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OBJECTIVES

The University Aviation Association publishes the Collegiate Aviation Review International throughout each calendar year. Papers published in each volume and issue are selected from submissions that were subjected to a double-blind peer review process.

The University Aviation Association is the only professional organization representing all levels of the non-engineering/technology element in collegiate aviation education and research. Working through its officers, trustees, committees, and professional staff, the University Aviation Association plays a vital role in collegiate aviation and in the aerospace 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 assignment, and other professional contributions that stimulate and develop aviation education
- To furnish an international vehicle for the dissemination of knowledge relative to aviation among institutions of higher learning and governmental and industrial organizations in the aviation/aerospace field
- To foster the interchange of information among institutions that offer non-engineering oriented aviation programs including business technology, transportation, and education
- To actively support aviation/aerospace oriented teacher education with particular emphasis on the presentation of educational workshops and the development of educational materials covering all disciplines within the aviation and aerospace field

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Collegiate Aviation Review International

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6-2-2021

The Impact of Human Factors and Maintenance Documentation on Aviation Safety: An Analysis of 15 Years of Accident Data Through the PEAR Framework

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Regardless of the type of maintenance performed on aircraft, instructions are to be used to provide the aviation technicians completing the maintenance activities with guidance on, and an outline of, the maintenance items to be performed and completed. However, the use of instructions does not guarantee the correct and proper completion of the maintenance activities as the instructions may be erroneous and/or maintenance personnel can misunderstand, misinterpret, or improperly follow the procedures outlined. Resulting maintenance errors can potentially result in aircraft accidents, as illustrated by Air Midwest Flight 5481. With the purpose of understanding how human factors associated with written maintenance instructions have contributed to aircraft accidents, the researchers qualitatively analyzed, using the people (P), environment (E), actions (A), resources (R) – PEAR – framework, 12 aircraft accidents that occurred from January 1, 2003, through December 31, 2017, under Part 121 or Part 135 operations in the United States that had maintenance instruction-related errors as contributing or causal factors. The detailed accident information, including causal factors, were retrieved from the aircraft accident reports provided by the National Transportation Safety Board (NTSB). The findings indicated that maintenance activities, specifically in terms of the adequacy and proper use of maintenance instructions, are largely impacted by human factor elements, such as the overall organizational environment and the resources available.

Recommended Citation:

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As mandated by the United States Code of Federal Regulations (C.F.R.), virtually every U.S. registered aircraft operating in the United States airspace is subjected to periodic maintenance activities (Title 14 C.F.R. § 91.405, 2011). However, the extent of the mandated maintenance activities is dependent upon the exact type of operations of each aircraft. On one hand, general aviation (GA) aircraft operating under Title 14 C.F.R. Part 91 are commonly subject to maintenance activities as part of annual inspections and 100-hour inspections. On the other hand, aircraft operating under Title 14 C.F.R. Part 121 and Title 14 C.F.R. Part 135 are subjected to maintenance activities per continuous airworthiness inspection programs (Title 14 C.F.R. § 91.409, 2011). Despite the different types of aircraft inspections and maintenance activities that are to be performed, all have one aspect in common, namely the requirement to use a form of documentation or instruction, such as maintenance manuals, checklists, and/or job cards that outline the details of the task at hand (Title 14 C.F.R. § 43.13, 2011). However, these maintenance instructions have the potential to negatively impact aviation safety. For instance, when poorly prepared, maintenance instructions could be a contributing factor to aircraft accidents (Hobbs, 2008). The maintenance instructions and documentation, amongst others, can present technical errors, be hard to follow, describe procedures in an unclear manner, or provide awkward instructions, which can result in procedural errors – when procedures are not executed as intended – and/or violations – when procedures are deliberately and intentionally not followed (International Civil Aviation Organization [ICAO], 2002). Thus, the risk of improperly performing maintenance activities, even with the guidance of technical documentation, is still present. In situations where maintenance activities are performed erroneously, a so-called maintenance error is said to have occurred (Dhillon & Liu, 2006). A listing of maintenance-related aircraft accidents prepared by the Federal Aviation Administration (FAA) illustrates that maintenance errors, regardless of how minor or insignificant a specific maintenance item might seem, can have serious effects and consequences, with the potential of creating major safety issues and result in fatal accidents, as was observed during the accident of Air Midwest Flight 5481 (FAA, 2018; National Transportation Safety Board [NTSB], 2004).

Literature Review

Impact of Aviation Maintenance on Aviation Safety

A prime example of the importance and impact of maintenance documentation on aviation safety, especially of misunderstanding maintenance instructions, is provided by the accident of Air Midwest Flight 5481.

Air Midwest Flight 5481. On January 8, 2008, a Beechcraft 1900D operated by Air Midwest as US Airways Express crashed shortly after takeoff from Charlotte-Douglas International Airport (CLT) in North Carolina, killing 21 people aboard, including two flight crewmembers. The National Transportation Safety Board (NTSB) (NTSB, 2004, p. x) identified the "airplane's loss of pitch control during takeoff" as the probable cause of the mishap, further elaborating that the loss of pitch control was due to the improper rigging of the elevator control system and a Center of Gravity (C.G.) too far aft of the certified limit. Two days prior to the accident, the elevator system control cables of the affected aircraft were examined during a maintenance check, and the tension of these control cables was found to be too low. In order to adjust the tension, the entire elevator rigging procedure was supposed to be followed as there was no individual job card specifically focusing on adjusting the tension of the control cables. However, both the mechanic and the supervisor misunderstood the procedures, and believed that only the steps in the elevator rigging procedure that focused on the tension adjustment had to be followed (NTSB, 2004). During the post-accident review the mechanics stated that "steps c, f, g, h, i, j, n, and s were not required because those steps were only necessary for cable replacement and not for cable tensioning" (NTSB, 2004, p. 23). However, skipping these steps resulted in an inadequate restriction of the aircraft's nose down travel, and thus contributed to the accident (Hobbs, 2008; NTSB, 2004). Through the example given by Air Midwest Flight 5481, the impact that maintenance instructions have on the proper completion of maintenance activities, especially when not properly understood, are illustrated, and the risks associated therewith are highlighted.

Aviation Maintenance and Safety

The human element, including flight personnel as well as personnel on the ground, such as aircraft technicians, has a great impact on safety in the aviation industry (FAA, 2018; Hobbs, 2004; Oster, Strong, & Zorn, 2013). Human error has been cited as a causal factor for between 75% to 80% of all aviation accidents, and around 12% of this proportion of aircraft accidents are linked to aircraft maintenance activities (FAA, 2018). As the aircraft maintenance system and environment are very complex and intricate, human errors should be expected (Latorella & Prabhu, 2000). According to Hobbs (2008), even if improper maintenance activities are not identified as the primary cause of an accident, they may still have played an important role therein.

In the five-year span between 1996 and 2001, 1,016 aviation mishaps with maintenance issues cited as causal factors were registered in the Maintenance Error Information Management System (MEIMS), a database which combines FAA, National Aeronautics and Space Administration (NASA), and U.S. Navy maintenance error data (Krulak, 2004). Similarly, in the Aviation Safety Review for 2016, the United Kingdom (UK) Civil Aviation Authority (CAA) highlighted aircraft maintenance as a prominent primary cause for airplane and helicopter accidents, serious incidents, and high severity occurrences (Civil Aviation Authority [CAA], 2017). The significance of maintenance on the safety of the aviation industry is further highlighted by the records of NASA's Aviation Safety Reporting System (ASRS) database. From the 54,318 incidents reported in the database for the time period between 2010 and 2020, 1,661 reports reference maintenance-related procedural violations (ASRS, n.d.).

One important aspect of maintenance-related errors is that they can exist without being visible or discovered for a prolonged period of time, and consequently are more latent and less obvious than other error-types (FAA, 2018). In the past, the search for a root cause frequently stopped when the last person that was in touch with, or worked on, the damaged component is found, instead of continuing the search deeper into the causes for the failure (Hibit & Marx, 1994). However, with the introduction of the continuing analysis and surveillance system (CASS) – an approach now required for airlines in the United States to prevent maintenance errors – performing a root cause analysis is a mandatory component of airlines' maintenance programs (McFadden & Worrells, 2012). While it is useful to know what the actual error-condition was, it is more crucial to understand the reason why a specific error occurred, as it allows to understand and analyze the root causes of the error (Hobbs, 2008).

Maintenance documentation is a critical aspect for the proper completion of aircraft maintenance activities. After reviewing 2,360 incidents listed in the ASRS database that occurred between 1996 and 2003, Hobbs and Kanki (2008) indicated that maintenance manuals were a common factor among the reports analyzed. Additionally, the maintenance error history (MEH) model presented by Rashid, Place, & Braithwaite (2013) illustrates that information, as provided in aircraft documents and manuals, technical compact discs (CDs), or bulletins, could be an error-trigger during the aircraft maintenance process. These trends were further reflected by Hobbs (2008), where elements related to maintenance documentation, such as poor designs or procedures, were identified to be contributing factors to maintenance errors and incidents. The organization of these sources of information is crucial and can result in an error-producing condition, as errors can occur when attempting to retrieve information from “confusing, misleading or excessively cluttered documentation and charts” (ICAO, 2002, p. 2-6).

The importance of aircraft maintenance activities and their impact on aviation safety is further highlighted by the FAA (2018) and Hobbs (2008) through a listing of aircraft accidents and incidents whose causes are related to maintenance issues and errors. The FAA (2018) and Hobbs (2008) incident and accident listings are combined in Table 1.

Human Factors in Aviation

Most of the aircraft accident literature has focused on the analysis and modeling of human factors (Wiegmann & Shappell, 2001), their impact on aircraft accidents (Australian Bureau of Air Safety Investigation (BASI), 1996; Dambier & Hinkelbein, 2006; Daramola, 2014; Kelly & Efthymiou, 2019; Kharoufah, Murray, Baxter, & Wild, 2018; Li & Harris, 2006; Li, Harris, & Yu, 2008; Liu, Chi, & Li, 2013; Mendonca, Huang, & Keller, 2017; Shappell & Wiegmann, 2004; Shappell, Detwiler, Holcomb, Hackworth, & Boquet, 2006), and accident prevention methods (Taneja, 2002). More specifically, the literature is mostly centered on the aircrew-aspects of human factors. Examples include a report by the [Australian] Bureau of Air Safety Investigation (BASI) focused on pilot-related human factors as causes of aircraft accidents (BASI, 1996) and Taneja’s (2002) review of methods to investigate and prevent of human factors as they relate to aircraft accidents. Furthermore, Wiegmann and Shappell (2001) studied the effectiveness of using the Human Factors Analysis and Classification System (HFACS) framework, placing special emphasis on the identification of human factors in aircraft accidents and incidents.

Table 1
Aircraft Accidents and Incidents Due to Maintenance Related Issues

Flight Identifier	Year	Mishap Type	Maintenance Related Cause
Eastern Airlines 855	1983	Incident	Installation of chip detectors without O-rings
Japan Airlines 123	1985	Accident	Improperly performed repair on rear pressure bulkhead
Aloha Airlines 243	1988	Accident	Unidentified disbonding and fatigue damage during inspection
British Airways 5390	1990	Accident	Improper bolts used during windscreen installation
Excalibur Airways, G-KMAM	1993	Incident	Lack of knowledge of Airbus flap change procedures
Emery Worldwide 228	2001	Incident	Improperly installed landing gear extension components, and failure to detect mistake
China Airlines 611	2002	Accident	Metal fatigue resulting from improper maintenance
Air Midwest 5481	2003	Accident	Improper rigging of the elevator control system during maintenance
Colgan Air 9446	2003	Accident	Improper replacement of cable and inadequate functional check
American Airlines 1400	2007	Accident	Improper engine manual engine start-up procedure used by maintenance personnel

Note: Adapted from "An Overview of Human Factors in Aviation Maintenance" by A. Hobbs, 2008, pp. 3-8 (https://www.atsb.gov.au/media/27818/hf_ar-2008-055.pdf). Copyright 2008 by the Australian Transport Safety Bureau; "Aviation Maintenance Technician Handbook – General" by Federal Aviation Administration, 2018, p.14-33 (https://www.faa.gov/regulations_policies/handbooks_manuals/aircraft/media/amt_general_handbook.pdf). Copyright 2018 by the Federal Aviation Administration.

