings suggest that with respect to weather involving snow, “TAF utilize IFR as prevailing conditions when confidence is high in light measurable snow events (and) that IFR conditions be forecast quickly after snow onset” (p. 4). To do this, Thompson and Baumgardt suggested that meteorologists use a variety of data, including historical METAR data as well as data from the Localized Aviation Model Output Statistics (MOS) Program (LAMP) in their forecast preparation process. Thompson and Baumgardt further suggested that because hourly historical METAR records are available at many locations that researchers examine historical METAR data to see how they related to TAF.

There is no argument that air traffic delays are a common phenomenon within the aviation field and that “inclement weather is the single biggest factor causing air traffic delays in the U.S.” (Klein, Kavoussi, & Lee, 2009, p. 1). The literature reviewed here demonstrates both the diversity of studies being conducted with respect to this issue as well as some of the limitations. For example, Stefanski (2009) focused only on delays in general without regard to weather and restricted his study to only a single month “to reduce the sheer size of the dataset" (p. 1). Although Sridhar and Kulkarni (2008) focused on weather delays specifically, they restricted their studies to those occurring at the 20 ARTCCs within the continental U.S. They also focused on 5 non-winter months (April to August) for a 3-year period. Klein et al. (2010) developed a robust airport delay prediction model and applied this model to predict delays using past delay data, but they did not examine differences in delays among airports. Lastly, Thompson and Baumgardt (2009) concentrated on historical METAR data at two airports to see how they were related to IFR conditions in corresponding TAFs.

Purpose Statement and Operational Definitions

Following Thompson and Baumgardt's (2009) recommendation to examine historical METAR data to see how they relate to TAF, the purpose of the current study was to examine the relationship between TAF and METAR at two airports: Seattle-Tacoma (SEA) and Chicago-Midway (MDW). The reason for selecting these airports was based on Sridhar and Kulkarni's (2008) findings with respect to the Seattle and Chicago ARTCCs, and on data from the Bureau of Transportation and Statistics, which showed MDW and SEA had the highest and lowest percentage of delays, respectively, for 2011. The rationale was to determine if the relationship between TAF and METAR was a contributing factor to weather delays at these airports in 2011.

The current study was guided by the following research questions: (1) What is the relationship between METAR and TAF at SEA and MDW, respectively, in 2011? and (2) To what extent was the relationship between METAR and TAF a contributing factor to weather delays at SEA and MDW, respectively, in 2011? In the context of the study, weather conditions were defined with respect to visibility and ceiling height, which were classified as Low Instrument Flight Rules (LIFR), Instrument Flight Rules (IFR), Marginal Visual Flight Rules (MVFR), and Visual Flight Rules (VFR). Federal Aviation Regulations define LIFR conditions as a ceiling below 500 feet above ground level (AGL) and/or less than 1 statute mile visibility. IFR conditions are defined as 500 feet AGL to below 1000 feet AGL and/or 1 statute mile to below 3 statute miles visibility. MVFR conditions are defined as a ceiling 1000 to 3000 feet AGL and/or 3 to 5 statute miles visibility. VFR conditions are defined as a ceiling greater than 3000 feet AGL (or no ceiling) and greater than 5 statute miles visibility. Furthermore, "ceiling" was defined as overcast conditions or broken cloud cover, and "no ceiling" was defined as clear skies, few clouds, or scattered clouds. An overcast cloud layer covers 8/8 of the sky, a broken layer covers 5/8-7/8 of the sky, scattered clouds cover 3/8-4/8, few clouds cover 1/8-2/8, and clear skies are no clouds (Aviation Weather Services, 2010, pp. 3-13). The cloud cover was automatically reported as overcast, broken, scattered, few or clear in the TAF and METAR reports.

Methodology

The population for this study was all TAF and METAR reports for 2011 from MDW and SEA airports. Because of limited access to 2011 TAF and METAR reports, we used a convenience sampling strategy that delimited the sample to the 4-month period September through December 2011. Data collection consisted of accessing the on-time flight performance database ("Research and Innovative Technology Administration," 2012). We then selected the "Get Lookup Table" link in the "OriginAirportID" section under the "Origin" headline to acquire the codes for Chicago-Midway (KMDW = 13232) and Seattle-Tacoma (KSEA = 14747).To retrieve airport data, we selected the following field names and descriptors for the targeted airports: dep_delay_new, arr_delay_new, cancelled, cancellation_code, diverted, flights, carrier_delay, weather_delay, NAS_delay, security_delay, late_aircraft_delay.Once all the appropriate descriptors were selected, we downloaded the corresponding data file and then prepared data tables using Excel. We collected TAF and METAR data from the respective TAF and METAR products pages at "Aviation Weather Charts Archive" (2012). The METARs were placed into Excel and labeled with the appropriate weather category and then matched with the corresponding TAF. The completed Excel tables were then loaded into the statistical software JMP Pro (2012) for data analysis.

Data Analysis

Descriptive Statistics

A summary of the number and minutes of flight delays by category departing MDW and SEA for the last 4 months of 2011 are provided in Table 1 and Table 2, respectively. As reported in these tables, MDW had 1,073 weather-related delays and SEA had 231 weather-related delays. Thus, MDW had 4.65 times more the number of weather-related delays than SEA. When examined with respect to total delays, the percentage of weather-related delays for MDW was 1073/49141, or about 2.1%, and the percentage of weather-related delays for SEA was 231/31842, or about 0.7%. When these data were examined with respect to number of minutes of delay, MDW had 47,958 minutes of weather-related delay out of 1,179,938 total delays, which is about 4.1%. Similarly, SEA had 7,814 minutes of weather-related delay out of 693,912 total delays, which is about 1.1%. Finally, when total departing flights are considered, MDW had 86,834 flights in all of 2011, of which 1073 were weather-related delays (1.2%) whereas SEA had 100,133 flights in all of 2011, of which 231 were weather-related delays (0.2%). In short, MDW had nearly five times as many weather-related delays as SEA despite less total departures.

A summary of the comparison between TAF and METAR for MDW and SEA for September–December 2011 is provided in Table 3. As reported in Table 3, each airport had 2,928 regularly scheduled METARs over the 4-month period. MDW had 3,302 total METAR reports of which 374 were special, unscheduled issuances. SEA had 3,845 total

METAR reports of which 917 were special, unscheduled reports giving SEA 2.45 times more special reports. Of the 3,302 METARs at MDW, the TAF correctly forecasted 2,137 (65%) VFR conditions, 396 (12%) MFR conditions, 22 (0.6%) LIFR conditions, and 142 (4%) IFR conditions. Of the 3,845 METARs at SEA, the TAF correctly forecasted 1,799 (47%) VFR conditions, 540 (14%) MFR conditions, 68 (1.8%) LIFR conditions, and 53 (1.4%) IFR conditions.

A summary of the TAF vs. METAR agreements for MDW for the last quarter of 2011 is provided in Table 4. The METAR reported VFR conditions 2,322 times (70.3%), MVFR occurred 638 times (19.3%), LIFR occurred 70 times (2.1%), and IFR conditions occurred 272 times (8%). The TAF was correct in forecasting 92% of the time for VFR conditions, 62.1% for MVFR, 31.4% for LIFR, and 52.2% of the time for IFR.

A summary of the TAF vs. METAR agreements for SEA for September–December of 2011 is provided in Table 5. The METAR reported VFR conditions 2,173 times (56.5%), MVFR occurred 1,042 times (27.1%), LIFR occurred 337 times (8.8%), and IFR conditions occurred 293 times (7.6%). The TAF was correct in forecasting 82.8% of the time for VFR conditions, 51.8% for MVFR, 20.2% for LIFR, and 10.9% for IFR.

Table 1

Number and Minutes of Delayed Flights by Category Departing Chicago-Midway (MDW) in 2011 by Month

	Type of Delay											
	Carrier		**Weather**		**NAS**		**Security**		**Late Aircraft**		**Total Delays**[a]	
Month	***N***	**Min.**	***N***	**Min.**	***N***	**Min.**	***N***	**Min.**	***N***	**Min.**	***N***	**Min.**
Jan.	1443	32498	103	2264	718	10829	0	0	1286	34565	4543	113843
Feb.	1075	24793	74	2140	867	15958	6	54	1002	27836	3501	83975
Mar.	1070	26391	56	2890	732	13164	8	108	957	32939	4297	98114
Apr.	1341	33908	95	4900	1006	20971	2	79	1395	57945	4511	136827
May	1344	31944	191	7275	955	21876	11	108	1416	66321	4872	151464
June	1213	31719	167	8298	776	19178	0	0	1230	56022	4781	140095
July	825	20681	73	3873	534	13093	1	9	835	32814	4376	101367
Aug.	917	21644	155	7532	554	15235	0	0	947	35852	4258	108973
Sep.	846	18968	69	2979	443	8437	1	125	833	29828	3957	92396
Oct.	690	16284	24	1826	412	8194	3	66	588	15541	3753	69914
Nov.	420	11743	24	1168	252	5007	1	7	377	11727	2950	20810
Dec.	444	13425	42	2813	248	5759	4	46	406	13389	3342	62160
Total	11628	283998	1073	47958	7497	157701	37	602	11272	414779	49141	1179938

Note. *N* = Total number of flights per category. *Source:* U.S. Dept. of Transportation's Bureau of Transportation Statistics (http://www.transtats.bts.gov).

[a] Total number of delayed flights and corresponding minutes represent *all* delays for 2011, including those not represented in the table. For example, NAS delays often include post-takeoff delays such as holds, which are not reported here.

Table 2

Number and Minutes of Delayed Flights by Category Departing Seattle-Tacoma (SEA) in 2011 by Month

	Type of Delay												**Total**
	Carrier		**Weather**		**NAS**		**Security**		**Late Aircraft**		**Total Delayed**[a]		**Flights**[b]
Month	***N***	**Min.**	***N***	**Min.**	***N***	**Min.**	***N***	**Min.**	***N***	**Min.**	***N***	**Min.**	***N***
Jan.	483	16145	37	1492	474	12960	2	27	471	16704	2617	60686	7585
Feb.	496	17967	60	1903	628	15744	2	17	446	16455	2286	58723	6812
Mar.	585	24723	17	571	651	17091	3	48	453	17750	2989	70508	7859
Apr.	443	16365	17	403	475	12583	6	93	407	16351	2449	58327	7719
May	572	17715	6	211	855	23402	8	109	376	14135	2579	54989	8537
June	540	19896	10	741	677	14922	5	45	496	20458	3018	66396	9337
July	563	20679	5	227	719	16923	3	48	515	22303	3022	68276	9828
Aug.	548	19396	4	258	554	15177	8	93	399	17299	3335	65791	9735
Sep.	376	14205	3	29	597	14444	1	24	214	8585	2251	39205	8558
Oct.	340	13928	7	356	497	12731	2	22	251	9892	2129	43485	8337
Nov.	425	18219	33	1130	615	16580	0	0	314	11572	2511	56141	7752
Dec.	457	15405	32	493	709	16592	1	37	368	13348	2656	51385	8074
Total	5828	214643	231	7814	7451	189149	41	563	4710	184852	31842	693912	100133

Note. *N* = Total number of flights per category. *Source:* U.S. Dept. of Transportation's Bureau of Transportation Statistics (http://www.transtats.bts.gov).

[a] Total number of delayed flights and corresponding minutes represent *all* delays for 2011, including those not represented in the table. For example, NAS delays often include post-takeoff delays such as holds, which are not reported here. [b] Total flights represent *all* flights for each month and overall.

Table 3

Comparison between TAF and METAR for MDW and SEA (September–December 2011)

	Airport							
	Chicago-Midway (MDW)[a]				**Seattle-Tacoma (SEA)**[b]			
	METAR				**METAR**			
TAF	**VFR**	**MVFR**	**LIFR**	**IFR**	**VFR**	**MVFR**	**LIFR**	**IFR**
VFR	2137	162	12	32	1799	406	152	93
MVFR	165	396	20	76	332	540	63	115
LIFR	0	3	22	22	21	34	68	32
IFR	20	77	16	142	21	62	54	53
Total	2322	638	70	272	2173	1042	337	293

Note.[a] *N* = 3302 METARS of which 374 were special reports. [b] *N* = 3845 METARS of which 917 were special reports. The frequencies along the diagonals (underscored) represent the number of times TAF forecasts matched corresponding METARS. These are further elaborated in Table 4 and Table 5.

Table 4

TAF vs. METAR Agreements for MDW (September–December 2011)

	VFR		**MVFR**		**LIFR**		**IFR**	
Report	***N***	**%**	***N***	**%**	***N***	**%**	***N***	**%**
TAF[a]	2137	92.0%	396	62.1%	22	31.4%	142	52.2%
METAR	2322	70.3%	638	19.3%	70	2.1%	272	8%

Note.[a]TAF percentages represent the ratio of TAF to METAR. For example, of the 2322 VFR METARs, TAF was correct 2137 times, or 92%. [b]METAR percentages represent the ratio of METAR frequencies (*N*) to the total number of METAR reports (3302). For example, VFR conditions were observed 2322/3302, or 70% of the time.