The HFACS model has since been applied in a variety of studies to understand the human factor elements associated with aircraft accidents, in both, civil and military operations. Through the application of the HFACS framework, the criticality of the human element in aviation is further emphasized, as skill-based errors, perception errors, decision errors, violations, and crew resource management are quoted as frequent aircraft accident causal factors (Dambier & Hinkelbein, 2006; Daramola, 2014; Kelly & Efthymiou, 2019; Li & Harris, 2006; Liu et al., 2013; Shappell & Wiegmann, 2001; Shappell et al., 2006; Wiegmann & Shappell, 2001). Overall, in general aviation (GA) and commercial aviation, skill-based errors dominate, causing approximately 80% and 70% of unsafe acts, respectively. On the military side, however, the contribution of skill-based errors is approximately equal to that of decision errors (Shappell & Wiegmann, 2004). By combining the HFACS framework with statistical methods, Li et al. (2008) determined that for safety interventions to be impactful, they are to be implemented at the Level three and Level four of the HFACS framework, relating to supervisory and organizational processes, respectively. Specifically, unsafe supervision (Level three) refers to latent failures resulting from inadequate acts of the supervisory echelons, while organizational influences (Level four) is tied to managerial and upper-level decisions and actions (Wiegmann & Shappell, 2001).

Additional human factors models with applications to aviation have also been developed and applied. Yang and Fan (2016) introduced a novel human factors model, namely the PEART (people, environment, actions, resources, and time) model. This model is based on the PEAR model, but with an additional element – time, as it is critical to also consider how time impacts an operation and the human factors associated therewith (Yang & Fan, 2016). Further, Zhang, Wang, Luo, & Tang (2013) created a statistical model based on Bayesian network theory to represent causality via conditional probability of the impact of human factors on civil aviation incidents.

Research on the human factors of the aircraft maintenance industry includes studies focusing on their impact on ergonomics and the maintainability of aircraft (Bernard, Zare, Sagot, & Paquin, 2020), relationship to errors (Padil, Said, & Azizan, 2018), influential factors (Jaiswal, Dalkilic, Verma, & Singh, 2019; Santos & Melicio, 2019), incorporation into safety management system (SMS) practices (Miller & Mrusek, 2019), and approaches to map the risks thereof (Kucuk, 2019). Only few reports usually issued by government-related agencies like the FAA in the United States and the Australian Transport Safety Bureau (ATSB) in Australia have focused on further analyzing and researching aircraft accidents with regards to their relationship to maintenance activities, as presented by the FAA (2018) and Hobbs (2008). However, in these reports, the accidents are overviewed in a general and broad manner or the focus thereof is not explicit to accidents caused by, or related to, maintenance instruction-related issues. Goldman, Fiedler, & King (2002) obtained reports of maintenance-related GA accidents that occurred between 1988 and 1997 from the NTSB. The associated data were analyzed, and the accidents were classified into categories by type of aircraft involved, installation error (i.e. what was the type of maintenance error), aircraft system affected, certification of the mechanics, and operational impact (Goldman et al., 2002). While this research provides an understanding of the frequencies of the relative categories, it does not present details on the causes of the maintenance errors analyzed or an analysis of the human factors involved.

The PEAR Model

The PEAR model provides a framework to characterize human factors – the relationship between people, their capabilities, and their environment and activities (FAA, 2018; ICAO, 2002). Specifically, the PEAR model considers four elements that impact human factors in the area of aviation maintenance, namely *people* (P), *environment* (E), *actions* (A), and *resources* (R) (FAA, 2018).

The people element of the PEAR model refers to the individuals that perform the maintenance activities (FAA, 2018). As not every individual involved in the maintenance activities presents the same characteristics, maintenance operations and activities have to respect each individual's limitations (ICAO, 2002). The PEAR model considers physical characteristics, physiological, psychological, as well as psychosocial characteristics (FAA, 2018; ICAO, 2002; Johnson & Maddox, 2007). By extension, as a critical element to human capability and performance, and a fundamental component of human factor analysis, fatigue – both from a physical as well as mental perspective – is further highlighted and studied under the *people* element of the PEAR model (Johnson & Maddox, 2007). The complete list of human factors characteristics considered under the people element of the PEAR model is outlined in Table 2.

Table 2
PEAR Elements Classification

<table>
<tr><th colspan="12">P - People</th></tr>
<tr><th colspan="3">Physical Elements</th><th colspan="3">Psychological Elements</th><th colspan="3">Physiological Elements</th><th colspan="3">Psychosocial Elements</th></tr>
<tr><td colspan="3">Physical size
Gender
Age
Strength
Sensory limitations</td><td colspan="3">Workload
Experience
Knowledge
Training
Attitude
Mental/emotional state</td><td colspan="3">Nutritional factors
Health
Lifestyle
Fatigue
Chemical dependency</td><td colspan="3">Interpersonal conflicts
Financial hardships
Personal loss</td></tr>
<tr><th colspan="12">E – Environment</th></tr>
<tr><th colspan="6">Physical Environment</th><th colspan="6">Organizational Environment</th></tr>
<tr><td colspan="6">Weather
Location of activities
Shift
Workspace
Safety
Sound level
Lightning characteristics</td><td colspan="6">Personnel
Corporate culture
Morale
Supervision
Company size
Profitability
Crew structure
Labor-management relations
Pressures</td></tr>
<tr><th colspan="12">A - Actions</th></tr>
<tr><td colspan="12">Steps required to perform and complete a task
The number of people involved to complete a task
Sequence of activities</td></tr>
<tr><th colspan="12">Requirements</th></tr>
<tr><td colspan="4">Communication
Attitude
Certification</td><td colspan="4">Information control
Knowledge</td><td colspan="4">Skill
Inspection</td></tr>
<tr><th colspan="12">R – Resources</th></tr>
<tr><td colspan="6">Manuals
Tools
Work stands and lifts
Other people
Materials
Quality systems
Procedures and work cards</td><td colspan="6">Computer software systems
Test equipment
Fixtures
Task lightning
Ground handling equipment
Training
Paperwork and associated signoffs</td></tr>
</table>

Note: Adapted from “Aviation Maintenance Technician Handbook – General” by Federal Aviation Administration, 2018, pp.14-10 – 14-12 (https://www.faa.gov/regulations_policies/handbooks_manuals/aircraft/media/amt_general_handbook.pdf). Copyright 2018 by the Federal Aviation Administration; “A PEAR shaped model for better human factors” by W.B. Johnson and M.E. Maddox, 2007, pp. 20-21 (https://www.faa.gov/about/initiatives/maintenance_hf/library/documents/media/reports_publications/pear_civil_aviation_training_magazine_4-07.pdf).

As shown in Table 2, the *environment* in the area of maintenance activities includes both the physical as well as the organizational environment (Johnson & Maddox, 2007). The *physical environment* refers to a series of physical conditions that can impact the maintenance activities, while the *organizational environment* refers to organizational characteristics that define a company, and thus, the workplace (FAA, 2018). From an organizational perspective, as highlighted by the HFACS model, decisions taken in the upper levels of management – such as the allocation of resources or implemented policies and procedures – have an impact on the frontline actions, and consequently impact safety (Wiegmann & Shappell, 2001).

The *actions* element of the PEAR model refers to all actions and activities that are performed and/or completed as part of the aviation maintenance operations. *Actions* range from the requirements needed to complete the maintenance activities, to the actual steps performed during the maintenance activities (FAA, 2018; Johnson & Maddox, 2007). Within the context of the HFACS framework, the actual steps performed, if leading to an accident, can be classified as unsafe acts of operator, in the form of errors and/or violations (Wiegmann & Shappell, 2001), following the definitions afore-provided. Table 2 highlights the human factors characteristics considered under the actions element of the PEAR model.

In the most basic sense, *resources* refers to any element that is required to complete maintenance activities, as shown in Table 2. This includes both tangible as intangible elements, such as tools and training, respectively (FAA, 2018). Under the HFACS model, resource management is classified as a subset of organizational influences, the fourth level of failure (Wiegmann & Shappell, 2001). When analyzing the *resources* element of the PEAR model, however, it is important to identify additional resources that are required, rather than merely characterizing existing resources (FAA, 2018). The allocation of resources is dictated by safety and cost-effectiveness objectives (Wiegmann & Shappell, 2001).

Significance of the Study

Often times, safety hazards that can lead to future aircraft accidents can be eliminated or mitigated after an accident when they are properly understood and proactive action is taken (ICAO, 2016; Sumwalt & Dalton, 2014). As presented in the literature review, aviation maintenance and its impact on safety is a known and frequently studied discipline, simultaneously highlighting maintenance documentation as a risk factor. However, the studies presented do not focus on specific accidents and incidents in which maintenance documentation, as a sub-element of maintenance activities, has impacted and threatened aviation safety. Consequently, researching aircraft accidents that were caused by, or related to maintenance instructions, and understanding recurring themes amongst the characteristics of the maintenance activities performed is expected to allow the industry to recognize and more effectively address the risks and factors associated with aircraft maintenance instructions. Through the expected increased understanding obtained through this research, proactive action can be taken to improve the area of maintenance instructions, with the objective of improving the overall safety of the aviation industry.

Research Questions

This study was an attempt to understand the underlying factors of aircraft accidents which occurred under Part 121 and Part 135 operations from 2003 to 2017 and were caused by maintenance errors related to, or induced by, written maintenance instructions, through the application of the PEAR model. Specifically, the following research questions were addressed:

1. What are the characteristics of the maintenance activities that could be improperly performed due to issues presented and caused by written maintenance instructions?
2. What are the underlying human factor-related causes of the maintenance errors induced by written maintenance instructions issues?

Methodology

To answer the research questions, data from aircraft accidents that occurred between January 1, 2003 and December 31, 2017 under Part 121 and Part 135 operations, and that were caused by, or related to, issues with written aircraft maintenance instructions and documentation were obtained from the NTSB aviation accidents databases (NTSB, n.d.-a; NTSB, n.d.-b). The gathered data were used to study the human factors elements that were related to the maintenance documentation issues through the application of the PEAR model.

Data Collection

Similar to Goldman et al. (2002), the aircraft accident data from 15 years were obtained through the online aviation accidents database (NTSB, n.d.-a). To query only the accidents of interests, the search filters on the NTSB website were adjusted to include accidents classified by the NTSB as “airplane” accidents occurring in the United States under Part 121 and Part 135 operations from January 1, 2003 to December 31, 2017. A key word search for “maintenance” was conducted to obtain only the reports from accidents in which the maintenance activities were investigated.

Data Analysis

The list resulting from the NTSB search included the accidents that occurred within the specified time range, under Part 121 and Part 135 operations, and whose reports have the keyword “maintenance” included. This included any mention of maintenance within the accident reports, and consequently did not specifically sort out accidents related to issues with maintenance instructions and documentation. To sort out the accidents that were related to, or caused by, maintenance instructions issues, the final or preliminary accident reports, depending on availability, were read and analyzed. After manually filtering out the accidents that were caused by maintenance documentation-related issues, the strategy used by Goldman et al. (2002) was followed. The selected accidents were coded in different categories in order to obtain accident demographic information. In this study, the accidents were coded in the categories described below.