Table 5

TAF vs. METAR Agreements for SEA (September–December 2011)

	VFR		**MVFR**		**LIFR**		**IFR**	
Report	***N***	**%**	***N***	**%**	***N***	**%**	***N***	**%**
TAF[a]	1799	82.8%	540	51.8%	68	20.2%	32	10.9%
METAR	2173	56.5%	1042	27.1%	337	8.8%	293	7.6%

Note.[a]TAF percentages represent the ratio of TAF to METAR. For example, of the 2173 VFR METARs, TAF was correct 1799 times, or 82.8%. [b]METAR percentages represent the ratio of METAR frequencies (*N*) to the total number of METAR reports (3845). For example, VFR conditions were observed 2173/3845, or 56.5% of the time.

Inferential Statistics

A summary of the results of the Chi-square analysis and agreement statistics between TAF and METAR for MDW and SEA by month is provided in Table 6. As reported in Table 6, the relationship between TAF and METAR was statistically significant for each of the targeted months for both MDW and SEA. In September for MDW, $\chi^2 = 403.87$, $df = 9$, $p < .0001$, and for SEA, $\chi^2 = 280.02$, $df = 9$, $p < .0001$. In October for MDW, $\chi^2 = 352.99$, $df = 4$, $p < .0001$, and for SEA, $\chi^2 = 204.03$, $df = 9$, $p < .0001$. In November for MDW, $\chi^2 = 606.85$, $df = 9$, $p < .0001$, and for SEA, $\chi^2 = 208.65$, $df = 9$, $p < .0001$. In December for MDW, $\chi^2 = 571.73$, $df = 9$, $p < .0001$, and for SEA, $\chi^2 = 334.68$, $df = 9$, $p < .0001$.

Table 6

Results of Chi-Square Analyses and Agreement Statistics between TAF and METAR for MDW and SEA by Month (September–December 2011)

	Airport							
	Chicago-Midway (MDW)				Seattle-Tacoma (SEA)			
Month	***N***	***df***	χ^{2a}	**Kappa**[b]	***N***	***df***	χ^2	**Kappa**
September	821	9	403.87*	0.54*	830	9	280.02*	0.51*
October	790	4	352.99*	0.71*	1040	9	204.03*	0.25*
November	823	9	606.85*	0.63*	920	9	208.65*	0.35*
December	868	9	571.73*	0.53*	1055	9	334.68*	0.30*

Note.[a]Chi-square reflects likelihood ratio. [b]Kappa coefficient is an agreement statistic that varies between 0 and 1 where 0 = no agreement between the factors and 1 = perfect agreement between the factors.
**p*< .0001.

Table 7

Results of Chi-Square Analyses and Agreement Statistics between TAF and METAR for MDW and SEA Overall (September–December 2011)

Airport	***N***	***df***	χ^{2a}	**Kappa**[b]
Chicago-Midway (MDW)	3302	9	2021.27*	0.60*
Seattle-Tacoma (SEA)	3845	9	1077.46*	0.35*

Note.[a]Chi-square reflects likelihood ratio. [b]Kappa coefficient is an agreement statistic that varies between 0 and 1 where 0 = no agreement between the factors and 1 = perfect agreement between the factors.
**p*< .0001.

In addition to the Chi-square analyses, the Kappa coefficient also was calculated for each airport. The Kappa coefficient is an agreement statistics that varies between 0 and 1 where 0 signifies no agreement between factors and 1 signifies perfect agreement between factors. As indicated in Table 6, the monthly Kappa coefficients were significant, which indicates there was a significant relationship between TAF and METARs at each airport. In September for MDW, Kappa = .54, $p < .0001$, and for SEA, Kappa = .51, $p < .0001$. In October for MDW, Kappa = .71, $p < .0001$, and for SEA, Kappa = .25, $p < .0001$. In November for MDW, Kappa = .63, $p < .0001$, and for SEA, Kappa = .35, $p < .0001$. In December for MDW, Kappa = .53, $p < .0001$, and for SEA, Kappa = .30, $p < .0001$.

A summary of the results of the Chi-square analysis and agreement statistics between TAF and METAR for MDW and SEA for the 4-month period, September–December 2011 is provided in Table 7. As reported in Table 7, the overall relationship between TAF and METAR was statistically significant. For MDW, $\chi^2 = 2021.27$, $df = 9$, $p < .0001$, and for SEA, $\chi^2 = 1077.46$, $df = 9$, $p < .0001$. The corresponding overall agreement statistics also were significant: For MDW, Kappa = .60, $p < .0001$; for SEA, Kappa = .35, $p < .0001$.

Discussion

When the study's results are applied to the first research question, the relationship between METAR and TAF data from September–December 2011 at Seattle-Tacoma and Chicago-Midway, respectively, was statistically significant, which indicates that forecasts at both airports were related to actual weather conditions. The TAF-METAR relationship at MDW, however, was nearly twice as strong as the TAF-METAR relationship at SEA as given by the Kappa coefficient. One plausible reason why MDW had a better TAF-METAR agreement was because 70% of the weather conditions at MDW during the targeted 4-month period were VFR as opposed to only 56% at SEA. SEA also had LIFR conditions 337 times (9%) whereas MDW only had LIFR conditions 70 times (2.1%). The greater prevalence of VFR conditions at MDW coupled with the greater prevalence of LIFR conditions at SEA suggests that MDW's forecasts would be more accurate than SEA's forecasts. This makes sense from a meteorological standpoint because it is typically easier to forecast good weather conditions (i.e., VFR) than bad weather conditions (i.e., IFR or LIFR).

With respect to the second research question, because the forecasts at both airports had strong statistical agreements with the actual ground conditions, it appears that the weather forecasts at MDW and SEA were not a contributing factor to weather delays from September–December 2011. What was surprising, though, was that MDW's Kappa agreement coefficient of .60 was nearly twice as high as SEA's Kappa coefficient of .35. Although SEA had more challenging weather than MDW as evidenced by more LIFR conditions and less VFR conditions, and SEA also had more total departures than MDW, SEA still had less weather related departure delays than MDW. Thus, we expected SEA to have a higher Kappa coefficient than MDW.

A plausible explanation for this finding is the number of METAR reports. Referencing Table 6, the number of METARs at MDW and SEA for the month of September was nearly the same at 821 and 830, respectively. The corresponding Kappa coefficients also were similar at .54 and .51, respectively. However, for October–December, SEA had considerably more METAR observations than MDW, which equated to lower Kappa coefficients. The Kappa coefficients for MDW during the last 3 months were much higher than those for SEA. These findings suggest an inverse relationship between the number of METARs and the Kappa coefficient: As the number of METARs increases, the agreement statistics between TAF and METAR decreases. This inverse relationship is plausible when the special METAR (SPECI), which is non-routinely issued when weather is changing rapidly, is taken into consideration because it is easier to forecast weather that is relatively constant than weather that is changing rapidly in a short time period. More concretely: Unchanging, good weather (VFR), which was the general case at MDW, is much easier to forecast than rapidly changing bad weather (SPECI with LIFR), which was the general case at SEA.

Accenting the TAF-METAR relationship discussion, the data also suggest that during the targeted 4-month period SEA, when compared to MDW, was challenged in forecasting IFR and LIFR conditions, especially when conditions changed rapidly. For example, referencing Table 4 and Table 5, SEA correctly forecasted LIFR conditions 20% of the time vs. 31% of the time for MDW, and SEA correctly forecasted IFR conditions only 11% of the time compared to 52% of the time for MDW.

In conclusion, the data indicate that a plausible explanation for Chicago-Midway's weather-related departure delays compared to that of Seattle-Tacoma's is not poor forecasting because the results reflect the opposite: MDW had the higher frequency of weather-related delays but it also had a stronger agreement between TAF and METAR when compared to SEA. Although surprising, the data provided plausible explanations for the outcome. A better understanding of the reasons for the weather related departure delays at MDW and SEA may be possible with further research on what causes the weather delays, given that the forecasts were not a contributing factor. Replicating the current study using 2012 and 2013 data, and data from a time period other than September–December could reveal further insight and possibly different results. Because of the high number of unscheduled SPECI reports (particularly at SEA), it also may be beneficial to replicate the study with only regularly scheduled METAR reports. This modification may reveal different results because the rapidly changing weather between observations would be not taken into consideration.

Limitations and Delimitations

Limitations refer to circumstances or events that are beyond the control of the researcher. One limitation to the current study is that we used data provided by the respective airports. Other studies that use different weather data (e.g., "dominant" weather only might be reported) might get different results. A second limitation is TAF data were provided directly from the targeted airports and were not prepared by a different airport. Therefore, any subsequent study involving an airport that relies on TAF data from a region and not directly from the airport itself might get different results. A third limitation is that our findings are relevant to U.S. TAF data and not to the European model, which issues short TAFs (Jacobs, 1998). A final limitation is that the findings are reflective of the last quarter of 2011, not the entire year. Thus, similar studies that use an entire year's worth of data might get different results.

Delimitations refer to circumstances or events the researcher imposes on the study that further limits the generalizability of the results. One delimitation of this study is that although TAF reports include wind, visibility, weather, and cloud reports, we considered only visibility and clouds. Furthermore, only the more severe weather phenomenon was considered. For example, if thunderstorms and rain were reported, then only thunderstorms were included. Thus, other studies that use all of the data provided by TAF might not get the same results. A second delimitation is that we restricted METAR and TAF data to only September–December of 2011. Other studies involving the same targeted airports but use historical METAR and TAF data from a different time period might not get the same results. A third delimitation is that we focused on the two airports with the least and most delays in 2011. Studies that use the same selection criteria for a different time period will not necessarily involve the same airports. A final delimitation is that we restricted this study to weather-related delays on departure. Studies that focus on weather-related delays on arrival might not get the same results.

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Evaluating Flight Instructor Perceptions of Light Sport Aircraft

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Abstract

The Federal Aviation Administration has forecasted tremendous growth in general aviation over the next 20 years, mostly due to large increases in the population of sport pilots. These future pilots will need to be taught by instructors who have the experience, interest, and appropriate attitudes to accommodate successful growth in light sport aviation. Flight instructors without a sport pilot rating are authorized to instruct in light sport aircraft but have little or no experience requirements with such aircraft before teaching. The purpose of this study was to determine the perceptions current instructors held about light sport aircraft. This was accomplished by surveying two different samples of certified flight instructors: a group of randomly selected flight instructors from the FAA national airmen database, and a sample of flight instructors registered with the National Association of Flight Instructors. Instructor perceptions about light sport aircraft are analyzed using statistical methods. Comments indicate a need for additional effort to ensure the delivery of safe, efficient, quality training in light sport aviation.

Introduction

Light sport aircraft (LSAs) have quickly increased in popularity over the past few years. Their relatively low cost, lower fuel burn, and decreased experience requirements make them attractive to both flight schools and private owners. Additionally, the increase in flight time required before applying to a regional airline first officer position has many pilots looking for an inexpensive way to build flight time. There are 6,528 active LSAs operating in the country, compared to 222,520 active general aviation aircraft (Federal Aviation Administration, 2012), but most flight instructors do not have an LSA-specific license. How effective do non-sport pilot flight instructors feel they could be in light sport aircraft, and what attitudes do they have about LSAs? The present study intended to begin to address these questions in support of the growth of the light sport license among general aviation pilots.

In September of 2004, the Federal Aviation Administration (FAA) created a new category of aircraft to be flown by a new type of pilot. This was not the first time the FAA attempted to create more interest in aviation by adding an additional license category: the recreational pilot certificate introduced in 1989 (Experimental Aircraft Association, 2007a) was a dismal failure, peaking in 1999 with a total of 343 pilots (GAMA, 2006). The recreational pilot certificate required slightly less training than a traditional private pilot certificate, but with substantial restrictions to its use ("Certification: pilots, flight instructors, and ground instructors," 2007). The light sport rule, however, was envisioned to fill a previously untapped market – aircraft too heavy to be unregulated ultralights, and too light to qualify as heavily regulated normal category aircraft. Examples of light sport aircraft include wood and fabric planes built in the 1930s and 1940s and newer all-composite models (Experimental Aircraft Association, 2007c). The overall effect of this ruling was twofold: it increased safety in a previously unregulated area of aviation, and it provided a path to licensure for a previously untapped population of potential pilots.

Along with a new aircraft category, the light sport rule also created a new section of airmen certificates. As with the aircraft, the new requirements for sport pilots exceed those of ultralight pilots, but are less than those of private pilots who fly normal category aircraft ("Ultralight vehicles," 2001).. Two key differences exist between private pilot standards and sport pilot standards: the minimum required experience for sport pilots is half that of private pilots, and sport pilots may use a driver's license as certification of medical standards in lieu of the medical certificate required of private pilots, as long as they have never failed a pilot medical examination. Since the holder of a higher certificate may exercise the privileges of a lower certificate, holders of a recreational, private, commercial, or airline transport pilot certificate who have allowed their FAA medical certificate to expire can fly again, as long as they hold a driver's license and comply with any relevant restrictions, such as wearing glasses. This reduction in requirements comes with a reduction in privileges, which will be explained in the next section(Federal Aviation Administration, 2004).