The accidents were coded with respect to the number and types of injuries, as provided by the NTSB report. The types of injuries are fatal, serious, minor, and none (NTSB, 2013; Title 49 C.F.R. § 830.2, 2011). The accidents were further coded in terms of the level of damage to the aircraft, as provided by the NTSB accident report. Aircraft damage can be coded into four categories, as provided and defined by the NTSB (2006): destroyed, substantial, minor, and none.

The *Aircraft System Affected* category identifies and classifies the aircraft system that the improper maintenance activity was taking place on. The aircraft system categories are adopted from Goldman et al. (2002), and are: flight controls, powerplant, landing gear, flight/navigation instruments, electrical system, fuselage, rotor system, wing (vertical and horizontal), fire warning system, air conditioning/heat/pressurization/oxygen, and anti-/de-ice systems.

The *Physical Description of Errors* category allows the classification of the aircraft accident in terms of the physical maintenance action that was performed incorrectly. The categories used were adopted from Hobbs (2008) and are: omission, commission, and timing and precision. According to Hobbs (2008), an omission refers to not performing a required action, as for example not safety wiring two bolts together, or omitting a series of steps in a procedure. Commission, on the other hand, refers to "[when] an action is performed that should not have been performed" (Hobbs, 2008, p. 10), as for example improperly connecting the end terminals of an electrical device. Lastly, timing and precision refers to actions that were "performed at the wrong time, in the wrong order, or without the necessary level of precision" (Hobbs, 2008, p. 19). Using the definitions provided by Hobbs (2008), examples of timing and precision errors could include connecting the negative lead of a battery first or inflating a tire to the wrong pressure.

The *Maintenance Activity* category identifies the type of maintenance that has been performed on the aircraft. The coding used was adapted from the NTSB Aviation Coding Manual (NTSB, 1998) and from Goldman et al. (2002). The categories used in the analysis are: adjustment, alignment, annual inspection, 100-hour inspection, balancing, calibration, compliance with an Airworthiness Directive (AD), design change, installation, inspection, lubrication, modification, major repair, major alternation, overhaul, pressurizing, rebuild/remanufacture, replacement, service bulletin (SB)/letter, and service aircraft/equipment (Goldman et al, 2002; NTSB, 1998).

Accidents that fit into more than one sub-category within the five categories provided above were counted in both sub-categories. For example, if two aircraft systems were affected in an accident, both of the systems were counted as systems affected. The frequency of the type of operation, type of injuries, aircraft damage, system affected, physical description of errors, and maintenance activity was then computed. Following the example provided by Goldman et al. (2002), the frequencies of each category were used to obtain an overall understanding of the demographic of the accidents that were caused by, or related to, maintenance instruction and documentation issues.

PEAR Model

The human factors that resulted in, or affected, the maintenance instructions-related issues were analyzed through the application of the PEAR model. Researchers utilized the PEAR model to identify the individual factors that affected the maintenance activities, focusing on the maintenance documentation issues that were improperly completed. More precisely, the NTSB reports of the selected accidents were carefully reviewed by the researchers to identify the frequency of the themes and categories of the PEAR model. The themes identified under the Results section reflect the human factors categories from the PEAR model, as outlined in the above-presented Table 2. The researchers aimed to identify said categories and themes in the selected NTSB reports to obtain a count of the human factors present in the accident reports analyzed. To reduce the potential impact of bias, the methodology implemented was based on the methods presented in previous studies focusing on aviation human factors and maintenance errors, as introduced in the Literature Review. Furthermore, the classification was guided by the researchers' previous experience in the field of aviation safety and human factors.

Research Questions

To answer Research Question 1, the information obtained from the demographic analysis was used as it provides data regarding the characteristics of these accidents. Specifically, a frequency analysis of the different sub-categories previously identified for the system affected, physical description of errors, and maintenance activity categories was performed. Through this analysis, recurring themes in terms of maintenance activity characteristics can be identified and discussed.

Research Question 2 was answered through the results from the PEAR analysis. Specifically, a frequency analysis was performed on the various PEAR elements and recurring themes amongst the people, environment, action, and resources human factor elements that were identified. The results from the frequency analysis and the recurring themes were used as the basis for the underlying maintenance human factor-related causes of the selected accidents.

Results

Eighty-five Part 121 accidents and 196 Part 135 accidents from the NTSB databases initially matched the aforementioned search criteria. Using the manual selection process, five Part 121 and seven Part 135 accidents were identified to have maintenance instruction-related issues as a causal factor. Table 3 provides an overview of the selected accidents.

Table 3
Selected Part 121 and Part 135 Accidents Overview

Accident	Date	Operation	Cause Related to Instructions
DCA03MA022	01/08/2003	Part 121	Improper understanding of instructions
DEN04LA023	11/18/2003	Part 135	Improper maintenance instructions
LAX05LA244	07/22/2005	Part 135	Failure to follow maintenance instructions
NYC06FA128	05/30/2006	Part 121	Inadequate maintenance instructions
DCA06FA058	07/28/2006	Part 121	Inadequate maintenance instructions
CHI07LA043	12/17/2006	Part 135	Improper maintenance instructions
DCA07MA310	09/28/2007	Part 121	Improper use of maintenance instructions
CHI08LA071	01/09/2008	Part 121	Failure to follow maintenance instructions
MIA08LA079	03/15/2008	Part 135	Failure to follow maintenance instructions
CEN10LA389	07/08/2010	Part 135	Failure to follow maintenance instructions
WPR12FA332	07/28/2012	Part 135	Failure to follow maintenance instructions
WPR14FA068	12/11/2013	Part 135	Improper understanding of instructions

An overview of the selected Part 121 and Part 135 accidents including the accident number, operation type, aircraft damage, aircraft system affected, physical description of the error, and maintenance activity are provided in Table 4. Both, the Part 121 and Part 135 accident detailed descriptive statistics based on the outlined parameters were calculated and are presented in Table 5. The analyzed accidents resulted in a total of 22 fatalities – one fatality was reported in a Part 135 accident (NTSB, n.d.-f) and 21 fatalities were reported in a Part 121 accident (NTSB, 2004). In approximately 80% of all selected accidents, the aircraft received substantial damage, while in the remaining cases the aircraft were found to be destroyed. The three individual systems most frequently affected by the improper maintenance in Part 121 and Part 135 accidents were the landing gear – accounting for 50% of accidents, powerplant – accounting for approximately 33% of the accidents, and flight controls – accounting for approximately 16% of the accidents. The majority of the accidents, specifically 60% and 75% of the Part 121 and Part 135 accidents, respectively, were caused by acts of omission, where a required maintenance activity or item was not completed. The improper maintenance actions were completed as part of seven different maintenance activities: adjustment, airworthiness directive (AD) compliance, inspections, service bulletin/letter implementations, overhaul, replacement, and service of aircraft and equipment. Three of the maintenance actions categories – adjustment, replacement, and service of aircraft and equipment – overlap between both, Part 121 and Part 135 accidents.

Analysis of the Accidents Applying the PEAR Framework

Table 6 lists the PEAR elements that were identified for each accident based on the information provided in the NTSB aircraft accident reports. All but two PEAR items were selected from the previously provided PEAR item list. The PEAR items listed in Table 6 as "Maintenance action improperly completed" and "Maintenance action not completed" under the *Action* PEAR column were not provided in the list created based on the FAA (2018) documentation nor Johnson and Maddox (2007). These elements were added by the researchers to more accurately reflect the accident information outlined in the NTSB aircraft accident reports. Some of the reports did not provide additional details on the accident causal factors other than outlining that the maintenance items provided in the maintenance documentation were not completed or completed improperly. Thus, these two categories account for the lack of detail in the NTSB accident reports while still providing an indication of the causal accident factors related to maintenance instructions.

The PEAR analysis results are synthesized in Table 7 to reflect the frequency of the PEAR items identified and their occurrence (Part 121 vs. Part 135 accidents). The most frequent PEAR element amongst Part 121 accidents as well as amongst both operation types together is *Resources*, with 10 and 16 occurrences, respectively. The most frequent PEAR element amongst Part 135 accidents is "Action", with seven occurrences. The least occurring PEAR element is *Environment* with a single occurrence from a Part 121 accident. Additionally, no *People* or *Environment* PEAR element items were identified for Part 135 accidents. The most frequent individual PEAR element item is the *Resources* item "Procedures and work cards", with eight occurrences total - four occurrences from each, Part 121 and Part 135 accidents. The *Action* item "Maintenance action not completed" is the only other individual PEAR element item with four occurrences from one accident category, in this case from Part 135 accidents. All remaining PEAR element items occur once or twice per operation type.

Table 4
Selected Part 121 and Part 135 Accidents Descriptive Information

Accident	**Operation**	**Injuries**	**Fatalities**	**Level of Damage**	**Aircraft System Affected**	**Physical Description of Error**	**Maintenance Activity**
Part 121 Accidents							
CHI08LA071	Part 121	-	-	Substantial	Powerplant	Omission	Replacement
DCA07MA310	Part 121	-	-	Substantial	Powerplant	Commission	Service
DCA06FA058	Part 121	-	-	Substantial	Landing Gear	Omission	Overhaul
NYC06FA128	Part 121	1 – Serious	-	Substantial	Landing Gear	Timing & Precision	Service
DCA03MA022	Part 121	1 – Minor	21	Destroyed	Flight Controls	Omission	Adjustment
Part 135 Accidents							
WPR14FA068	Part 135	3 – Serious; 5 – Minor	1	Destroyed	Powerplant	Omission	Service Bulletin; Inspection
WPR12FA332	Part 135	-	-	Substantial	Flight Controls	Timing & Precision	Airworthiness Directive
CEN10LA389	Part 135	-	-	Substantial	Landing Gear	Omission	Replacement
MIA08LA079	Part 135	-	-	Substantial	Landing Gear	Timing & Precision; Omission	Adjustment
CHI07LA043	Part 135	-	-	Substantial	Landing Gear	Omission	Inspection; Adjustment; Replacement
LAX05LA244	Part 135	-	-	Substantial	Powerplant	Omission	Inspection
DEN04LA023	Part 135	-	-	Substantial	Landing Gear	Omission	Service

Table 5
Distribution of Accident Descriptive Criteria by Operation Category

Categories	Sub-Categories	Part 121	Part 135	All Accidents Combined
Fatalities & Injuries	Fatal	6.954%	4.166%	6.748%
	Serious	0.331%	12.500%	1.227%
	Minor	0.331%	25%	2.147%
	None	92.384%	58.333%	89.877%
Level of Damage	Destroyed	20%	14.286 %	16.666%
	Substantial	80%	85.714%	83.333%
	Minor	-	-	-
	None	-	-	-
Aircraft System Affected	Flight Controls	20%	14.286%	16.666%
	Powerplant	40%	28.571%	33.333%
	Landing Gear	40%	57.143%	50%
Physical Description of Error	Omission	60%	75%	69.231%
	Commission	20%	-	7.692%
	Timing & Precision	20%	25%	23.077%
Maintenance Activity	Airworthiness Directive	-	10%	6.666%
	Inspection	-	30%	20%
	Service Bulletin/Letter	-	10%	6.666%
	Overhaul	20%	-	6.666%
	Replacement	20%	20%	20%
	Service Aircraft/Equipment	40%	10%	20%

Discussion

The characteristics of the improperly performed maintenance activities are determined based on the affected aircraft systems, the physical description of the errors, and the maintenance activity itself, as summarized in Table 5. Relating to aircraft systems, the landing gear is the system most susceptible to be involved in instruction-related inadequate maintenance activities. The spread of affected aircraft systems, however, is narrow, as only two other systems presented maintenance-related issues caused by the maintenance instructions, namely the powerplant and flight control systems. While the specific relative frequency of the systems involved differs, the powerplant, flight controls, and landing gear were similarly ranked amongst the most frequent aircraft systems involved in accidents by Goldman et al. (2002). The results obtained, nevertheless, need to be considered in relation to the framework of the analysis, and are not indicative of other systems not being subjected to instruction-induced faulty maintenance. Specifically, the analysis performed only considers maintenance issues related to aircraft accidents. Consequently, the system failure needs to be significant to trigger an accident-causing fault. Therefore, in context, the criticality of adequate maintenance for, and the importance of maintenance instructions of, the flight control, powerplant, and landing gear systems are illustrated by highlighting the severity of a fault thereof – namely, an aircraft accident. Furthermore, in a study conducted by Goldman et al. (2002) the aircraft systems involved in accidents were statistically related to the fatalities and injuries occurring, highlighting the importance of inadequate maintenance of specific aircraft systems.

Most of the improperly performed maintenance activities were in the form of acts of omission. For both, Part 121 and Part 135 accidents, acts of omission were responsible for 60% and 75% of the inadequately performed maintenance activities, respectively. The most prominent example of an act of omission relates to the afore-quoted Air Midwest Flight 5481, where a misunderstanding of the maintenance instructions resulted in a technician not performing all the required steps, creating the accident-causing condition (Hobbs, 2008; NTSB, 2004). Omissions include both situations where steps explicitly spelled out in the maintenance instructions are not completed (NTSB, n.d.-c), as well as situations where the maintenance program and instructions do not include the required and necessary items (NTSB, n.d.-f). The frequency of occurrence of acts of omissions highlights the importance of performing every maintenance step required and the need for maintenance instructions to explicitly outline all required maintenance steps. This includes eliminating any ambivalence in the maintenance instructions to avoid uncertainties regarding the need to complete specified steps, such as in the event of Air Midwest Flight 5481.

No individual maintenance activity stands out by itself, but rather four categories are observed to have a 20% occurrence: adjustment, inspections, replacement, and service of aircraft and equipment, while three categories had an approximately six percent occurrence: AD compliance, service bulletin/letter implementations, and overhaul. As a wide spread in terms of maintenance activities is observed, not a singular type of activity is distinguished for individual error-inducing maintenance instructions. When analyzing the maintenance instructions with respect to the maintenance activities performed, where the instructions originated from and whether they were adapted, for instance to meet specific aircraft constraints, their usability, relevance, and applicability are crucial factors to consider (Zafiharimalala, Robin, & Tricot, 2014). For example, in accident DEN04LA023 (NTSB, n.d.-d), the approved maintenance instructions adapted for inspections and used by the airline did not match the maintenance requirements and instructions provided by the manufacturer. A similar discrepancy was reported in accident NYC06FA128 (NTSB, n.d.-e), where the manufacturer-provided instructions were not accurately reflected in the job card adapted to the specific operator’s activities, thus missing crucial maintenance steps. Furthermore, certain type of maintenance activities inherently contain more detailed instructions than others, causing instructions to be either insufficient in content or overly detailed, leading technicians to refrain from using the provided documentation systematically (Zafiharimalala et al., 2014).

The analysis of the accidents applying the PEAR framework provided insight related to the human factor elements associated to the use of maintenance instructions. As aforementioned, the most impactful category of the PEAR framework is the *Resources* category. Under the HFACS model (Wiegmann & Shappell, 2001), resource management is listed as an organizational influence, impacted by the upper managerial levels. Within the *Resources* category, the two most frequent items are procedures and work cards, as well as manuals. As the analysis performed solely focused on maintenance-related accidents in which the maintenance instructions are quoted as causal factors, the high frequency of these items can be expected. Similarly, the relative high frequency of “Maintenance action improperly completed” and “Maintenance action not completed” under the *Action* category can be explained by the narrow focus of the study. Nevertheless, the PEAR analysis highlights that maintenance instructions by themselves are not able to support the maintenance activities, and that other factors centered around the human element are required to support the maintenance effort.

Table 6
PEAR Analysis Results

Accident Number	Operation	PEAR Elements			
		People	**Environment**	**Action**	**Resources**
CHI08LA071	Part 121	- Psychological characteristics: Excessive workload	-	- Maintenance action not completed - Sequence of activities	- Other people
DCA07MA310	Part 121	-	-	-	- Procedures and work cards - Quality system
DCA06FA058	Part 121	-	-	-	- Procedures and work cards
NYC06FA128	Part 121	-	-	-	- Procedures and work cards - Manuals
DCA03MA022	Part 121	- Psychological characteristics: Experience, knowledge, and training	- Organizational environment: Supervision	- Steps required to perform and complete a task - Requirements: Knowledge	- Procedures and work cards - Manuals - Training - Quality systems
WPR14FA068	Part 135	-	-	- Maintenance action not completed	- Procedures and work cards - Manuals
WPR12FA332	Part 135	-	-	- Maintenance action improperly completed	-
CEN10LA389	Part 135	-	-	- Maintenance action not completed	-
MIA08LA079	Part 135	-	-	- Maintenance action improperly completed	-
CHI07LA043	Part 135	-	-	- Steps required to perform and complete a task	- Procedures and work cards - Manuals
LAX05LA244	Part 135	-	-	- Maintenance action not completed	- Procedures and work cards
DEN04LA023	Part 135	-	-	- Maintenance action not completed	- Procedures and work cards

Table 7
PEAR Analysis Summary

	PEAR Items	Part 121 Accidents	Part 135 Accidents	Total
People	- Psychological characteristics: Workload	1	-	1
	- Psychological characteristics: Experience	1	-	1
	- Psychological characteristics: Knowledge	1	-	1
	- Psychological characteristics: Training	1	-	1
	Total People Items	4	-	4
Environment	- Organizational environment: Supervision	1	-	1
	Total Environment Items	1	-	1
Action	- Maintenance action not completed	1	4	5
	- Sequence of activities	1	-	1
	- Steps required to perform and complete a task	1	1	2
	- Requirements: Knowledge	1	-	1
	- Maintenance action improperly completed	-	2	2
	Total Action Items	4	7	11
Resources	- Other people	1	-	1
	- Procedures and work cards	4	4	8
	- Quality system	2	-	2
	- Manuals	2	2	4
	- Training	1	-	1
	Total Resources Items	10	6	16

For instance, the workload, knowledge, experience, and training – all psychological characteristics outlined under the *People* category – are PEAR elements related to the selected accidents. In the United States, the FAA regulates the certification of aircraft maintenance technicians (AMTs) and dictates the skills (Title 14 C.F.R. § 65.79, 2001), knowledge (Title 14 C.F.R. § 65.75, 1966), and experience (Title 14 C.F.R. § 65.77, 1970) required to be certified to perform maintenance activities on aircraft. By extension, to work as an AMT, certain recency requirements are to be met (Title 14 C.F.R. § 65.83, 2014), adding to the knowledge, experience, and training components. Furthermore, in relation to maintenance instructions, the FAA stipulates that "a certificated mechanic may not exercise the privileges of his certificate and rating unless he understands the current instructions of the manufacturer, and the maintenance manuals, for the specific operation concerned" (Title 14 C.F.R. § 65.81, 1980, para. 2). This regulation ties training of AMTs to the use and understanding of maintenance instructions, outlining the importance and criticality of instructions in the realm of aircraft maintenance activities. However, as presented by the accidents analyzed, a technician's training, knowledge, and experience are not the only human-centered factors that affect the technicians' performance. On-the-job situational elements, such as the workload, are further crucial, and as such, are to be considered. Accident number CHI08LA071 (NTSB, n.d.-c) illustrates a scenario in which the workload influenced the maintenance activities. Specifically, the technicians performing the maintenance task on the accident aircraft were called to help another technician and did not return to the original task, consequently failing to complete outstanding steps of the outlined maintenance task (NTSB, n.d.-c).

Nevertheless, the front-line technicians are supported by supervisors and quality systems, which, as shown by the PEAR analysis, can also fail to provide the required safety barriers, resulting in accident-causing conditions. In the analyzed accidents, one incident of a supervision failure was recorded under the *Environment* category of the PEAR framework, while two instances of quality system deficiencies were noted under the *Resources* category of the framework. Both, a quality system and adequate supervision are essential requirements for aircraft maintenance activities (Shanmugam & Robert, 2015). Per Shanmugam and Robert (2015), supervision can be classified into two main categories. First, relating to the required level of supervision, supervision is a managerial component. Second, relating to the supervision policy, supervision is an element associated with the certification of staff and technicians, thus tying back to the FAA-mandated AMT certification requirements afore-discussed. The quality system is its own category, and contains, amongst others, the following elements: quality and safety policy, quality review meetings, approval of document, and competency assessment (Shanmugam & Robert, 2015).

The accident of Air Midwest Flight 5481 provides a perfect example of a scenario in which both, supervision and quality system issues tied to maintenance instructions resulted in an accident-causing situation. Specifically, the supervisor of the technician performing the cable rigging operation – which resulted in the accident condition – was also in charge of quality assurance and further misunderstood the rigging instructions, agreeing to skip the steps in the instructions (NTSB, 2004). As aforementioned, skipping certain steps of the maintenance instructions during the rigging process ultimately restricted the aircraft's pitch control, resulting in the accident of the aircraft (NTSB, 2004).

Limitations

The current study experienced some limitations. These factors ranged from the data sources used, the classification framework, and the scope of the analyzed accidents. First, the selection of accidents included a manual filtering process, in which accidents reports dated within the specified timeframe including the keyword "maintenance" were filtered. However, as a keyword search was employed, accident reports not meeting the keyword search criteria but still falling under the overall research framework may have been missed, and thus excluded from the analysis. Similarly, the data used for the classification of the causal factors of the accidents was retrieved from the accident reports provided by the NTSB. Consequently, the analysis was limited and restricted to the information provided by the NTSB reports. Furthermore, the detail provided by the NTSB reports varied across accidents, as certain accident reports included data from interviews and laboratory analyses, while others merely described the factual accident information. To expand and enhance the PEAR analysis performed, the information from the NTSB provided reports could be supplemented with further research into the accident causal factors, specifically with relation to maintenance documentation.

Due to the afore-described lack of detail in certain NTSB-provided reports, two additional PEAR categories were added to the PEAR analysis. As previously explained, the added categories accounted for the ambiguity and indefiniteness in the NTSB reports, but in return provided little detail in terms of human factor-related accident causal factors. By extension, the classification of the causal factors into the PEAR categories was based on the researchers' interpretation of the accident information provided, and thus includes a certain level of subjectivity. Furthermore, the scope of the accident reviewed is comparatively narrow, as it restricted to 15 years of accidents occurring under Part 121 and Part 135 operations in the United States. To expand the applicability and generalizability of the results obtained, the research framework could be applied to accidents occurring under Part 91 operations, outside of the United States, or in an expanded timeframe.

Conclusion

The analysis performed furthered the study and understanding of human factors in the field of aircraft maintenance, highlighting the impact and associated importance of maintenance documentation. Acts of omission – where a required maintenance step is not performed – were identified to be the most frequent error type, while the aircraft systems most subjected to instruction-related errors were the landing gear, powerplant, and flight control systems. Relating to human factors, trends identified by the applied PEAR model could be tied to FAA training requirements for aircraft technicians while simultaneously mirroring and furthering the results of previous human factors studies performed in the field of aviation. Specifically, the importance and relevance of factors supporting the aircraft maintenance efforts with a specific focus on the instructions used therein, such as available resources as well as the overall environment, were found to be crucial.