Light Sport License Characteristics

While the requirements to exercise sport pilot privileges are greatly reduced from those of private pilots, the privileges are also greatly reduced. Sport pilots are limited to personal flying in aircraft that weigh no more than 1,320 pounds on land or no more than 1,430 pounds on water. LSAs are limited to a single reciprocating engine; although there is no restriction on horsepower, the weight restriction effectively limits the horsepower of the aircraft. Sport pilots are prohibited from flying at night, flying for business, carrying more than one passenger, flying without reference to the ground or with less than 3 miles of visibility, flying internationally, flying above 10,000 feet, towing an object, or flying through class B, C, or D airspace without additional training. Sport pilots are prohibited from flying an aircraft that has a Vh speed (maximum speed in level flight with maximum continuous power) faster than 87 knots without additional training. Even after receiving additional training, they can fly no aircraft with a Vh speed of more than 120 knots ("Certification: pilots, flight instructors, and ground instructors," 2007; "Definitions and abbreviations," 2006). Effectively, sport pilots are limited to pleasure flying in good weather.

Despite these strict limitations, the sport pilot certificate has been much more successful than the recreational pilot certificate. The number of sport pilots is already much higher than the peak number of recreational pilots, with 134 sport pilots after the first year and 939 at the end of 2006. This well exceeded the previous forecast of 300 sport pilots by the end of 2006 (GAMA, 2006). Further growth is projected to 12,800 sport pilots in 2015 and 20,600 sport pilots in 2025 (Federal Aviation Administration, 2008a).

Registered LSA are expected to grow from the 170 registered in 2005 to 13,200 aircraft by 2020 (Federal Aviation Administration, 2007b). Many of the first LSA registered were previously-built two-seat ultralights operating under an FAA exemption. These aircraft had until January 31, 2008 to be grandfathered into the light sport rule with experimental light sport aircraft (E-LSA) airworthiness certificates ("Certification procedures for products and parts," 2007). After this date, all new LSA were given special light sport aircraft (S-LSA) airworthiness certificates. Industry predictions call for about 10,000 new S-LSAs to be manufactured by 2020. The actual number of aircraft meeting LSA restrictions to be produced will be even higher, because this number does not account for aircraft certified under standard and experimental aircraft categories, which meet the definition of an LSA. A listing of possible experimental aircraft that meet the LSA definition is available from the EAA (Experimental Aircraft Association, 2007b). Variances in experimental aircraft and the airworthiness status of vintage aircraft make the exact number of aircraft meeting the technical requirements to be classified as an LSA unknown. Regardless, the growing number of sport pilots will have an increasing selection of aircraft.

Aircraft availability, however, is not the only factor driving the growth in recreational aviation. Growth is coming because a sport pilot certificate is easier to obtain and available to a larger number of people. After the failure of the recreational pilot certificate category, the FAA recognized that any new type of licensure would have to be significantly different from previous categories in order to generate interest. A new category of pilots, however, necessitated a new type of flight instructor.

Instructing in Light Sport Aircraft

Until 2004, certified flight instructors (CFIs) could only be certificated under 14 CFR 61 subpart H. Afterward, subpart K created a new class of flight instructors (CFI-SPs) to teach newly licensed sport pilots ("Certification: pilots, flight instructors, and ground instructors," 2007). The requirements to be a CFI far exceed the requirements to be a CFI-SP, but the current regulations do not require CFIs to receive any flight or ground training pertaining to light sport aviation. While the requirements for CFI-SPs are much lower, the privileges granted are lower as well. CFI-SPs can only train sport pilots, while CFIs can instruct recreational, private, and commercial pilots in a light sport aircraft with no additional training, and can instruct sport pilots with just 5 hours of experience in a similar LSA (Federal Aviation Administration, 2004).

Certified vs. Experienced Instructors

As Reinhart (1990) has suggested, simply being legal in an aircraft does not assure that a pilot is either safe or an effective flight instructor. Upon receiving the certificate, most instructors are advised that it is a “license to learn” and are encouraged by FAA publications to find an experienced flight instructor to mentor them (Federal Aviation Administration, 2007a). CFIs need many traits to successfully provide quality training to sport pilot students.

The FAA requires flight knowledge, skills, and experience to obtain a flight instructor certificate, but much more than that is needed to be a good instructor. In addition to being qualified, an instructor must be properly motivated. FAA instructional publications (1999) report improved effectiveness of intrinsically motivated instructors is due to an enhancement in the principle of effect. This principle states that learning is enhanced when associated with pleasant and enjoyable feelings, and conversely learning is weakened when accompanied by negative feelings (Federal Aviation Administration, 1999). This is especially important in recreational aviation, where even on a training flight an objective of the flight is enjoyment. A study of instructor effectiveness in kayaking by Phipps and Claxton (1997) revealed other issues in a similarly complex, high-risk activity, including the negative impact of showing too much risk too soon when instructors perform advanced maneuvers that beginning students cannot yet handle. Those experiences could frighten and turn students away.

Similarly, studies by Block (2007) focused specifically on the method individual instructors used to teach. More experienced instructors were more aware of basic teaching considerations, but many instructors were not motivated to improve their teaching methods – they saw teaching as a path to other employment in aviation, not an end goal. Their students took longer to progress, as a result. Additionally, instructors used to flying and teaching in more complex aircraft will need to make adjustments to teaching in a LSA, a type of “backward transition” made when transferring from more complex aircraft to simpler aircraft (Wiener, Chute, & Moses, 1999). Instructors will need to avoid the complacency that could be induced by flying a “simpler” aircraft. Even though the aircraft are simpler, their performance characteristics could be very different from any other aircraft the instructors have flown.

In summary, sport pilots and LSA represent an exciting new direction for aviation. More people than ever before are eligible to begin flight training, and all general aviation pilots have an increasing selection of low-cost aircraft from which to choose. In order for this renewed interest in aviation to continue, however, training in LSA must be just as safe and enjoyable for pilot applicants as training in typical aircraft has been, if not more so, as additional emphasis is placed on flying for enjoyment with light sport pilots. Instructors must be able to provide safe, comfortable learning experiences to their students (Federal Aviation Administration, 2008b).

Although a new category of instructors has been created, most instructors are currently licensed as CFIs, not CFI-SPs. CFIs are authorized to instruct in light sport aircraft with little to no experience in them, but these LSA may be very different than any other aircraft that they have flown. Do current CFIs feel comfortable flying and/or instructing in LSA? If the new light sport certificate is to be successful in the long-term, new light sport pilots need confident, knowledgeable instructors who are not only legally qualified to instruct light sport, but willing and eager to do so. In order to examine whether current instructors are indeed comfortable flying/instructing LSA, two samples of current CFIs were asked about their attitudes toward typical primary training aircraft and toward LSA.

Methodology

This research study used an online survey to measure attitudes of current CFIs about light sport aviation. This was thought to be more convenient for the sample population and greatly facilitated dissemination and data analysis, providing an overall more efficient use of time and resources for all parties involved. Participants were informed that their responses would be kept confidential, and that the data would only be referred to in the aggregate.

The variables measured included demographic information, attitudes, and perceptions of effectiveness. In order to compare instructor views of LSAs as opposed to more traditional/typical primary training aircraft such as the C-172 or Piper Warrior, instructors were asked about their level of comfort in typical small aircraft and in LSAs. Responses for each question were then averaged and subtracted to show the mean difference. Before use, the survey was validated by pilot testing and a thorough review by the Light Sport Aviation Branch of the FAA and the executive director of the National Association of Flight Instructors (NAFI).

In order to sample CFIs with different backgrounds, two different groups were used: a sample of licensed flight instructor addresses available from the FAA, and a sample of flight instructors who subscribe to the NAFI electronic newsletter. The NAFI flight instructors were thought be to more active in flight instruction and perhaps more familiar with light sport aircraft, and so provided an appropriate comparison to FAA-database instructors. A postcard with a link to the online survey was sent to a simple random sample of 1,000 ASEL and/or ASES CFIs and CFIIs (out of 77,591 registered with the FAA). This mailing generated 69 responses, a rate of 6.9%. Concurrently, a hyperlink to the survey was included in the NAFI electronic newsletter E-mentor, accessible to the entire readership of approximately 4,000 CFIs. Of the 163 responses, one participant was not a flight instructor and was removed, giving a true response rate of 4.05%. The surveys were open for four weeks. Both surveys had identical content, but used different links to differentiate between the responses. This low response rate was in keeping with that found by authors of similar mail-based studies (Dillman, 2000), but for the purpose of this initial exploratory study of light sport instructors it generated an appropriate sample size. Future studies on a larger scale are warranted, based on initial findings described herein.

Results

Demographics

Flight instructors who responded from the FAA database were mostly white (98%) males (97%), with large numbers of instructors in their 30s and in their 60s. The average age was 48.7 years, with a minimum of 21 and a maximum of 78. Half of flight instructors (52%) identified themselves as active flight instructors, and a quarter (26%) reported having flight time in light sport aircraft. Only two participants (3% of those who responded) were registered with the Experimental Aircraft Association (EAA) as sport pilot instructors (instructors licensed under subpart H, but who are willing to provide light sport instruction). The full EAA database has 902 sport pilot instructors on file, or 1.37% of CFIs with ASEL privileges.

NAFI flight instructors were also split between instructors in their 20s and 30s, and instructors in their 60s, with a minimum of 22 and a maximum of 83: The average was 53.3. The population was again mostly white (95%) males (96%) who consider themselves active flight instructors (90%). A large number (21.25%) were registered with the EAA as sport pilot instructors licensed under subpart H, including one who reported having a sport pilot flight instructor certificate (licensed under subpart K). A readership of 4,000 meant that, statistically, 1.37% or 55 sport pilot instructors should have seen the link, of which 34 (61.8%) responded. This response rate is much higher than for sport pilot instructors culled from the FAA database, possibly due to a lower number of sport pilots included in the simple random sample than in the NAFI sample, or due to a greater proportional concentration of sport pilot instructors in the NAFI sample than in the larger FAA database.

Attitudes toward Typical Primary Training Aircraft

Participants were first asked about their attitudes towards typical primary training single-engine aircraft in order to establish a baseline of self-ratings. A five point Likert-type scale was used; a selection of one indicated “no experience from which to judge,” while two through five corresponded to Strongly Disagree, Disagree, Agree, to Strongly Agree, respectively (depicted as NE, SD, D, A, and SA in the figures). Responses across both groups were very similar, with slightly more variation in the ratings of flight instructors listed in the FAA database, possibly due to a wider range of flight experiences. The average ratings for both groups were also very similar.
Open-ended responses indicated that many who rated their attitudes toward primary training single-engine aircraft as uncomfortable or unenjoyable (see specific survey items in Figures 1-5) felt so due to issues such as lack of currency or unwillingness to lose access to the more sophisticated equipment found in larger aircraft. In addition, some respondents reported they would not feel comfortable teaching in typical primary-flight training as they thought they would become bored with “pattern work” – flying a

relatively monotonous pattern with a more basic student.

Attitudes toward Light Sport Aircraft

The next section of the survey asked the same five questions as previously described, though now regarding light sport aircraft rather than typical primary training single-engine aircraft; see Figures 1-5 for these responses and survey questions. Again, both the FAA and NAFI groups have very similar positively-skewed responses, with similar percentages of instructors selecting "no experience from which to judge" and either "agree" or "strongly agree."

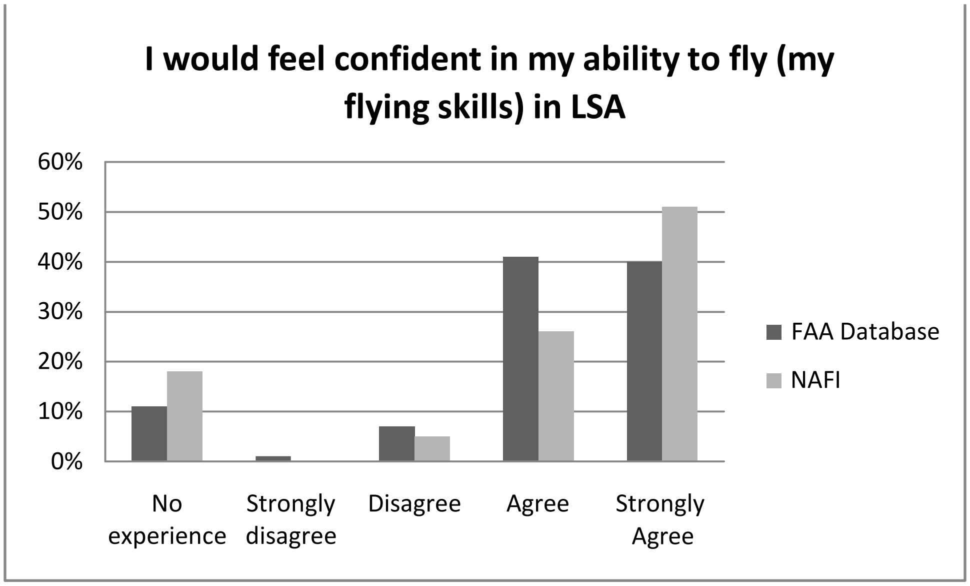

Figure 1. Responses from instructors selected from the FAA database and NAFI registered instructors to the statement "I would feel confident in my ability to fly these aircraft."