The findings support the idea that aviation safety is a combination of multiple elements working together. As stated in previous research, and highlighted through the results of the completed study, the existence of written maintenance instructions does not warrant the proper completion of the associated maintenance items. Instead, supporting elements such as technician training as well as adequate supervision and the overall working environment are key factors affecting the adequate maintenance of aircraft. The HFACS model discussed in literature as well as in the discussion of the results, reflects similar aspects. While the maintenance errors occur at the front line (the *Action* category of the PEAR framework), underlying factors – i.e. maintenance documentation in this study – often stem from managerial and regulatory levels. As aforementioned, people-related aspects such as training, experience, and knowledge, are primarily being addressed by FAA-regulated training for aviation maintenance technicians. On the other hand, elements under the *Resources* and *Environment* categories identified under the PEAR framework in this study, are frequently intrinsically tied to managerial and organizational elements of maintenance organizations. Consequently, to continuously increase the safety of aviation, when designing and implementing maintenance instructions, elements that contribute to the actual understanding and implementation of said instructions – i.e. considering the "working environment" thereof – are critical and need to be considered.

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Aviation English Assessment and Training

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Due to a significant global increase in demand for air travel, there has been a corresponding increase in demand for ab initio flight training. Thousands of international flight students seek admission to collegiate aviation programs in the United States and Canada every year. These international flight students come to the United States and Canada because flight training is nonexistent in their native countries. In fact, flight training in most of these countries is impossible due to airspace restrictions and onerous regulations. If there is flight training available in these countries, the cost is usually prohibitive compared to the cost in the United States and Canada. The requirements and recommendations for international aeronautical communications is described in the International Civil Aviation Organization (ICAO) Annex 10, Volume II which establishes the English language as the de facto language of international aviation. The majority of these international flight students are non-native English speakers (NNES) which can make it difficult for them to succeed in an already challenging academic environment. Inadequate English language proficiency is also a significant safety issue. Unfortunately, there are very few aviation English assessment programs available to evaluate NNES flight students for aviation English proficiency. There are also very few aviation English training programs available for those who are unable to demonstrate proficiency. This research seeks to answer two questions: Does inadequate aviation English proficiency continue to be a flight safety issue? Has compliance with the ICAO Language Proficiency Requirements (LPRs) helped, or has it contributed to this problem?

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The International Civil Aviation Organization (ICAO) is a special agency of the United Nations (UN) which is responsible for the management and development of international aviation. ICAO Annex 10, Volume II describes the requirements and recommendations for aeronautical communications and establishes the English language for radiotelephony and the use of standard ICAO phraseology in all situations for which it is specified (ICAO, 2001). The demand for air travel has increased significantly around the globe, which has led to an increase in demand for flight training. Many student pilots come to the United States from China, South Korea, Japan, and other countries where the demand for air travel is growing rapidly. Inadequate English language proficiency is a significant safety issue that causes delays in progress and could even prevent international student pilots from successfully completing their flight training. High quality aviation English evaluation and training programs are needed to assess the language proficiency of non-native English speaking (NNES) flight students, and subsequently provide language support for those who require it. Currently, there are very few quality aviation English evaluation and training programs available in the United States.

Purpose

The focus of this research is data from the National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) concerning the number of safety incident reports due to inadequate aviation English proficiency submitted between 2009 and 2019. Communication errors have been a contributing factor in many commercial aviation accidents including the worst aviation accident in history at Tenerife (Netherlands Aviation Safety Board [NASB], 1978). A quantitative analysis was done to determine whether the number of ASRS incident reports due to inadequate aviation English proficiency have decreased since the ICAO Language Proficiency Requirements became applicable in 2008.

Research Question

Did the number of ASRS incident reports due to inadequate aviation English decrease after the member states of ICAO implemented the Language Proficiency Requirements (LPRs) in 2008?

Hypotheses

Null Hypothesis: The number of reported aviation incidents due to inadequate aviation English proficiency did not decrease between June 2009 and June 2019.

Alternate Hypothesis: The number of reported aviation incidents due to inadequate aviation English proficiency decreased between June 2009 and June 2019.

The probability of making a Type I error or rejecting a true null hypothesis will be set at significance level .05 ($\alpha = .05$).

Literature Review

Aviation English and Safety

One of the probable causes for the worst aviation accident in history was due in part to inadequate English language proficiency (NASB, 1978). KLM Flight 4805 and Pan American Flight 1736 were two Boeing 747's that diverted to Los Rodeos Airport on the island of Tenerife when a bomb exploded at their destination at Gran Canaria Airport. Los Rodeos Airport and Gran Canaria Airport are both located in the Spanish Canary Islands off the coast of North Africa. Due to the large number of flights diverted to Los Rodeos Airport, the air traffic controllers were forced to park aircraft on the taxiway. When Gran Canaria reopened, both aircraft were cleared to taxi down the runway because the taxiway was blocked by other aircraft. KLM Flight 4805 was cleared to taxi first. Pan American Flight 1736 was cleared to taxi behind KLM Flight 4805 and leave the runway at the last exit before reaching the end. Due to a dense fog that had settled over the airport, visibility was limited, and voice communication on the ground control radio frequency was the only way to determine the position of each aircraft.

The accident investigation determined that the Captain of KLM Flight 4805 erroneously thought that Pan American Flight 1736 had exited the runway and misinterpreted a clearance received from the air traffic controller to be a clearance to take-off. The First Officer on KLM Flight 4805 repeated the clearance and stated "we are now at take-off" which is not standard phraseology. The air traffic controller had not issued a clearance to take-off and did not understand that KLM Flight 4805 had begun its take-off roll while Pan American Flight 1736 was still taxiing down the runway. Approximately 8 seconds before impact, the Pan American crew saw KLM Flight 4805 and attempted to accelerate off the runway, but it was too late. The two aircraft collided causing a total of 583 fatalities (NASB, 1978).

As a result of the investigation, the Netherlands Aviation Safety Board (NASB) made three recommendations. First, they recommended placing a greater emphasis on the importance of exact compliance with instructions and clearances. Second, the use of standard, concise, and unequivocal aeronautical language was recommended. Finally, they recommended the avoidance of the word "TAKE-OFF" in any air traffic control clearance that is not explicitly a take-off clearance (NASB, 1978). This accident clearly demonstrates the importance of clear and accurate communication to the safety of flight.

The communication error that contributed to this tragedy was only one link in a long chain of errors leading up to the accident, including fatigue and the pressure to complete the flight before the crews' duty time expired. However, the fact remains that a simple miscommunication was a critical factor in the accident. The flight crew involved in the Tenerife accident were all highly experienced airline pilots. KLM 4805 Captain Jacob Van Zanten had 11,700 hours of total flight time with 1,545 hours on the Boeing 747 (NASB, 1978). If experienced pilots with thousands of flight hours can make serious communication errors, pilots who have very little flight experience, and who must communicate using English as a second or foreign language could be even more likely to make serious communication errors. While aviation accidents due to inadequate English language proficiency are relatively rare, the consequences can be catastrophic, as illustrated by the following mid-air collision between two small training aircraft in Canada.

On March 17, 2017, two Cessna 152 training aircraft were involved in a fatal mid-air collision at an altitude of 1,500 feet mean sea level (MSL) just 1.7 nautical miles east southeast of the Montreal St. Hubert Airport (CYHU) where both aircraft were based. The aircraft were operated by a flight school located at CYHU. Cessna C-GPNP was being flown by a private pilot completing commercial pilot training and returning to CYHU from a solo flight to a local practice area. Cessna C-FGOI was being flown by a student pilot who was departing from CYHU on a solo flight to a local practice area (Transportation Safety Board of Canada, 2018).

The private pilot flying C-GPNP had 135.8 total flying hours at the time of the accident. The student pilot flying C-FGOI only had 39.5 total flying hours. Both were international students whose first language was neither English nor French. The English language proficiency of both pilots had been assessed at ICAO Operational Level 4 which is the minimum level recommended by the ICAO Language Proficiency Requirements (LPRs). Cessna C-GPNP had experienced radio communication problems caused by a defect in the push-to-talk switch. The pilot could hear air traffic control (ATC) transmissions, but the pilot's transmissions could only be heard by ATC intermittently (Transportation Safety Board of Canada, 2018).

When the student pilot was cleared to take-off from CYHU, ATC instructed him to turn left eastbound and maintain an altitude "not above 1,100 feet." The readback of the ATC instructions by the student pilot was correct. At the same time, the private pilot was returning to CYHU from the southeast at 2,000 feet and five nautical miles from the airport. During the flight back to CYHU, the private pilot descended to 1,800 feet, and the student pilot climbed to 1,100 feet as instructed by ATC. When the two aircraft reached a separation distance of 1.8 nautical miles, the air traffic controller issued a traffic advisory to the private pilot flying Cessna C-GPNP to look for Cessna C-FGOI, and then repeated the traffic advisory after the private pilot failed to acknowledge the transmission. By this time, the two aircraft were only 1.3 nautical miles apart. At a separation distance of .5 nautical miles, the air traffic controller made one more attempt to contact the private pilot. Contrary to ATC instructions, the student pilot had climbed above 1,100 feet while the private pilot was still at 1,800 feet. When the private pilot flying Cessna C-GPNP realized that ATC could not hear his radio transmissions, he began to troubleshoot the technical problem which caused him to descend below 1,800 feet. The airplanes collided at 1,500 feet resulting in the death of one of the pilots (Transportation Safety Board of Canada, 2018).

The Transport Safety Board of Canada could not determine why the student pilot of C-FGOI climbed above the altitude restriction of 1,100 feet. However, the report indicated that student pilots were not required by Canadian Aviation Regulations at that time to demonstrate English language proficiency before being authorized for solo flights. As a result, there was a high risk of miscommunication of critical flight information by student pilots with minimal English language proficiency. Due to this finding, the safety action taken included publication of a civil aviation safety alert (CASA) that required flight training units ensure that student pilots have been evaluated at an operational level of language proficiency prior to the first solo flight (Transportation Safety Board of Canada, 2018).

These accidents clearly demonstrate how miscommunications due to inadequate aviation English language proficiency can be catastrophic. It is therefore important to understand the prevalence of incidents due to problems with English language proficiency. Baugh and Stolzer (2018) sought to determine if there is a relationship between inadequate aviation English and safety in General Aviation (GA) and specifically in GA flight training. The authors hoped to better understand this relationship to improve the effectiveness of GA safety management systems (SMS). The number of near miss reports submitted to the Aviation Safety Reporting System (ASRS) that involved student pilots was analyzed. While the number of reports suggested that incidents due to inadequate English language proficiency are underreported, the number of near miss reports (NMAC) is evidence that the potential severity of these incidents is extremely high (Baugh and Stolzer, 2018).

ICAO Language Proficiency Requirements

The International Civil Aviation Organization (ICAO) was formed in 1944 at the "Chicago Convention" to promote international civil aviation. Today, 192 member states work together in ICAO to advance the development and ensure the safety of international civil aviation. ICAO standards and recommended practices are published in 19 Annexes to the ICAO Convention. One of these standards requires pilots and air traffic controllers who work on international flights to demonstrate the ability to speak and understand the English language.

The origin of what are commonly referred to as the ICAO Language Proficiency Requirements (LPRs) is ICAO Assembly Resolution A32-16, proposed by India to ICAO in 1998 partly in response to a midair collision over India but also to address a few commercial aviation accidents in which inadequate English language proficiency in radiotelephony communications was determined to be a factor (Friginal, Matthews, & Roberts, 2019). The LPRs include a rating scale that establishes minimum speaking and listening proficiency for pilots and air traffic controllers who operate along international air routes at "Operational Level 4" on the six-band ICAO rating scale. The ICAO LPRs, in fact, only address the English language proficiency required for effective radiotelephony communications, and do not address reading proficiency, nor the English language needs of flight students, flight instructors, or aviation ground personnel (Friginal et al., 2019). Reading proficiency, important because most aircraft operating manuals, checklists, and maintenance manuals are written in the English language, had not been widely identified by accident investigators as a contributing factor in accident investigations at the time of the adoption of the LPRs.

Article 42 of the ICAO Convention requires that standards relating to licensing requirements must be implemented within five years of their adoption by ICAO: the standards were adopted in 2003 and became applicable in 2008. However, the effort required to ensure that personnel achieve ICAO Operational Level 4 is significant, and many member states found it difficult to fully comply by 2008. Partially as a result, the formal applicability date for compliance was extended by three years to March 5, 2011 (Friginal et al., 2019). Even after the 2011 extended deadline, and still today, a number of Member States continue to report difficulties in achieving full compliance. An additional challenge to the aviation industry is that language testing and language training are by and large unregulated industry sectors. Because there is no accreditation process for language testing and training programs or instructors, the quality of available programs is inconsistent (Werfelman, 2007).

ICAO LPRs Compliance Methods

Every ICAO member state has implemented its own language proficiency guidance and procedures since it is the responsibility of each member state to implement ICAO standards into their national regulations and to monitor compliance with the LPRs. Inevitably, global levels of compliance with the ICAO LPRs has been inconsistent. In the United States, the Federal Aviation Administration (2016) issued an Advisory Circular, AC 60-28b, to provide guidance and procedures on compliance with the "Aviation English Language Standards" (AELS). In Canada, Advisory Circular, AC 401-009 was published by Transport Canada (2018) on "The Conduct of Aviation Language Proficiency Demonstrations."

ICAO LPRs Compliance by Transport Canada

Transport Canada Advisory Circular, AC 401-009, begins with an introduction which states the following: "This Advisory Circular describes the acceptable means of demonstrating compliance with regulations and standards. This AC on its own does not change, create, amend or permit deviations from regulatory requirements, nor does it establish minimum standards" (Transport Canada, 2018, p. 3) The next section describes the purpose of the document as follows: "The purpose of this document is to provide guidance regarding the conduct of formal and informal aviation language proficiency demonstrations" (Transport Canada, 2018, p. 3).

Under Transport Canada (2018) definitions, a formal aviation language proficiency demonstration is defined as:

> a demonstration of language proficiency conducted by persons authorized to do so under Section 7.1(3) of this AC to confirm the expert proficiency level of candidates that meet the requirements of Section 6.0(2) of this AC. Language Assessor means a person who has entered into a Memorandum of Understanding with Transport Canada to provide Page 4)

The Advisory Circular goes on to say that Transport Canada (2018) is responsible to:

> implement, maintain, and oversee the program, appoint enough Language Assessors to ensure a timely delivery of service, ensure that all persons authorized to conduct informal and formal language proficiency demonstrations have received training appropriate to the requirements of their functions and maintain and provide to stakeholders a list of Language Assessors. (p. 4)

Transport Canada Advisory Circular AC 401-009 clearly requires that language proficiency assessments be performed by Language Assessors who are qualified to do language assessments. Language Assessors must be approved and hold a Memorandum of Understanding with Transport Canada and receive specialized training to perform this role (Transport Canada, 2018).

AC 401-009 states that any candidate who demonstrates a language proficiency at the ICAO Expert Level 6 according to the ICAO Language Proficiency Rating Scale will not require a language assessment. Any candidate who is assessed at ICAO Operational Level 4 (minimum proficiency) must be reassessed every 5 years. Anyone unable to demonstrate Level 4 is disqualified for a Canadian pilot or air traffic controller license. The Advisory Circular also differentiates between a formal and informal assessment. Candidates who demonstrate Expert Level 6 language proficiency (e.g. native English or French speakers) do not require a formal assessment. Flight instructors are required to determine whether a student's language proficiency is at the Operational level before allowing the student to conduct any radio communications. When an Operational level of language proficiency is in doubt, AC 401-009 recommends a formal language proficiency demonstration (Transport Canada, 2018).

Informal language proficiency demonstrations may be conducted by trained and qualified Civil Aviation Safety Inspectors and Pilot Examiners (PE's) who are authorized to conduct informal language proficiency demonstrations during the knowledge examination of a check ride. If the candidate cannot demonstrate an Expert level of language proficiency, the PE must advise the candidate that a formal language assessment by a Language Assessor is required and report the result to Transport Canada (Transport Canada, 2018).

Language Assessors are required to complete training before they can conduct a formal language assessment. They must become familiar with the AC and listen to rated speech samples that were developed by ICAO. Applications for the Language Assessor Memorandum of Understanding are reviewed by Transport Canada for approval on a case-by-case basis. Language Assessors must undergo initial training and recurrent training as well as scheduled and special monitoring events (Transport Canada, 2018).

A strength of the Transport Canada AC 401-009 is the requirement for a formal language assessment by a trained and qualified Language Assessor for any candidate who is unable to meet the Expert level of language proficiency. However, it is important to note that there is no requirement for any advanced training in linguistics to be a formal Language Assessor in AC 401-009. ICAO recommends at least two raters to perform language proficiency assessments: one should be a language specialist while the other rater should be an aviation operational specialist (Friginal et al., 2019). AC 401-009 does not include this requirement.

ICAO LPRs Compliance by the Federal Aviation Administration

Federal Aviation Administration (2017) Advisory Circular 60-28B states the following:

> This advisory circular introduces the Federal Aviation Administration (FAA) Aviation English Language Standard (AELS) and provides guidance to applicants, airmen, training organizations, Designated Examiners (DE), and flight and ground instructors on how to determine that an applicant for an FAA certificate or a person holding an FAA certificate meets the FAA AELS. AELS will be evaluated before acceptance of a student pilot application or issuance of a student solo endorsement, recommendation or examination of an applicant for an FAA pilot certificate or additional aircraft rating, and whenever an

> individual is tested or checked as required by the Administrator under Title 14 of the Code of Federal Regulations (14 CFR). (p. 1)

The AC goes on to state that the United States is a member nation of the International Civil Aviation Organization (ICAO) and has agreed to comply with the ICAO Language Proficiency Requirements (LPRs). All applicants for an FAA certificate must demonstrate ICAO Operational Level 4 English language proficiency. The definitions section of AC 60-28B refers to ICAO Doc 9835 which is the *Manual on the Implementation of ICAO Language Proficiency Requirements* and the attachment in ICAO Annex 1 Personnel Licensing. ICAO Language Proficiency Operational Level 4 is defined as the AELS minimum to receive the “English Proficient” certificate endorsement. AC 60-28B also defines an FAA AELS Evaluator to be “any individual who is authorized to conduct certification, training, testing or checking, or to issue an endorsement required by the regulations” (FAA, 2017, p. 3).

The AC lists FAA personnel, Designated Examiners (DE’s), flight and ground instructors, Training Center Evaluators (TCE), check FE’s/check pilots, training facilities and flight schools as persons and organizations responsible for continuously monitoring AELS. Unlike Transport Canada AC 401-009, there is absolutely no requirement for any special training. Instead, the AC section 6.2 recommends developing multiple plans of action to make sure the evaluation does not become predictable and refers the reader to the ICAO language proficiency website to listen to audio of the different ICAO English language levels. Section 4.1 notes that the AELS requires a minimum Operational Level 4 on the ICAO Language Proficiency Rating Scale and then describes what the evaluator should look for regarding pronunciation, structure, vocabulary, fluency, comprehension, and interactions. These descriptions are taken directly from the ICAO Language Proficiency Rating Scale. In addition, the reader is referred to Appendix A which simply gives guidance to an evaluator on how to conduct an evaluation for the AELS. According to FAA (2017) Section A.2.3. of Appendix A states the following:

> Based upon the applicant’s aviation experience, training, and/or FAA certificate held (or the certificate applied for), the evaluator may ask questions specific to the certificate application. For example, have the applicant/airman listen to the evaluator read an ATC clearance or instructions, an Airplane Flight Manual (AFM)/Pilot’s Operating Handbook (POH), or weather report, etc., then ask the applicant to explain the material. The evaluator can determine if the applicant understands in English what they heard and read and if they can effectively communicate in English in a discernible and understandable manner. (p. A-2)

The AC then explains that this will determine the applicant’s ability to communicate with ATC, pilots and others who are involved in the preparation and operation of the aircraft (FAA, 2017).

The most significant difference between Transport Canada AC 401-009 and FAA AC 60-28B is the qualifications required to evaluate candidates for language proficiency. Transport Canada does not require Language Assessors to have any special linguistic knowledge or training, and there is no requirement for two evaluators as recommended by ICAO. However, Transport Canada does require Language Assessors to receive special training and approval to perform language assessments. The FAA requires no special training or approval. The typical flight instructor, check airmen, and Designated Examiner (DE) does not have the specialized knowledge, experience and training required to assess an applicant for English language proficiency. As a result, many candidates for an FAA certificate may receive the endorsement for English Proficiency without a thorough and appropriate assessment.

Another weakness in both approaches is the absence of any guidance for applicants who are assessed below ICAO Operational Level 4. Transport Canada AC 401-009 advises applicants that they must wait 90 days before they can be reassessed (Transport Canada, 2018). FAA AC 60-28B states that an applicant or airman who does not meet the FAA AELS must be referred to the local Flight Standards District Office (FSDO) for evaluation. A certificated airman who is unable to meet the FAA AELS, may be required to undergo a reexamination under Title 49 of the United States Code of Federal Regulations. This is otherwise known as a 709 ride. If an airman is unable to meet the FAA AELS, AC 60-28B states that only the FSDO and appropriately rated aviation safety inspectors or the FAA policy division is authorized to override the original decision. Unlike Transport Canada AC 401-009, the FAA AC 60-28B does not give the applicant a time limit on reexamination. Notably, neither Advisory Circular gives any guidance about training in aviation English after an applicant is assessed below ICAO Operational Level 4 (FAA, 2017).

Methods

This research employs an ex post facto quantitative approach to data extracted from the Aviation Safety Reporting System. A quantitative analysis was performed on this data to determine the number of ASRS reports due to inadequate aviation English proficiency from 2009 to 2019. A linear regression was performed on the data to determine whether the number of reports submitted has decreased since the ICAO LPRs were implemented in 2008.

The Aviation Safety Reporting System (ASRS) is a voluntary reporting system designed to collect aviation incident reports from pilots, air traffic controllers and any other aviation personnel. Highly experienced ASRS staff collect, analyze, and respond to thousands of reports submitted every year. Millions of safety reports have been submitted since the start of the ASRS in 1975.

Limitations of Data

The safety reports submitted to the ASRS are voluntary. As a result, many incidents may not be reported in the system and coding of these reports may contain inaccuracies. Also, there is no specific category in the ASRS database for incidents due to inadequate English language proficiency. Therefore, it was necessary to conduct a search for the words *English* and *accent* in the narratives and synopses to identify incident reports due to inadequate English language proficiency. Unfortunately, many language related incident reports may not include these specific words. As a result, language related incidents may be underreported.

Results

Data for this research was limited to reports submitted between June 2009 and June 2019. A total of 50,885 reports were submitted during this period (Table 1). Unfortunately, the ASRS does not include a report category for language-related incidents. Therefore, a search of the database was performed looking for the words *English, misunderstanding, foreign, communications, language,* and *accent*, resulting in 3,513 reports. However, many of these incident reports were not related to problems with the English language. To determine which were English language incidents, searches were performed using just one word at a time. Searches for the words *foreign, communications, misunderstanding,* and *language* resulted in very few reports. Searching for the words *English and accent* returned 312 valid reports. After analyzing these reports, 247 were found to be incidents related to English language problems.