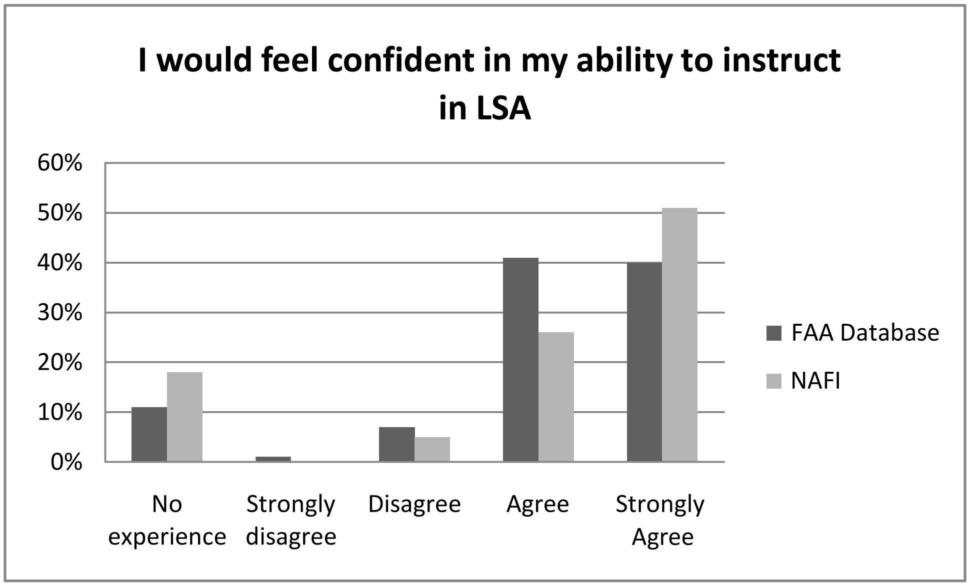

Figure 2. Responses from instructors selected from the FAA database and NAFI registered instructors to the statement “I would feel confident in my ability to instruct in these planes.”

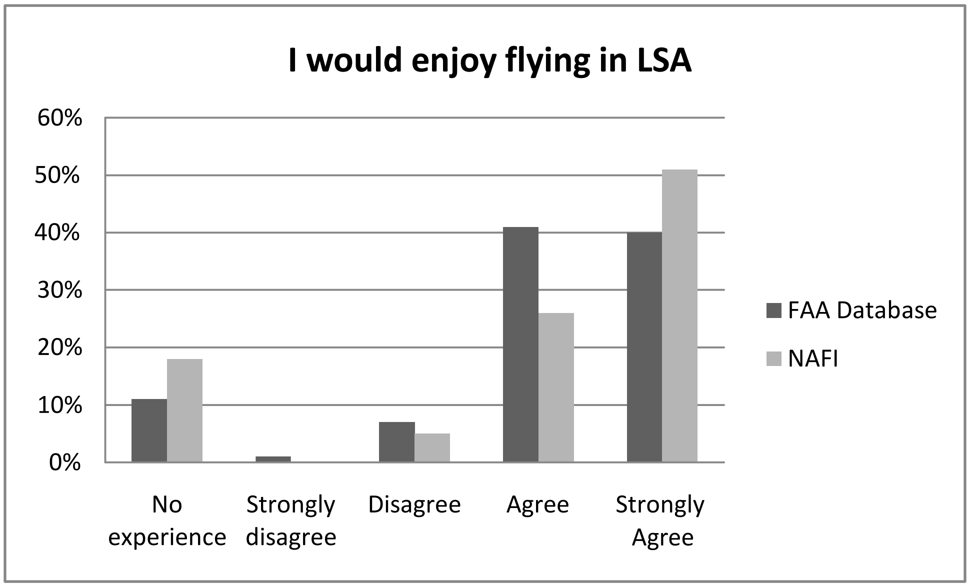

Figure 3. Responses from instructors selected from the FAA database and NAFI registered instructors to the statement “I would enjoy flying in these aircraft.”

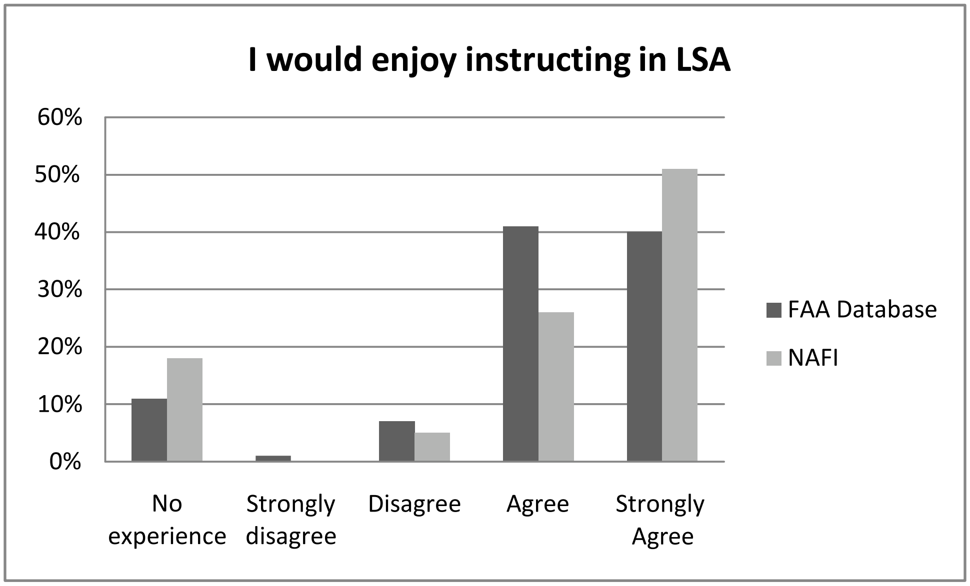

Figure 4. Responses from instructors selected from the FAA database and NAFI registered instructors to the statement "I would enjoy instructing in these aircraft."

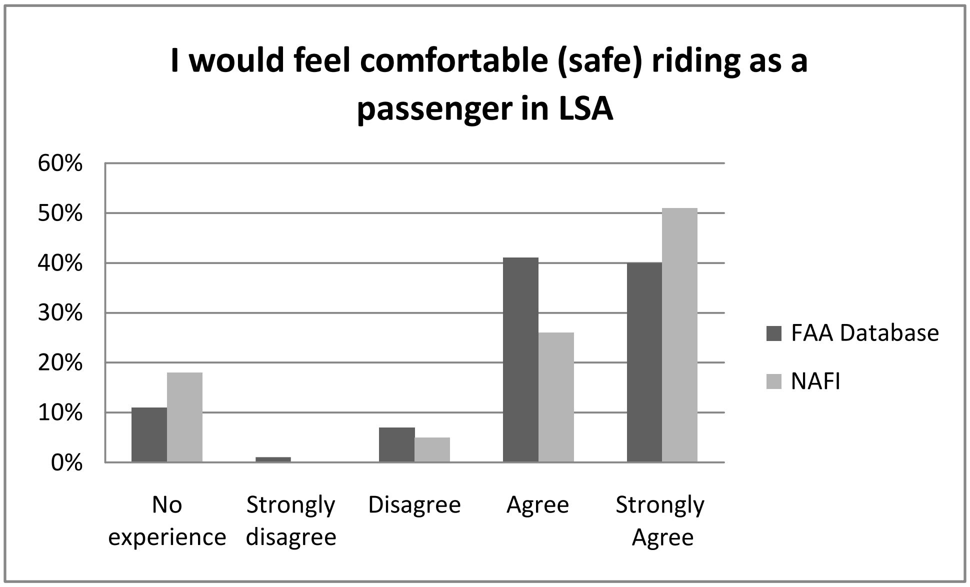

Figure 5. Responses from instructors selected from the FAA database and NAFI registered instructors to the statement "I would feel comfortable (safe) riding as a passenger in these aircraft."

Open-ended responses regarding the LSA ratings showed the importance of using the difference in averages instead of directly comparing survey responses. Some pilots who reported owning LSAs rated themselves very low, while others who had never flown LSAs thought they would make good instructors "after gaining familiarity and endorsements." Some reported their rating of safety and comfort to be largely dependent on the pilot with whom they were flying.

Differences between LSAs and Typical Training Aircraft

In order to examine how LSAs compared to typical primary training aircraft, the average ratings from each of the five questions for typical training aircraft were subtracted from the average rating of each of the five questions for LSAs. This mean difference for the five questions and for the average overall response is shown in Table 1. The scored differences show that LSAs were rated lower (mean = -0.811 for FAA registered instructors and -0.841 for NAFI registered instructors) than typical training aircraft, regardless of the instructor's background. It is unusual to note that, while the NAFI- registered flight instructors had more experience in LSAs and a greater concentration of LSA instructor pilots, they actually rated their perceptions and comfort with LSAs as worse than the flight instructors who reported minimal experience with LSAs.

I would…	feel safe as a passenger	feel comfortable flying	feel comfortable instructing	enjoy flying	enjoy instructing	**Overall Mean Difference**
FAA	-0.800	-0.754	-0.967	-0.656	-0.885	**-0.811**
NAFI	-0.822	-0.848	-0.945	-0.740	-0.855	**-0.841**

Table 1. *Average rating difference for FAA database flight instructors and NAFI registered flight instructors.*

Discussion

LSA are becoming increasingly common over time, as manufacturers tap into a previously undiscovered market. These new aircraft will require additional instructors to train both sport pilot applicants, and recreational, private, and commercial pilots in light sport aircraft.

This study gathered self-rated perceptions about typical training aircraft and LSAs from two national samples of flight instructors in order to determine the extent to which CFIs are prepared to instruct in light sport aircraft. Regional differences could not be compared due to the small number of participants. As such, the findings of this study are broader, describing general perceptions that apply to the larger population of flight instructors. Most (70%) reported no experience in LSA; in spite of this, CFIs rated their perceptions of their abilities to instruct in these aircraft highly. The lack of experience that most instructors reported, combined with a high perception of their ability to instruct in LSA, points toward a larger issue. What competencies are important to assess in flight instructors before they initially instruct in LSA? Because of the diversity in aircraft that could potentially be classified as LSA, it is largely left to the individual instructor to determine what, if any, additional training or practice should be conducted beyond that required by the FAA.

Further research in light sport instruction is necessary to better understand how to best prepare future sport pilots. Gathering feedback from recent sport pilot applicants would allow researchers to gain valuable insight into specific competencies or skill sets that require additional reinforcement from instructors. Other subpopulations that should be explored are EAA registered sport pilot instructors and CFI-SPs, in order to assess how well-prepared all instructors are for light sport instruction.

Biographical Sketch – Timothy Harbeck

Timothy Harbeck was a leading student in the Professional Flight Program in Purdue University's Department of Aviation Technology. Upon completion of his undergraduate degree and acceptance of a first officer position with a commercial airline, Harbeck was diagnosed with incurable brain cancer. Desiring to use his remaining time to assist others in the aviation field, Harbeck began work on a master's degree in aviation at Purdue, as well as teaching undergraduate courses in the field. The present article is adapted from his master's thesis project, completed six months before his death. Harbeck continues to be an example of integrity and courage for his students, peers, and the faculty who worked with him.

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Human Ranging of Aircraft: A Pilot Study

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Abstract

The purpose of this research was to investigate the basic ability of humans to range in-flight aircraft. The question was posed during another research study by the author for the purpose of setting a quantitative baseline for automated sense-and-avoid distance. An experimental research design was used for the study. Aircraft position was based on reported Automated Dependent Surveillance Broadcast (ADS-B) data which is based on the Global Positioning System (GPS) fix of the aircraft. Humans in the pilot study ranged aircraft with a mean absolute error of 50.34% at ranges between 650 and 9,738 meters.

Introduction

This pilot study examined the ability of human subjects to visually range in-flight aircraft. Unmanned systems are becoming more prevalent in our society, in the military, and in industry. Unmanned Aerial Systems (UAS) are commonplace in military operations. Limited commercial operations are allowed in the National Airspace System (NAS) on a case-by-case basis. One of the current Federal Aviation Administration (FAA) requirements placed on UAS operators in the NAS is sense-and-avoid capability (FAA, 2008). Humans and robots can sense using multiple complex systems. Previous work on human ranging of targets was well established as early as 1954, but was limited to human subjects ranging targets up to 400 yards (Gibson & Bergman, 1954; Gibson, Bergman, & Purdy, 1955; Purdy & Gibson, 1955). Gibson and Bergman (1954) found that untrained subjects on a mowed grass field estimating ranges within 400 yards had an absolute error of between 7 and 20 percent.

A pilot flying a manned aircraft uses several methods to sense-and-avoid other aircraft. In reference to the sense-and-avoid principal, "A frequently asked question in human factors engineering is whether the role assigned to the human being is within his or her capabilities" (Liebowitz, 1988, p. 85). In both radar and non-radar environments visual scanning is the primary method used by pilots. Pilots must pick aircraft out of the visual field and determine whether an aircraft is a threat. Initial threat determination is based on whether or not the aircraft is on a collision course with the pilot's aircraft. Final threat determination is based on direction and velocity. Humans range objects using a combination of visual cues to include oculomotor cues (heuristic feelings in eye muscles, not possible beyond about 3 meters), pictorial cues (a pilot sees and identifies a Cessna 172 (C-172)), movement cues (a C-172 moves across a visual field at an estimable rate), and binocular disparity (the differences in scene between the left and right eye)(Goldstein, 1999).

Statement of the Problem

UAS require sense and avoid capabilities for operation in the NAS. Below 10,000 feet in the NAS, aircraft are limited to 250 knots indicated airspeed (KIAS). At 250 KIAS, the closing rate is such that aircraft within 5 nautical miles (3.125 kilometers) of one another are considered a possible threat to each other. In terms of sense-and-avoid, if pilots can spot an aircraft in their visual field, they can then begin to determine threat by determining range.

Many manned aircraft carry transponders. However, many do not and are not required to do so by Federal Aviation Regulation (FAR). Systems like Terminal Collision Avoidance Systems (TCAS) and Automated Dependent Surveillance – Broadcast (ADS-B) technologies are common in many new aircraft. However, they depend on other aircraft having transponders of one type or another. The threat of collision with a UAS is based on aircraft without transponders. These aircraft by FAR would be operating in Visual Meteorological Conditions (VMC). Therefore, human see-and-avoid is the primary current method of collision avoidance.

Significance of the Study

The study is significant in the fact that it establishes a quantitative baseline for human ability to range aircraft. This information is useful to both UAS and manned sense-and-avoid system developers.

Review of Human Sensing

The following review of human sensing gives an overview of human vision. It also establishes a rationale for the best case conditions for human visual sensing.

Humans use a variety of sensors to perceive the environment surrounding them and then recognize patterns that will produce a behavior. Behavior can be action or inaction. Human senses include visual (seeing), vestibular (inner ear), aural (hearing), taste, olfactory (smell), and tactile (touch). These senses are often combined into systems such as the somatosensory system, for example, which includes proprioception (the sense of position of the limbs) and kinesthesis (the sense of movement of the limbs) (Goldstein, 1999). The somatosensory system combines visual, vestibular, and kinesthetic sensors to achieve perception.

Humans use two senses for ranging of objects: aural and visual. For aural sensing, binaural cues (the differences between the left and right ear) result in interaural differences. Interaural time differences for example will give a cue of direction. Since pilots would be in an aircraft that interferes with these aural cues, aural ranging is not a variable in this study. This means that for detection and ranging of aircraft 100 % of human sensing of in-flight aircraft will result from visual cues.

Visual Sensing

Human visual sensing is based on the reception of visible light on the retina. Humans perceive visible light in the electromagnetic radiation spectrum in the range 380 to 760 nanometers in wavelength (DeHart, 1985). The retina is made up of an optical array of rod and cone shaped receptors. Photons excite the rods and cones and produce a stimulus. This stimulus is the result of light being transduced into electricity, a signal which is carried to the brain through the cerebral cortex. The pattern produced by the stimulus on the optical array results in a perceptual cue (Goldstein, 1999).

Rods and cones. The distribution of rods and cones in the eye is not even. The highest density of cones occurs near the center of the retina in an area about the size of this small letter "o" in a size 10 font (Goldstein, 1999). The fovea is the point of central focus of light through the lens of the eye. Outward from the fovea the distribution of rods and cones changes exponentially. Overall, the retina contains far more rods than cones, about 120 million rods and 6 million cones (Goldstein, 1999).

Rods are more sensitive to shorter wavelengths than cones. Cones receive peak light at a wavelength of 555 nanometers in the yellow-green spectrum. At about 510 nanometers rods begin to receive more light than cones and peak at around 490 nanometers in the blue-green spectrum. These differences in light cause differences in visual acuity as light changes. Visual acuity is highest in the cone rich fovea in bright light and shift to the rods as light diminishes until all luminosity is gone (DeHart, 1985). Based on this discussion, rods are more sensitive to light than cones due to the fact that they require less light. This means that movement of an object is more likely to be detected by the rods. This results in peripheral vision being more sensitive to movement. However, the cones are more sensitive to detail. Therefore, if fine movement is detected it must be targeted and directly viewed in the visual field. Direct viewing becomes more difficult as the light intensity drops.

Perceiving visual space. Humans perceive visual space using a combination of depth cues. "The *cues* approach to depth perception focuses on identifying information in the retinal image that is correlated with depth in the scene" (Goldstein, 1999,p. 215). There are two basic types of visual cues: oculomotor and visual. Oculomotor cues are cues which are kinesthetic. Visual cues are produced by the scene played out on the retina and are subdivided into monocular and binocular cues. Monocular cues include pictorial and movement-produced cues. Binocular cues are based in stereopsis (Goldstein, 1999; Blake & Sekuler, 2006).

Oculomotor cues. Oculomotor cues are based on a human's ability to sense the position of our eyes and the tension in eye muscles. These cues are based on basic feelings in the eyes that occur from two sources, the eye muscles that move the eyes and from the movement of the lens of the eye. Convergence occurs when the eyes target something close to the face and the eyes cross, producing tension in the muscles of the eyes. This is a cue that the object is near. Accommodation occurs when the lens of the eye changes shape and bulges to focus on an object near the face (Goldstein, 1999; Blake & Sekuler, 2006). Oculomotor cues are only reliable at a distance of about 1 to 3 meters and are not reliable cues in the detection of distant objects such as in-flight aircraft.

Pictorial cues. Pictorial cues are static depth cues that can be depicted in a painting by an artist or in a photograph (Goldstein, 1999; Gibb, Gray, & Scharff, 2010). Making sense of pictorial cues is heuristic in nature, meaning that the observer must be able to identify objects in a scene and have some prior knowledge about those objects. Pictorial cues include: occlusion, atmospheric perspective, relative height, familiar size, linear perspective, texture gradient, and shadows. (Goldstein 1999; Gib et al., 2010).

Take for example, a flatland that leads to distant mountains. An occlusion would occur if one mountain partially hides another and an observer would know that the occluded mountain is farther away. If the sky were clear then an observer would be able to see more detail and the atmosphere would have an effect that would make the mountain seem to be nearer than if it were hazy (atmospheric perspective). If the mountain were near and the peak above the observer, then the object would appear higher in the visual scene and a sense of height would be gained (relative height). If a car were on the side of the mountain on a road, a sense of familiar size would be gained. If a straight road led to the mountain, and the lines of the road disappeared into the distance, then a sense of linear perspective would be gained. If a series of equally farmed fields were next to the road in the valley, and led up to the mountain, then a texture gradient would be evident, and the farther fields would appear smaller. If the sun were setting behind the mountains, then shadows would begin to fall in front of the mountain and provide more linear perspective. Using these pictorial cues an observer could make an estimation of range.

A pilot attempting to determine the range of an aircraft might use any of these visual cues to estimate range. The primary pictorial cue that may affect range estimation in aviation is atmospheric perspective, especially if there are no other visual cues in the sky. Haze in the atmosphere will reduce the visible detail of an aircraft. This might make the aircraft unrecognizable or seem slightly smaller. The pilot would merely know that an object is in the distant sky and range determination would be highly unreliable.

Movement-produced cues. An observer may move and the observed object may move. These movements produce two movement cues, motion parallax and deletion/accretion. Motion parallax is produced by the appearance of near or far objects appearing to move at relatively different rates across the visual field. Deletion/accretion occurs when two objects overlap and movement covers (deletion) or uncovers (accretion) the object which is more distant. Deletion/accretion is related to motion parallax in that the overlapping surfaces appear to move relative to one another. Deletion/accretion is related to the pictorial cue of occlusion (Gibb et al, 2010). An object that moves faster in the visual field will appear nearer than an object that moves slower. (Goldstein, 1999; Gibb et al., 2010).

Take for example a driver speeding down a road in an open field who enters a segment of road lined with evenly spaced trees. The trees in the distance will appear to move more slowly than the trees that are near due to motion parallax. Accretion is also occurring as distant trees are uncovered. Depending on where the driver looks, his/her sense of speed will change. If the driver enters another segment of road where the trees are at twice the distance from the road, then a variable in the motion cue has changed and the driver may experience a difference in perceived distance. Other variables that would affect the perceived cue might be the type, size, and spacing of the trees. Atmospheric perspective will also affect motion parallax by reducing the detail of the trees making them appear smaller and spaced further apart.

Motion processing. The object moving in the visual field will cause a local shift of an image on the retina. An observer moving the eyes or the body will cause an entire shift of the visual image on the retina. “Expansion, contraction, and rotation of the entire visual field are all components of *optical flow* information” (Gibb et al., 2010, p. 45). Optical flow is another term for motion parallax (Davis, Johnson, Stepanek, & Fogarty, 2008).

Binocular disparity. Stereoscopic vision is based in binocular disparity. “Stereoscopic vision involves combining the images from the two eyes in order to judge the depth of objects in one’s environment” (Gibb et al., 2010). Binocular disparity is based on the differences between the scenes presented to the optical matrix of the retina. Retinal disparity is the difference between the location of an object on a given plane in the two separate scenes, or images (Blake & Sekuler, 2006). The appearance of the model aircraft in Figure 1 is an example of disparity between a left and right camera image at a range of approximately 1 meter and a baseline of approximately 0.1 meter.

In essence, each eye gives a different viewpoint of a viewed object (Goldstein, 1999). Simply closing one’s eyes alternately, while focusing on an object, will create the effect. The magnitude of disparity is a function of how far away the object is and how far apart the eyes are located. Binocular disparity (δ) is related to depth (ΔD), interocular separation (I), and distance (D) as seen in Equation 1 (Gib et al.):

$$\delta \approx I \, \Delta D / D^2 \qquad (1)$$

Binocular disparity will change with the square of the distance and become very small as distance increases. In humans, interocular separation can be assumed at approximately 65 millimeters and will not vary more than a few millimeters in a normal adult (Hibbard, 2008).

Rearranging Equation 1 results in Equation 2:

$$\Delta D = \delta D^2 / I \qquad (2)$$

Figure 2 is an example of how distance affects the relative disparity of an object when viewed from 1 and 5 meters on a 0.065 meter baseline from an Olympus FE-230 point and shoot CCD camera.

Environmental variables affecting pilots. Atmospheric perspective and low luminosity have already been discussed as environmental variables that can affect the variability of depth perception in humans. Environmental variables that specifically affect pilots include vibration, hypoxia, visual acuity, and contaminated windscreens.

Vibration directly affects the lens of the eye. A large range of vibrations are transmissible to the pilot in an aircraft (Dehart & Davis, 2002). “Difficulties in reading instruments and performing visual searches occur when vibrations introduce relative movement of the eye with respect to the observed object or target” (DeHart & Davis, 2002, p. 165).

Hypoxic (altitude) hypoxia occurs in pilots as altitude is increased. As altitude increases, the density of the air humans breathe decreases. Therefore, the amount of oxygen per breath decreases. This reduction of oxygen results in lower blood oxygenation, and has adverse effects in humans. The symptoms of hypoxic hypoxia become evident after about 5,000 feet above mean sea level (MSL) (Reinhart, 2008). “Vision is the first of the special senses to be altered by a lack of oxygen, as evidenced by diminished night vision” (DeHart & Davis, 2002, p. 368).

Figure 1. Narrow base-line disparity.