Table 1 shows a breakdown of these reports. From June 2009 to June 2019, the mean number of total reports due to English language issues was 24.7 and the standard deviation was 6.86 as shown in Table 2. Figure 2 is a scatterplot of the total number of reports per year with a trendline which shows a slight upward trend of the total number of reports from 2009 to 2019.

Table 1
ASRS Incident Reports (June 2009-June 2019)

	Part 121			**Part 91**			**Part 135**			**No Entry**			**Total**		
Year	**Not ESL**	**ESL**	**Total**	**Not ESL**	**ESL**	**Total**	**Not ESL**	**ESL**	**Total**	**Not ESL**	**ESL**	**Total**	**Not ESL**	**ESL**	**Total**
2009	2242	10	2252	816	5	821	115	0	115	211	0	211	3384	15	3399
2010	3542	11	3553	1176	5	1181	193	1	194	565	8	573	5476	25	5501
2011	3479	18	3497	1333	6	1339	202	1	203	599	8	607	5613	33	5646
2012	3085	11	3096	1394	8	1402	219	0	219	334	4	338	5032	23	5055
2013	2833	15	2848	1168	6	1174	190	1	191	259	2	261	4450	24	4474
2014	2757	18	2775	1233	7	1240	199	1	200	358	4	362	4547	30	4577
2015	3520	19	3539	1573	7	1580	309	2	311	539	2	541	5941	30	5971
2016	3125	6	3131	1593	5	1598	307	0	307	371	1	372	5396	12	5408
2017	3009	17	3026	1542	6	1548	254	1	255	385	0	385	5190	24	5214
2018	3463	20	3483	1416	6	1422	269	1	270	461	4	465	5609	31	5640
Totals	**31055**	**145**	**31200**	**13244**	**61**	**13305**	**2257**	**8**	**2265**	**4082**	**33**	**4115**	**50638**	**247**	**50885**

Note. **ESL** = Incidents due to language issues. **Not ESL** = Incidents not due to language issues. **No Entry** = Federal Aviation Regulation was not entered in database.

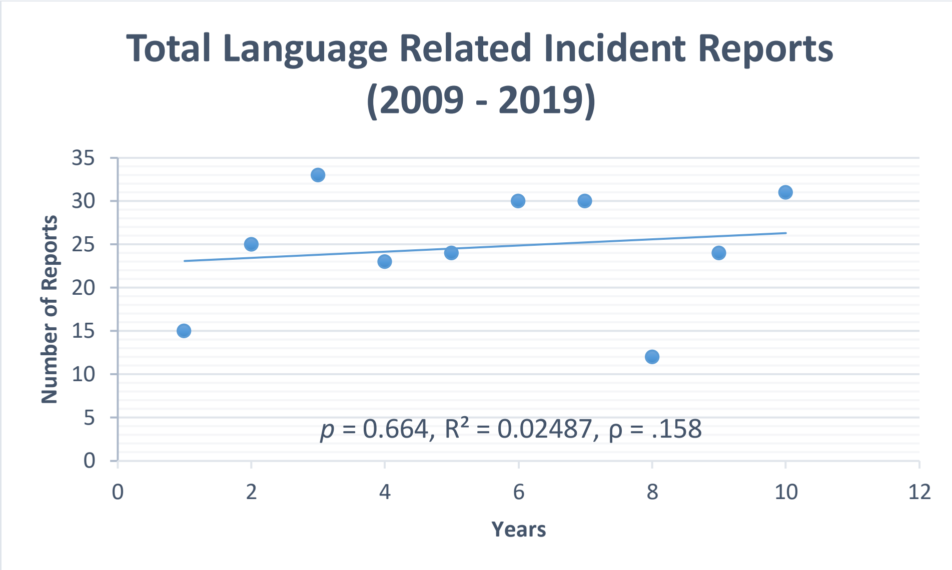

Figure 1. Total Language Related Incident Reports (2009-2019).

Table 2
Summary Statistics

Part	Incident Type	N	Min	Max	Mean	SD
91	Non-Language	10	816	1593	1324.4	237.56
	Language Related	10	5	8	6.1	.9944
	Total	10	821	1598	1330.5	237.88
121	Non-Language	10	2242	3542	3105.5	419.14
	Language Related	10	6	20	14.5	4.696
	Total	10	2252	3553	3120.0	420.70
135	Non-Language	10	115	309	225.7	59.76
	Language Related	10	0	2	.8	.6324
	Total	10	115	311	226.5	59.98
No Entry	Non-Language	10	211	599	408.2	129.95
	Language Related	10	0	8	3.3	2.907
	Total	10	211	607	411.5	132.03
Totals	Non-Language	10	3384	5941	5063.8	755.06
	Language Related	10	12	33	24.7	6.864
	Total	10	3399	5971	5088.5	758.39

A linear regression was done on the total number of language related incidents reported to the ASRS between June 2009 and June 2019 as shown in Figure 1. A simple linear regression was found to be statistically insignificant, $F(1, 8) = .204$, $p = .664$ with an R^2 of .025. Additionally, the scatterplot showed a weak relationship between the year and ASRS reports, and this was confirmed by Pearson's correlation test, $\rho = .158$. Therefore, we fail to reject the null hypothesis. The number of reported aviation incidents due to inadequate aviation English proficiency did not decrease between June 2009 and June 2019. This analysis suggests that the number of ASRS reports due to inadequate aviation English proficiency is still a threat to aviation safety despite the implementation of the ICAO LPRs in 2008. The largest number of reports in Table 1 were submitted by Part 121 scheduled air carriers with a total of 145 reports. The mean number of reports submitted by Part 121 air carriers was 14.5 with a standard deviation of 4.696 as shown in Table 2.

Part 91 operators submitted a total of 61 reports as shown in Table 1. The mean number of reports submitted by Part 91 operators was 6.1 with a standard deviation of .9944 as shown in Table 2. To determine the number of ASRS incident reports involving Part 91 training flights, a search was performed on the Part 91 incident reports to determine the number that were submitted with a mission of "training." This search yielded 21 incident reports out of the 61 total incident reports filed between June 2009 and June 2019 that were related to inadequate aviation English language proficiency during a training flight. Therefore, 34% of the Part 91 incident reports were related to a flight training incident. This relatively small number of incident reports supports the conclusion of Baugh & Stolzer (2018) that incidents related to English language proficiency are underreported. However, the potential severity of these incidents is extremely high considering that seven of the 21 training incidents (33%) resulted in a near miss (NMAC event category).

Conclusions

The data from the ASRS demonstrates that the number of reported incidents due to inadequate English language proficiency did not decrease after the ICAO LPR's were strengthened in 2003 and continue to threaten aviation safety. While the number of reports from Part 91 operators is relatively small compared to the number of reports from Part 121 operators, the number of near miss reports from Part 91 operators demonstrates the potential high cost of these incidents.

It is not just commercial air carriers that are endangered by this problem. The fatal midair collision between two Canadian training aircraft flown by international flight students who were nonnative English speakers (NNES) was partly due to communication issues (Transport Canada, 2018). In the United States, an estimated 40,000 international student pilots train every year, and many are NNES (FAA, 2019; Hoffman, 2020), creating the possibility of a similar event occurring in the future. The Canadian accident and the disaster at Tenerife show that pilots of all experience levels have been involved in accidents that were due to communication issues. Therefore, it is imperative that candidates for pilot certificates be properly assessed for English language proficiency, and that those who do not meet the proficiency requirements receive specialized training in aviation English courses informed by best practices in language teaching. Unfortunately, the language testing and training industry is not well regulated, which has led to inconsistency in aviation English assessment and training.

It is the responsibility of each member state to develop tests and procedures to comply with the ICAO LPRs. ICAO provided guidance in ICAO Document 9835, *Manual on the Implementation of the ICAO Language Proficiency Requirements* and held a series of workshops and seminars (Friginal et al., 2019). For example, Document 9835 recommends that member states form groups of qualified and experienced language raters; however, it is not the mission nor the mandate of ICAO to produce a standard language test. For many reasons, including the lack of standardized language testing, compliance has been inconsistent and uneven (Friginal et al., 2019).

While Canadian and the U.S. regulations are clearly intended to comply with ICAO LPRs, the guidance and procedures outlined in AC 401-009 and AC 60-28B do not consistently follow the recommendations in ICAO Document 9835. Strengthening and clarifying assessment procedures, in accordance with ICAO Document 9835, will improve member states' ability to fully comply with the ICAO LPRs, and better ensure that language-related disasters are not repeated.

Recommendations

The results of this research clearly demonstrate that safety incidents due to inadequate aviation English proficiency continue to threaten aviation safety. ICAO recognized this and made recommendations to strengthen language proficiency requirements and improve aviation safety as a result. More than a decade after ICAO strengthened the language proficiency requirements, incidents and accidents due to inadequate English language proficiency continue to occur. While incidents due to inadequate aviation English proficiency appear to be underreported, data from the ASRS demonstrate the high potential cost of these incidents. Due to ICAO's reliance on each member state to comply with the LPRs and ICAO's limited resources, compliance with the ICAO LPRs has been inconsistent and ineffective as shown by the examples in this report.

To develop and implement solutions to the issue of language proficiency in flight training, academically well-qualified English as a second language (ESL) specialists and aviation experts must collaborate to design and implement assessment programs to evaluate international flight students for aviation English proficiency and aviation English training curricula to help those who are unable to demonstrate proficiency. These programs should be designed to closely follow ICAO recommendations for aviation English assessment and training.

As mentioned in a previous section, the FAA's AELS is one current measure in place to reduce the likelihood of English proficiency as a safety hazard. Lynch and Porcellato (2020) articulate the challenges facing the Designated Examiners, instructor pilots, and flight training institutions in assessing and monitoring flight students' English proficiency; namely that these persons responsible for compliance with the FAA AELS might have no training in language assessment, and they receive minimal guidance from the FAA on how to conduct and rate these high-stakes, safety-critical assessments. One solution to the challenge facing flight training programs is to screen NNES candidates before they begin flight training.

Many university-based flight training programs rely on university entrance requirements such as TOEFL or IELTS results to screen candidates for English proficiency (Campbell-Laird, 2006). While there appears to be some overlap in the academic skills needed to attend a U.S. university and those needed to pursue flight training, there are critical differences. Lynch and Porcellato (2020) highlight the mismatch between the nuanced skills likely needed for flight training and the composite scores of popular tests like TOEFL and IELTS. These scores include flight training-irrelevant language skills, such as academic writing, which may mask areas of weakness in oral skills. In other words, students may meet academic English proficiency requirements but still lack critical language skills needed for effective flight training. Put simply, flight training is a unique linguistic environment, and a tailored English proficiency test is required for more valid results.

At least one university-based flight training program has begun developing aviation English proficiency screening tools for this purpose. These assessments help to identify incoming students whose English proficiency is sufficient to begin flight training and those who need additional aviation English instruction prior to flight training. Ongoing research and development of screening tools should incorporate guidance from ICAO Document 9835, as well as research findings from aviation English scholars about the linguistic domain of flight training such as that conducted by Bieswanger, Prado, and Roberts (2020) and the forthcoming work of Udell, Schneider, and Kim (2020). Such research will help identify salient linguistic tasks and features of English proficiency required for flight training, particularly in U.S. university-based programs. The flight training industry will benefit from well-designed screening tools that can offer a first line of support for incoming NNES flight training candidates in their pursuit of safe and efficient training.

Demonstration of an English language proficiency level which is inadequate for the linguistic demands of ab initio flight training should not mean a student pilot cannot pursue flight training. However, to maintain operational safety, it is recommended that the student does not begin practical flight training until achieving the required English language proficiency level. Language acquisition takes considerable time and is dependent on several internal and external variables. It is impossible to predict the exact amount of time which will be required to reach the appropriate level. Research indicates it may take between 200-400 hours of aviation English training to achieve results (Mathews, 2008), and in some cases even more time may be required.