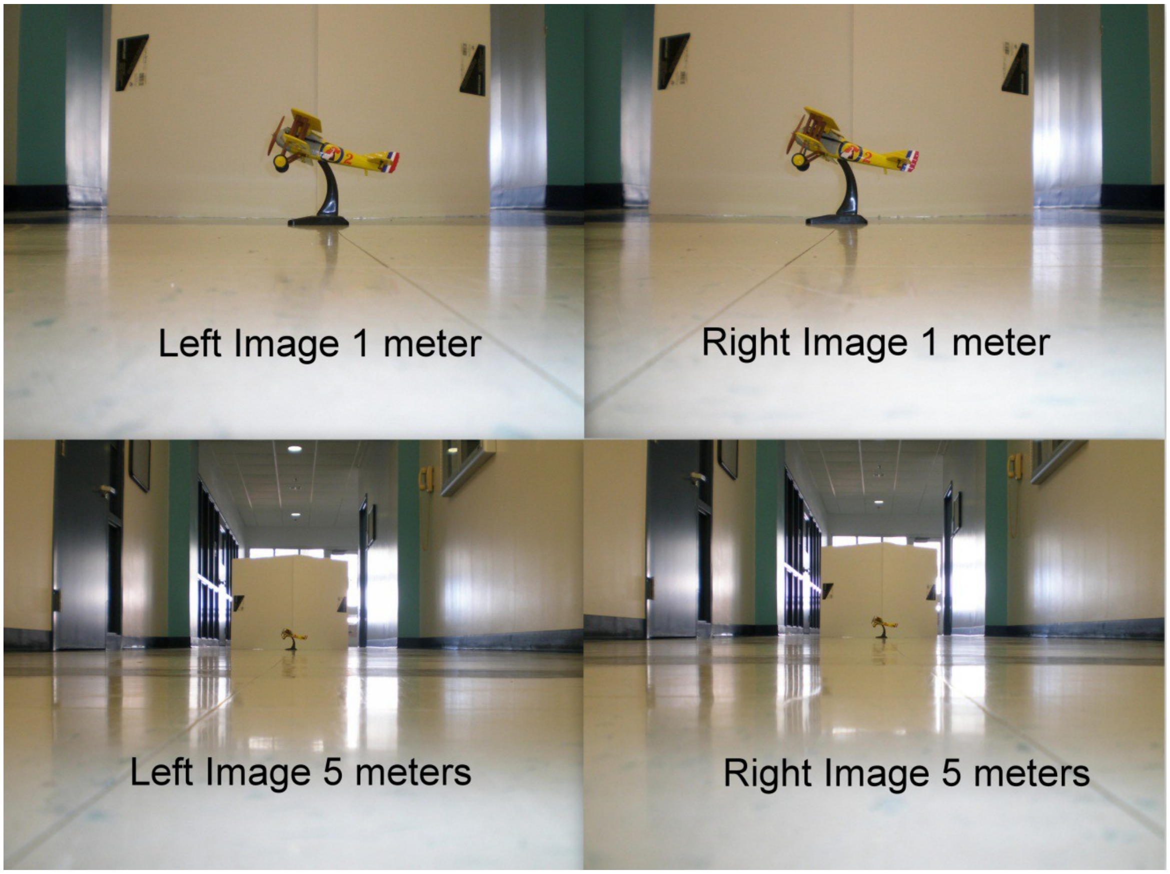

Figure 2. Relative disparity at 1 and 5 meters using a human equivalent baseline of 0.065 meter.

As distance increases to very large ranges such as between two aircraft, small changes in disparity serve as a poor cue for depth perception and it is assumed that pilots will rely primarily on monocular cues (Gibb et al., 2010). According to Goldstein (1999), binocular disparity cues become unreliable at about 30 meters.

In private pilots, visual acuity would serve as a variable in visual sensing. Private pilots are required by the FAA to hold a 3rd Class medical certificate. Vision requirement to obtain the 3rd Class medical certificate is 20/40 or better visual acuity in each eye with or without correction (FAA, 2010). Visual acuity is how sharp or crisp an object will appear to be at a given distance. Normal visual acuity is 20/20 and is tested for example by a subject being able to read a given line of letters on a chart at 6 meters distance (DeHart, 1985). Anything greater than 20/20, 20/40 for example, means that the subject will not have the same clarity of a visual image as a person with 20/20 visual acuity. This difference in visual acuity will affect the variability of depth perception in the same way as atmospheric perspective by reducing detail and reliability of pictorial cues. A film of dirt on a windscreen might have a similar effect.

Summary

Humans visually sense based on the reception of visible light. Visual space is perceived based on several depth cues to include both monocular and binocular cues. At ranges beyond about 30 meters binocular cues become unreliable and monocular cues are primary for depth perception. Visual sensing reliability diminishes as environmental factors involved in aviation are considered. For the purpose of this research, the best case scenario for perceiving visual space would be a person standing on the ground at sea level near noon on a clear day. The worst case scenario would be a private pilot with 20/40 visual acuity in an aircraft with high vibration and a dirty windscreen flying at sunrise or sunset above 5,000 feet MSL. The best case scenario will be considered for this research as it would be the minimum error encountered. The only variable not accounted for in the pilot study on human ranging was that of acuity.

Method

The following will present the research design, procedures, and data collection techniques that were used in this study. The technologies used in this study will also be discussed.

Research Design

The research design used in this study was a quantitative experimental method. The samples were completely self-selected in the sense that the experimenter had no control over the subjects involved in the human ranging pilot study or the aircraft involved in the stereo ranging study.

Samples

Human subjects were taken from the random population of students who walked by the experimental area. Aircraft samples were taken from in-flight aircraft within visible range and field of view of the subject.

Variables

The independent variable in both the human range pilot study and the stereo range study that required precision was that of Global Positioning System (GPS) determined position of the aircraft. The method of record for the study was that of ADS-B reported position. ERAU fleet Cessna 172 aircraft are equipped with identical Garmin G1000 integrated ADS-B glass cockpits.

There were two independent variables in the human ranging pilot study. The first independent variable was the GPS determined position of the aircraft. The second independent variable was the human subject estimated range of the aircraft.

Independent variable 1. GPS determined aircraft position was the first independent variable. In this study, GPS position was determined using ADS-B reported data. The ADS-B data was taken from a program developed by the ERAU NEAR Lab that continuously logs ADS-B data. Units of measure were recorded in kilometers and converted to meters for final reporting and analysis.

Independent variable 2. Human subject estimated range was determined by the subject. Each subject was asked to pick an aircraft visible to them and within their field of view and state the range of the aircraft using the unit of measure that they felt most comfortable using. All units of measure were converted to meters for reporting and analysis.

Procedure

The following procedure outlines the experimental setup of the human range pilot study. The experiment took place at ERAU Daytona Beach under VMC with a METAR reported visibility of greater than 6 nautical miles. Only ADS-B reporting aircraft were included in the study. To ensure consistency, only ERAU ADS-B equipped Cessna 172 fleet aircraft were included in the data.

Location setup. A table was set up in an area with high student traffic. The area had a 360 degree lateral view of the sky and between 3 and 30 degrees vertical view in reference to the horizon.

Data collection. Two sources of data were recorded in this study, ADS-B data and subject reported data. The ADS-B data was recorded on an ERAU server. The data was provided to the researcher in a comma separated variable (.CSV) format. The subject reported data was hand recorded.

Subject reported data. Subjects verbally announced the estimated range of an aircraft. The subject estimated range was then recorded along with time, researcher estimated range, researcher estimated altitude, and magnetic bearing to the aircraft. Magnetic bearing was determined using a lensatic compass.

ADS-B data. The ERAU ADS-B database was queried for ADS-B data for the time duration of the experiment. The researcher filtered the data to a radius of 15 kilometers. The researcher was then able to identify the aircraft in the database data-set based on time, bearing, and altitude when compared to the recorded subject data. No other aircraft were in the vicinity of the viewing field when a subject observed the aircraft.

Results

A total of 31 subjects participated in the human ranging pilot study. Seven of the aircraft targets did not have ADS-B onboard, so seven of the data points were not usable. Therefore, a total of 24 data points were analyzed. There were two extreme outliers that were outside of two standard deviations. The outliers were removed from the data leaving 22 total data points that are included in the analysis of the ranging study. The aircraft ADS-B positions ranged from 650.6 to 9,738.3 meters. The 22 subjects' estimations ranged varied from 24 to 11,265 meters. The absolute percent error was calculated for each pairing between the ADS-B position and the estimated range. The mean absolute percent error was 50.34%. Appendix A presents the post-processed human ranging pilot study data.

Table 1

Human Ranging Pilot Study Descriptive Data

Data Type	ADS-B Position	Subject Estimated Range
n	22	22
Mean	3406.3 m	1691.7 m
Standard Deviation	2780.6 m	2504.5 m
High	9738.3 m	11265.0 m
Low	650.6 m	24.0 m

Discussion

The study was completed as a pilot study. The limitations and recommendations identified in this discussion should be considered for future studies.

Limitations of the Study

Limitations of the study include the following:

No demographic data on the subjects was recorded.

1. No information on aviation experience was recorded.
2. No information on visual acuity was recorded.
3. Only one type of aircraft was used in the study.
4. The study was performed on a single day with no variation in meteorological conditions.
5. No localization information was asked of the subjects.

No identifying data was collected due to the fact that this study was time sensitive as an addition to another primary study in stereo ranging of aircraft using wide-baseline stereopsis. The question was posed during the stereopsis research as to how well humans can range in-flight aircraft, and a review of the literature resulted in no specific works on the topic. Internal review board (IRB) approval would have been required for collecting identifying data of the human subjects, and the time frame to do so did not fit that of the stereopsis research.

Recommendations for Future Research

Recommendations for this study include the use of aircraft capable of logging GPS position and a full scale expansion of the ranging pilot study.

1. Replicate the study using Cessna 172 (C-172) aircraft equipped with the Garmin FDM capable of logging the GPS position of the aircraft at 10hz.
2. Replicate the study under varying meteorological conditions.
3. Perform a scale version of the human ranging study to include localization.
4. Collect data on pilots versus non-pilots experience level.
5. Collect demographic data on each subject.
6. Test visual acuity of each subject.

Replicating the study with a Garmin FDM would allow the researcher to gain a more precise position of the aircraft at the time of observation. It also allows the researcher to gather localization data about the aircraft. Localization data includes altitude, rate of climb, and heading in addition to the latitude and longitude of the aircraft. These are variables that are used to determine threat in the pilot see-and-avoid process.

Variations in meteorological conditions would be a positive addition to the study. Visibility would be the primary factor due to the effect it may have on aircraft detail (atmospheric perspective) presented to the naked eye.

Conclusion

The question of how well humans range in-flight aircraft was very broad in nature. The main purpose of this study was to determine an initial baseline for human ranging of in-flight aircraft for the stereopsis research being performed by the primary researcher in sense-and-avoid for UAS. This paper provided a discussion of the method, results, limitations, and recommendations of the study. The results provide data that suggests that humans have a very large error in estimating the range of in-flight aircraft. Further research is needed in a full scale study to determine the actual error.

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Appendix A

Human Ranging Pilot Study Data

Set	Target Address	Meters ADS-B	Bearing ADS-B	Time ADS-B	EST Time	Est. Bearing	Est. Meters	%Error	% Error Absolute
1	10845621	650.57	25.65	18.8598329	18.879	30	400	-38.515	38.515
2	10779949	865.30	54.27	19.45060981	19.46	40	610	-29.504	29.504
3	10832657	925.62	163.63	19.03388889	19.036	150	244	-73.639	73.639
4	11098297	938.23	156.00	19.10411024	19.108	140	1931	105.814	105.814
5	11112212	1056.01	68.97	18.91838759	18.922	60	300	-71.591	71.591
6	10854781	1154.66	135.17	19.5996658	19.604	160	644	-44.226	44.226
7	10886065	1467.70	108.99	18.35688802	18.367	100	402	-72.610	72.610
8	10888918	1758.29	100.02	18.58272135	18.588	130	100	-94.313	94.313
9	11109359	1784.23	99.32	19.34210938	19.347	100	2414	35.297	35.297
10	11098297	2036.71	175.70	19.27333333	19.246	160	1207	-40.738	40.738
11	11098297	2077.47	103.63	19.1146658	19.119	110	4023	93.649	93.649
12	11098297	2127.90	101.72	19.32866536	19.3	140	600	-71.803	71.803
13	10761279	2441.08	110.13	18.4573329	18.479	123	1979	-18.929	18.929
14	10761279	3238.57	153.92	18.3818316	18.4	160	4023	24.221	24.221
15	10834559	3414.68	152.05	18.98294271	19	140	549	-83.922	83.922
16	10863941	4885.51	10.27	19.29405382	19.297	10	4023	-17.654	17.654
17	10832657	5378.40	97.92	19.07116536	19.092	70	305	-94.329	94.329
18	10852879	6331.40	102.84	18.68255425	18.683	120	1200	-81.047	81.047
19	11109359	6521.37	149.54	19.3971658	19.404	140	61	-99.065	99.065
20	10832657	7039.47	103.01	19.08399957	19.097	100	914	-87.016	87.016
21	10501486	9107.41	246.76	19.42861111	19.433	210	11265	23.690	23.690
22	11404308	9738.26	170.65	19.01822483	19.008	170	24	-99.754	99.754

The Current Status of Advanced Cockpit Technology (ACT) Education within Collegiate Aviation: A Preliminary Outlook

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Abstract

Several studies in the past have examined the preparedness of collegiate aviation to meet the demands for the upcoming NextGen (i.e., automated) cockpit. Such research revealed a conflict as to the current prominence of advanced cockpit technology education. The purpose of the study was to explore current tendencies in the education of advanced cockpit technology (ACT) within collegiate aviation by analyzing present-day course catalogs and/or program descriptions located in their university websites. The results for both aviation accredited universities and regular aviation programs indicate a noticeable increase in the teaching of ACT. Using unobtrusive research methods, the study found that 90% of aviation programs show clear evidence of either acquiring a Technically Advanced Aircraft (TAA) or having a specific course with theoretical and/or practical applications of advanced cockpit technology. These conclusions support the idea that collegiate general aviation (GA) training is undergoing the required technological transition that larger air carriers and corporate pilots underwent years ago.

Introduction

Research regarding the status of advanced cockpit technology (ACT) education within collegiate aviation has been performed with inconclusive results. Although some studies suggest that the teaching of such technology using Technically Advanced Aircraft (TAA) is becoming more widespread (AOPA, 2005; Casner 2009) another study found that 73% of pilots are still receiving their flight training with the use of analog instruments (Di Renzo, &Bliss, 2010). In addition, Fanjoy and Young (2004) completed a U.S. survey of four-year flight training institutions and found that, although most flight training program administrators agree that advanced cockpit education is an important element in preparing the future professional pilot, only 51% offer comprehensive training in this area. The majority of these institutions cited cost and curriculum priorities as the reasons for their lack of implementation in their universities and deferral of such training to future airline employers (Velázquez, 2013). Recently, Leonard (2013) found that only a small amount of ADS-B training is currently taking place in the United States, and "the training that is taking place is non-standardized and limited due to the perception that ADS-B is only to be used as a traffic advisory tool" (p. 79).

Review of Literature

According to the Federal Aviation Administration (FAA), a TAA is one with, at least, (a) an IFR-certified Global Positioning System (GPS), (b) a moving map display, and (c) an autopilot (Fiduccia et al., 2003).Most TAA manufacturers add features above those required by the FAA definition. The Aircraft Owners and Pilots Association (AOPA, 2005) argue the majority of active fleet sales to flight training providers, including university programs, have been TAA. However, Casner (2003b) found that airlines continue to struggle with training pilots transitioning from the general aviation training cockpit notwithstanding the fact that the introduction of advanced cockpit automation during early piston-engine training "pays large dividends when later confronted with the task of mastering automation found in jet fleet" (p. 2). Di Renzo and Bliss (2010) suspect advanced cockpit technology education is not as widespread as many think. In addition, Chidester et al. (2007) found that 85% of FAA Aviation Safety Inspectors (ASI) had not received formal education in TAA.

AOPA (2005) argues that with the advent of innovative automation technology the adoption of new piloting techniques is necessary since the pilot now becomes more of a *systems manager*. TAA instrumentation frequently "provides more data than most pilots know what to do with so there is another need for training" (AOPA, 2005, p. 29). Casner (2003b) argues that although the FAA testing contains specific knowledge and flight requirements for the evaluation of topics such as aerodynamics and weather, within their practical test standards (PTS), no such requirements have been put in order for the evaluation of these new critical and emerging piloting skills. The lack of formal training outlines and FAA guidance might be influencing the incorporation of ACT education in collegiate aviation.

The introduction of advanced cockpit education raises additional issues in the educational and human factors sectors. The FAA (2008) argues that students should be taught when to use these levels of automation and when not to. Although advanced cockpit technology increases situation awareness, it can also present a serious hazard if the system malfunctions and the pilots are unprepared (FAA, 2009). In addition, workload seriously increases if pilots mismanage the automation machine (AOPA, 2005). Thus, the proper sequencing of training or timing of TAA education is also a concern within the flight training industry (AOPA, 2005). Researchers at MTSU (Craig et al., 2005) studied such dichotomy by having a group of pilots undergo ab-initio TAA training and compared their success, measured in flight time required to reach certain milestones, e.g., solo flight, certificate completion, etc., versus those who had already received training in airplanes with analog instrumentation. The MTSU initial findings reveal that TAA ab-initio students take longer to solo for the first time but subsequently reach other highlights earlier than students trained with analog instrumentation.

Research Methodology

Purpose of the Study

The purpose of the study was to gain a better understanding of how, and if, flight training institutions were incorporating advanced cockpit technology education today, given the conflicting research conclusions in recent publications. To accomplish such task, a review of collegiate aviation programs was completed. The current study analyzed university catalogs and program descriptions for course availability on subjects such as Technically Advanced Aircraft (TAA) and/or Advanced Cockpit Technology using an archival design and unobtrusive research methods. Archival research data may be gathered from numerical records, verbal documents, or visual artifacts such as websites (Vogt et al., 2012). In addition, any evidence on the availability of TAA, flight training devices (FTD) and/or simulators for the purpose of ACT education was also recorded. The study was guided by the following research question:

- Are flight training institutions, within collegiate aviation, incorporating advanced cockpit technology (ACT) education in their curriculums? If so, how?

Study Population

A total of twenty (20), ten aviation-accredited and ten non-accredited, programs were randomly selected using a Random Integer Generator (RIG). The aviation accredited programs were assigned a number from 1 to 29, the total of aviation programs offering flight training. The ten accredited programs were selected from a list of aviation accredited flight education programs found in the Aviation Accreditation Board International (AABI) website. The other 10 programs were selected using the University Aviation Association (UAA) list of member institutions. The same process was used with the institutions listed as UAA members, that is, institutions were assigned a number between 1 and 106. It is important to note that the random selection of institutions was done, in both cases, by specifying a sampling frame or unit (i.e., the list of UAA member institutions and the list of AABI accredited programs). In addition, numbers were chosen without replacement meaning that if the institution number was repeated the researcher moved on to the next selection.

These samples were compared to ascertain any differences between the advanced cockpit technology education offered in accredited programs and that found in non-accredited aviation institutions. As specified earlier, during sampling, it was important to establish the universe to be sampled from (Babbie, 2010). Equally important, was to distinguish between units of analyses and units of observation. The units of analyses were the various university catalogs and/or program brochures while the units of observation were the course descriptions or outlines of type of equipment used.

Sampling is an important issue in any research. When collecting qualitative data, researchers often refer to reaching the saturation point to know when to stop collecting records (Vogt et al., 2012). The concept is crucial when conducting archival research such as this one. The saturation point is the moment when it is no longer useful or productive to continue collecting data; “the point at which the yield in useful data does not justify the effort to collect more of it” (p. 200). During the initial analysis of AABI-accredited institutions it became clear these programs had already made efforts towards the education of ACT. After this discovery, the focus was shifted to compare the aviation-accredited programs with the non-AABI accredited.

Data Analysis

In order to find a pathway to analysis, the first stage consisted of pre-coding. When available, the different course catalogs and/or program descriptions were explored to understand the strategies used by universities to educate on ACT. Subsequently, all of the relevant information from these sources (e.g., catalogs and/or program descriptions) were separated and entered individually into a computer-aided qualitative data analysis software called QSR NVivo (version 10). The use of such qualitative analysis software allowed for a second stage of coding where themes began to emerge (i.e., specific TAA equipment, topics covered within ACT courses, etc.).During this stage, manifest coding, a common technique in content analysis, was used to determine the level of institution engagement in the education of ACT. During manifest coding, a researcher objectively codes the contents of a document (Babbie, 2010). Figure 1 shows a word query tag cloud illustrating the prominence of specific words within the sources analyzed (e.g., catalogs and program descriptions). The relative font size indicates which words were used most commonly throughout the sources. The most frequently used words were *systems*, *flight*, *navigation*, and *glass cockpit*.

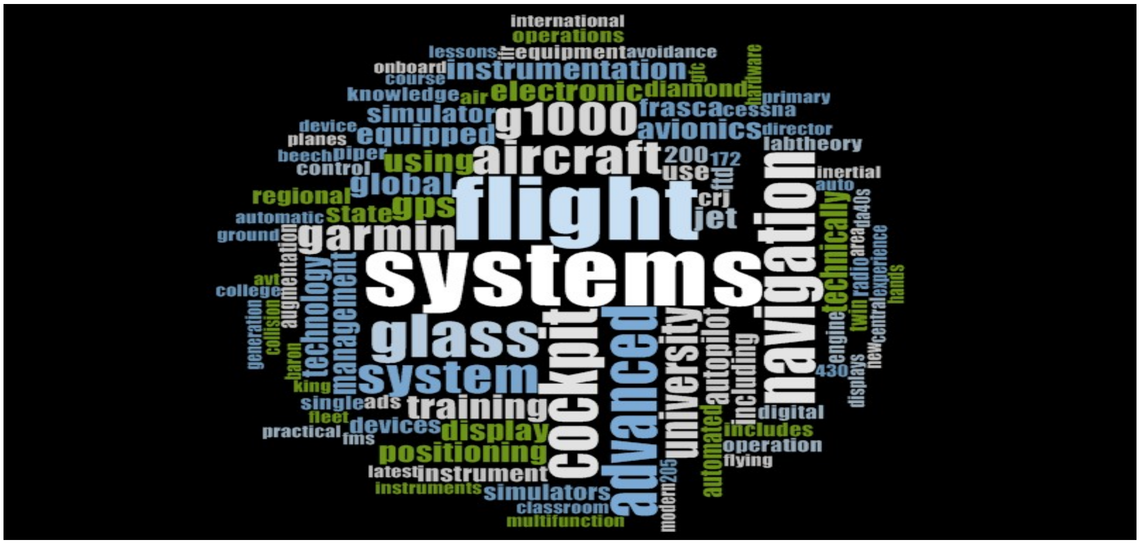

Figure 1. Tag cloud helps visualize word query.

The word glass cockpit was also further researched to explore connections of the phrase within the documented sources. In Figure 2, a *Word Tree* regarding the mentioning of glass cockpit within university course catalogs and/or program descriptions reveals that programs are frequently using the Garmin G1000 as their preferred method for glass cockpit education. In addition, the aircraft mostly used for these purposes is the Diamond airplane. Finally, in some instances, the glass cockpit is provided as training software in ground course laboratories, FTDs and/or simulators.

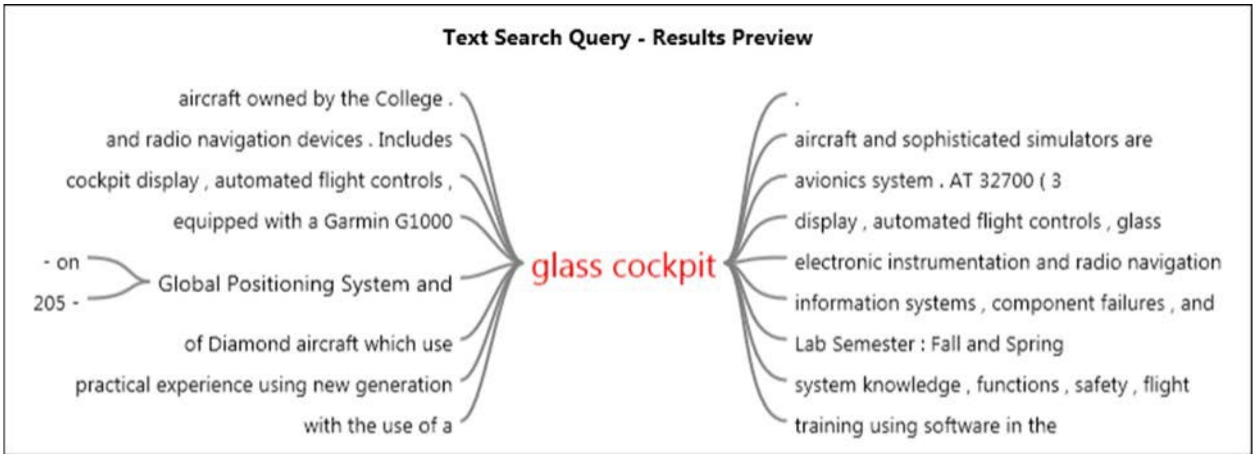

*Figure 2.*Word Tree regarding the mentioning of glass cockpit within university course catalogs and/or program descriptions.

The following information originates from the sampled AABI accredited university programs. Table 1 indicates the university name with the accompanying airplane and equipment currently being used to teach advanced cockpit technology. The information was obtained directly from the course catalog and/or website’s program description. The absence of any specific information does not necessarily indicate real-time absence of the component. Thus, for future research the author intends to survey university programs to gain a deeper understanding of the information contained or missing from such sources. Non-accredited aviation institutions were also sampled.   Table 2 contains the same information for non-accredited aviation institutions.

In comparison, 70% of AABI and non-AABI accredited aviation programs reveal through their course catalogs or program descriptions the availability of ACT education. Flight training institutions may also provide ACT education through specific-type courses. These courses may contain ground, FTD, simulator, flight instruction or a combination of these. Table 3 shows the information for AABI accredited institutions that possess such course(s) along with a brief overview of important advanced avionics or NextGen topics contained within them. Non-accredited aviation institutions were also sampled. Table 4 contains the same information as Table 3, only for non-accredited aviation institutions.

The analysis of AABI accredited universities revealed that 80% possess a specific and separate course where they either teach the theoretical applications of such technologies or provide hands-on training with FTDs, simulators, or airplanes. Only 60% of the sampled non-AABI accredited universities showed such a course.

Finally, a cluster analysis was accomplished using the NVivo software. Figure 3 illustrates a cluster analysis diagram of coding similarities.

Table I

AABI Programs and their current equipment for ACT education

University	Equipment and Description
Arizona State University (ASU)	Single--Engine Cessna 172 (GIOOO)
Embry-Riddle Aeronautical University (ERAU) Daytona	The entire C-172 and Diamond DA 42 Twin Star fleet is equipped with Garmin GI000 includes the ADS-B onboard collision avoidance system.
Florida Institute of Technology (FIT)	No specific information on equipment was found
Inter-American University of Puerto Rico (IUPR)	No specific information on equipment was found
Middle Tennessee State University (MTSU)	All DA40s have the Garmin GIOOO suites and the latest eight have the GFC Automated Flight Control System and Garmin's Synthetic Vision Technology.
Purdue University	Recently upgraded its fleet of airplanes to include an Embraer Phenom 100 jet and 16 Cirrus SR-20G3 single engine aircraft. The planes and their corresponding simulators are equipped with a Garmin GI000 glass cockpit avionics system.
Rocky Mountain College (RMC)	Flight training is conducted in Piper and Beechcraft aircraft owned by the College. Glass cockpit aircraft and sophisticated simulators are used in training.
Southern Illinois University at Carbondale (SIU)	Flight Training Device (FTD) lessons using the GIOOO FTD.
St Cloud State University (SCSU)	No specific information on equipment was found
University of North Dakota (UND)	(GIOOO) in the Cessna 172S. The Piper Seminole is IFR equipped with dual Garmin GNS 430 GPS units and a two-axis autopilot.

Table 2

Non-AABI Programs and their current equipment for ACT education

University	Equipment and Description
Bowling Green State University (BGSU)	No specific information on equipment was found
Central Washington University	PC lab for computer-based training, two Frasca 141 single engine FTDs, a Frasca TrueFlight Baron G58 FTD with Garmin GIOOO glass flight deck, a Frasca 242T which simulates a Super King Air 200, and a Frasca CRJ 200.
Delta State University	Diamond airplanes also feature digital instrument displays, called glass technology, which replace the traditional analog six-pack of round gauges.
Farmingdale State College	No specific information on equipment was found
Indiana State University (ISU)	DA40s and glass-cockpit simulator.
Liberty University	The majority of aircraft used by the SOA are equipped with Garmin G1000 Navigation Systems (Cessna 172s).CRJ-200 Regional Jet simulator as part of the Advanced Jet Systems course (recommended for the Airline Hiring Agreements).
Texas A&M University-Central Texas	No specific information on equipment was found
University of Alaska at Anchorage (UAA)	Diamond aircraft which use glass cockpit
Utah Valley University (UVU)	All-Diamond fleet
Walla Walla University	Piper Arrow is equipped with a Garmin 500 instrument panel and multi-functional display, MVP 50 digital systems monitor, Garmin 430 WAAS IFR GPS, and modern radio and navigation equipment. Piper Seminole is equipped with autopilot, supplemental oxygen, modern radio and navigation equipment, a Garmin 430 WAAS IFR GPS and MX20 multi-functional display. In addition, a GlOOO Flight Training Device

Table 3

AABI Programs and their current courses for ACT education

University	Course and relevant topics
ASU	*AMT 382 Air Navigation*: Theory and application of modern advanced navigation and flight instrument systems
ERAU	*AS 435 Electronic Flight Management Systems*: autopilot and flight management systems.
FIT	*AVF 3005 Technically Advanced Instrument Flight*: primary flight display, multifunction display and GPS navigation system.
MTSU	*AERO 4230 - Advanced Air Navigation*: Advanced navigation equipment and operation procedures, including international, transoceanic, and polar routes, inertial navigation, GPS.
Purdue	*AT 32700 Advanced Transport Flight Operations*: automated cockpit instrumentation, domestic/international flight operations, and global navigation
RMC	*AVS 205 - Global Positioning System and Glass Cockpit Lab*: hands-on global positioning system and glass cockpit training using software in the classroom and hardware in flight training devices
SIU	*AF306 Intro to Technically Advanced Aircraft Operations*: Technically Advanced Aircraft (TAA) systems, navigation and autopilot
SCSU	*AVIT 205. Aircraft Electronic Systems*: electronics systems including operation of electrical systems and major components, autopilot systems, global positioning systems, flight management systems, multifunction electronic display systems.

Table 4

Non-AABI Programs and their current courses for ACT education

University	Course and relevant topics
BGSU	*AERT 3300 - Digital Cockpit Instrumentation*: flight instruction in the use of digital cockpit aircraft instrumentation, including systems differences, flight director, and autopilot use.
Farmingdale	*AVN 424 Advanced Avionics and Cockpit Automation*: automatic flight control and flight director systems, stability augmentation systems, power management systems, flight management systems and auto land/go around systems. Latest technology navigation systems topics including inertial navigation systems (INS), inertia reference systems (IRS), Global Positioning Systems (GPS) including Local Area Augmentation Systems (LAAS) and twice Area Augmentation Systems (WAAS).
ISU	*AVT 3171319 - Technically Advanced Aircraft/Lab:* introduction to advanced avionics, electronic flight instruments, navigating with the use of a glass cockpit display, automated flight controls, glass cockpit information systems, component failures, and emergencies.
Liberty	*AVIA 4351436 Advanced Jet Systems/Training:* This course is designed to replicate an airline "New Hire" class in order to give our students a feel for what to expect once they graduate and join either the airlines or a corporate charter business. Our faculty who teach the course have flown the CRJ-200.
UAA	*ATP A232 Advanced Aviation Navigation:* advanced navigation and flight display systems technology, the theory and operation of Global Positioning System (GPS) and Automatic Dependent Surveillance-Broadcast (ADS-B) navigation equipment.
UVU	*AVSC 1260 21st Century Avionics and Instrumentation*: knowledge and practical experience using new generation glass cockpit electronic instrumentation and radio navigation devices. Includes glass cockpit system knowledge, functions, safety, flight planning, crew concepts, and the use of GPS technology.

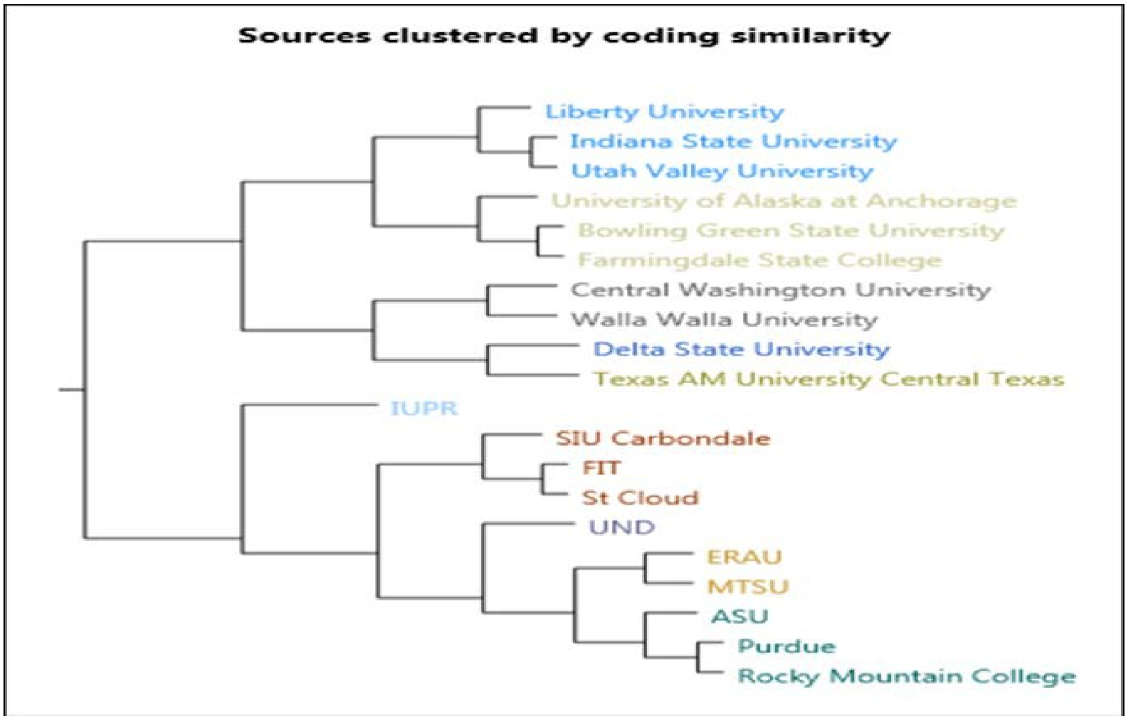

Figure 3. Cluster analysis diagram of coding similarities.

The diagram indicates how sources of information have coding similarities, which in turn could suggest similar collegiate strategies for the education of ACT. The programs of Middle Tennessee State University and Embry-Riddle Aeronautical University have the same color (orange) and were therefore coded similarly. MTSU and ERAU were the only two universities with evidence of added safety features to their existing fleet of TAA. MTSU airplanes include GFC Automated Flight Control System and Garmin's Synthetic Vision Technology (SVT) while ERAU’s aircraft have the Automatic Dependent Surveillance-Broadcast (ADS-B)onboard collision avoidance system technology. Other similar coded programs were Liberty University with Indiana State University and Utah Valley University. Again, the cluster analysis suggests similar strategies in the offering of ACT education. The nearness of University program names also indicates similar coding. The Inter-American University of Puerto Rico has a different color than all other program names and is located further away from the rest of the group suggesting a different strategy for ACT education.

Conclusion

The study has revealed many positive aspects regarding the current state of advanced cockpit technology education in collegiate aviation. The overwhelming majority of AABI and non-AABI accredited institution possess either a course on the theoretical and/or practical applications of ACT or specific equipment for the training of students in such advanced avionics systems. Fanjoy and Young (2004) conducted an in-depth survey of collegiate aviation programs and found that only 51% had ACTs in place for their students. Although the scope of the present research is smaller, and has been limited to archival methods and content analyses, the growth of such percentage almost 10 years later indicates that collegiate aviation is increasing its level of readiness to prepare the future commercial pilot.

Regarding separate specific-courses for ACT education, 80% of AABI accredited institutions had a course in place regardless of its acquisition of TAA equipment or other glass cockpit technology. Only 60% of non-AABI accredited universities had such a course for their students. These figures will likely increase as we move beyond the 2020 time frame when the FAA mandate requiring aircraft to be properly equipped with ADS-B technology arrives.

The Future of Flight Training

As the present study concluded, an international FAA-sponsored panel of air safety experts had established that pilots are relying too much on automation and that two-thirds of many accidents were attributed to poor manual flight skills or mistakes using flight computers (Pasztor, 2013). In addition, the FAA just completed a key revision of pilot-training rules reflecting some of the report's recommendations, including new requirements for teaching more-effective ways to monitor other crew members and flight instruments. For example, AC 61-98B, *Currency Requirements and Guidance for the Flight Review and Instrument Proficiency Check,* is being updated to include a section on “manual flight after automation failure” (Cianciolo, 2014, p. 12). Notwithstanding, the incorporation of advanced cockpit technology in aviation higher education should continue to rise. With the conclusions of the expert panel, the FAA must now consider acting upon the recommendations and provide the flight training industry with the guidelines necessary to ensure sound incorporation of such technologies in flight education.

As every reader can appreciate, the incorporation of advanced technology education is an area worthy of further research. Many questions still lie ahead, regarding the most effective way to train, the best moment to introduce such technologies, and the effects of automation on basic *stick-and-rudder* skills. Flight training institutions are the first to address these learning concepts thus their current adequacy to meet the demands of the future generation of pilots is essential.

The immediate concern is addressing the preparedness of the future pilot population with said technologies. Learning to fly a TAA will change the flight-training world, and it should pay noticeable dividends to all segments of the industry (AOPA, 2005). Such studies are relevant to government, manufacturing industry, and education to identify training adequacy and expectancy meeting the FAA’s 2020 NextGen mandate requiring all airplanes to be properly equipped with automation technologies.

Recommendations

As previously indicated, the absence of any specific information, within the tables or figures of the present study, does not necessarily indicate real-time absence of ACT education. Thus, the results of the study can be considered exploratory rather than definitive. Future research should study the level of preparedness of collegiate aviation to meet the demands for the NextGen cockpit by conducting interviews of program administrators and/or survey research to cover a wider variety of aviation higher education institutions. Consequently, for future research, the author intends to survey university programs to gain a deeper understanding of the information contained or missing from sources within the present study.

AOPA (2005) accurately claims that students learning cockpit automation must adopt new piloting techniques geared more towards becoming *systems managers*. Educational research is needed in the areas of training for such technologies. Although the FAA has recently incorporated test items to evaluate flying candidates in the use of automation and resource management, what is needed is educational research that proposes or discovers ways to formulate instructional guidelines for the new and emerging paradigm of flying and flight training.

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