Importantly, due to the uniqueness of the flight training domain, the training provided should be designed specifically for the flight training context (Friginal et al., 2019). Student pilots need to communicate with many people in many contexts, including air traffic controllers, flight instructors, classmates, and FAA examiners. They use English in learning environments like classrooms and simulators, and in real, high-stakes operational environments like airports and flight decks. In addition to listening and speaking skills, student pilots require reading proficiency to comprehend information-dense technical texts such as the FAA's 500-page *Pilot's Handbook of Aeronautical Knowledge* (FAA, 2016). Student pilots must also communicate in both formal and informal assessment settings during oral and written examinations. This domain description demonstrates some of the key differences between flight training and professional pilot domains. As the ICAO Language Proficiency Requirements were developed for the professional pilot and air traffic controller domain, this description also highlights the challenges of applying the ICAO LPRs to the evaluation of student pilots who will use English in the ab initio flight training domain.

A quality aviation English course for flight training, purposefully built for that distinct context, must also be taught by an academically well-qualified instructor. ICAO Document 9835 recommends that the instructor have master's degree credentials in the field of Teaching English as a Second Language (TESOL) or Applied Linguistics. To ensure operational accuracy, it is also recommended that instructors work with aviation subject matter experts during course design and implementation.

ICAO also recommends that a training course follow a Content-Based Language Teaching approach: Students learn aviation content relevant to flight training while also developing the English language skills needed in flight training. For example, in a landing gear module, students could learn foundational knowledge about landing gear, including a case study about a landing gear incident, and practice associated language tasks such as *reporting an incident*. The curriculum may also introduce students to routine phraseology, providing the opportunity to develop familiarization through role play scenarios in a low-stakes, safe classroom environment. Students have reported these types of practice environments to be particularly beneficial before having to participate in radiotelephony communications with air traffic controllers while also flying an aircraft.

Along with aviation English proficiency screening, an English course designed for flight students will move the flight training industry towards a more systematic and principled approach at addressing the issue of English language proficiency. The assessment and training course strategically work together as an advantageous and productive part of a student pilot's flight training journey, increasing efficiency, and improving operational safety. With these proactive interventions, students can enter the high-stakes, expensive, and heavily procedural process of flight training prepared, resulting in overall smoother operations for flight training organizations.

The authors recommend that ICAO member states revise their compliance procedures with the ICAO LPRs to include assessment programs that closely follow ICAO guidance such as the Aviation English proficiency screening tool described in this report. In addition, well designed aviation English training programs should be included to help improve proficiency. Relying solely on aviation experts without specialized training in language testing or training to evaluate applicants for language proficiency may lead to pilots, air traffic controllers, and other aviation professionals in the system who are unable to understand and communicate critical information to ensure the safety of flight.

The available data about incidents due to inadequate aviation English proficiency is very limited. To improve data collection for future research, the authors recommend inclusion of a category in the ASRS for language related incidents. In addition, aviation accident investigators should be trained to identify accidents in which language issues were a factor. One tool developed to promote a more consistent and standardized system of identifying and considering possible language factors is the *Language as a Factor in Aviation Accidents and Serious Incidents: A Handbook for Accident Investigators* (Mathews, Brickhouse, Carson, & Valdes, 2019). While developed for accident investigators, it contains useful guidance for the reporting of language issues, including a checklist to identify possible language environments and a taxonomy to promote the use of standardized terminology in reports.

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A Ranking Method to Prioritize VFR Airports to be Provided Instrument Approach Procedures

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The primary purpose of this work is to investigate the necessity of a more comprehensive and systematic method to prioritize airports to be provided with instrument approaches and landing procedures in the Brazilian air transportation landscape. First, an overview of the main contributors to risks associated with the approach and landing phases is provided, covering the most critical aspects of unstable approaches and controlled flight into terrain (CFIT) events. Second, considering the emergence of Terrain Awareness and Alerting Systems (TAWS), the role of its contribution to safety is discussed and the certification context related to the design, installation, and operation of those systems. A ranking method is developed based on the analysis of TAWS alert events in several Brazilian airports. The technique results in a ranking list of airports eligible for instrument procedures and points to objective means to improve safety, accessibility, and efficiency on the flight operations to those locations.

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Introduction

Several airports across Brazil, including those operated by regional and leading commercial airlines, are not certificated to operate Instrument Flight Rules (IFR). These airports run with only visual approach procedures or instrument approach procedures to a point in the airspace where the approach continues under visual meteorological conditions (VMC). That is a substantial concern for the growth of regional and commercial air transport. Weather conditions increased approach, and landing minimums in altitude and required ceiling, causing flight cancellations and diversions to alternate airports to influence accessibility to those airports.

Table 1
Frequent Contributing Factors for Flight Cancellations in Top 15 VFR-only Airports, per traffic volume (2016 – 2019).

Contributing Factors	Percentage
Adverse weather	79 %
Airport infrastructure	2 %
The airline, Aircraft maintenance	13 %
Airline, Operations	5 %
Other	1 %

Note: Adapted from (ANAC, 2020).

Adverse weather has accounted for the contributing factor of 79 % of total flight cancellations in high traffic volume visual flight rule (VFR) only airports, as illustrated in Table 1.

The Commercial Aviation Safety Team (CAST) is an industry-wide multidisciplinary, international working group encompassing airlines, manufacturers, labor, and government institutions to develop and implement comprehensive safety enhancement plans. According to CAST, as visual approaches have been commonly associated with a higher number of unstable approaches and potentially higher ground proximity warning alerts, safety concerns must always be addressed (CAST, 2018).

Unstable approaches have been notably present in most safety events associated with approach and landing phases (IATA, 2020). Furthermore, the highly irregular approach event rate observed in the first months of 2020 has been connected with the overall flight downturn effects triggered by the covid-19 pandemic. The drops in operations, followed by a slow recovery, may have impacted the flight crew's proficiency (IATA, 2020).

IATA's Flight Data eXchange (FDX), from the Global Aviation Data Management (GADM) program, similarly describes the most significant contributing factors to unstable approaches. Airspeed, thrust, and ground proximity warning systems (GPWS) are the most relevant to maintaining stable methods, including a constant descent flight path angle (IATA, 2020).

Also, IATA (2017) significantly correlated unstable approaches with safety events as the following:

- Hard landing;
- Runway excursion;
- Short landing;
- Loss of Control In-Flight (LOC-I);
- Controlled Flight Into Terrain (CFIT).

The International Civil Aviation Organization (ICAO) also has identified high-risk accident categories as safety priorities in its latest edition of the Global Aviation Safety Plan (GASP) (ICAO, 2019): runway safety-related events, LOC_I, and CFIT. CFIT events have been a significant historical component of accidents in the 1960s. Conversely, technological milestones achieved during the 1980s with the development of aircraft glass cockpit, satellite-based navigation systems, procedures, and warning systems have contributed to reducing CFIT accident rates, becoming a significant risk mitigation factor (ICAO, 2019).

Problem Statement

The Brazilian airspace management is under the Brazilian Air Force Department of Airspace Control (DECEA). The Institute of Aeronautical Cartography (ICA) handles the analysis, development, and certification of visual and instrument navigation flight procedures, with departure, approach, and landing (Brasil, 2010). There is a long-term perspective of growth in air traffic in Brazil, associated with the increasing quantity of airports planned to be operated by companies under RBAC 121 and RBAC 135 (*Regulamento Brasileiro de Aviação Civil*, Brazilian operational regulations, like the United States Code of Federal Regulations Part 121 and Part 135, respectively).

Thus, that scenario suggests an increase in the demand for the development of instrument approach procedures for VFR-only airports, providing equivalent levels of safety associated with the approach and landing operations and higher operational efficiency levels. Table 2 lists regional airports in Brazil with relevant commercial traffic volume and their current operations certification status.

Table 2
Regional Airports with Relevant Traffic Volume.

IATA / ICAO Code	Condition
GVR / SBGV	IFR
OPS / SBSI	IFR
TXF / SNTF	VFR
JPR / SBJI	VFR
PGZ / SBPG	IFR
OAL / SSKW	VFR
TJL / SBTG	VFR
BYO / SBDB	IFR
ROO / SBRD	IFR
LEC / SBLE	VFR
VAL / SNVB	VFR
DIQ / SNDV	VFR
FEC / SBFE	VFR
BRA / SNBR	VFR
PAV / SBUF	VFR
PIN / SWPI	VFR
RVD / SWLC	VFR

Note. Adapted from (DECEA, 2020).

This research highlights the need for a ranking method to implement the IFR approach and landing procedures, mitigating risks associated with unstable approaches on VFR-only airports. This research is the condensed version of a thesis (Leão, et. al, 2021).

The development process of instrument procedures is a complicated and time-consuming undertaking (Ashford, 2013). It requires detailed analyses of the topographic characteristics of the airport's regions, the estimation of aircraft flight path within regulation-based terrain separation criteria, aircraft flight performance simulations, and flight tests to provide adequate compliance with certification regulation (Bezerra & Gomes, 2016).

Therefore, adequate prioritization of those airports is a critical aspect to the safe and efficient development of Brazilian air transportation and is an essential topic in discussions held with significant stakeholders, including airline companies, airport authorities, and DECEA, in industry-level forums as the BCAST (Brazilian Commercial Aviation Safety Team), and the Brazilian Chapter of CAST (BCAST, 2019).

Several new potential flight network expansion VFR-only airports have observed flight diversions and cancellations, unstable approaches, and alert terrain proximity. Therefore, the research question to be addressed is: What prioritization methods could be proposed and applied to effectively contribute to ranking current VFR-only airports to be provided with instrument approach procedures, including non-precision, RNAV approach procedures, for instance?

As expected, TAWS events during take-off and climb are commonly rare. Therefore, applying the Index criteria refines the rank of airports to be further analyzed by DECEA and ICA as its institute in charge of developing and implementing navigation procedures. Once the guidelines are designed and certified, accessibility to those airports is expected to increase over time, with significant improvements on operations' efficiency and reduced costs to airlines associated with fewer flight cancellations and diversions to alternate airports due to adverse meteorologic conditions. Also, a decrease in unstable approach events and ground proximity alerts is expected. As a result, they contribute to higher safety levels in operations to those airports (Ziółkowski & Skłodowski, 2018). The proposed approach contains an analysis of Terrain Awareness and Warning Systems (TAWS), or Ground Proximity Warning Systems (GPWS) alerts as possible adequate metrics. The study of TAWS alerts data related to landing procedures is provided by airlines, collected in local industry committees, as the Brazilian Commercial Aviation Safety Team (BCAST). Combined with current, historical, and forecast traffic volume information over regional, VFR-only airports, a set of indicators and a ranking methodology are proposed to determine high-priority airports to receive instrument procedures.

TAWS and GPWS alerts

The Terrain Awareness and Warning System (TAWS) is a generic term that describes an alerting system designed to provide information to the flight crew to detect a potentially hazardous terrain proximity situation and avoid a CFIT accident (FAA, 2000). The primary function of the TAWS system is gathering and processing data on flight parameters of an aircraft to create alerts to preclude catastrophic air accidents. Tooley and Wyatt in Ref. (12, chapter 17) offer a brief but at the same time very explanatory explanation of TAWS system operation, its underlying principles, and capabilities.

Specific systems currently in use include the GPWS and the Enhanced Ground Proximity Warning System (EGPWS) (Administration, 2017; FAA, 2000). In addition, TAWS design, installation, and operation requirements are covered by several regulations applicable to avionics manufacturers to which TSO-C151c is applicable (FAA, 2012), Operating under Title 14 of the Code of Federal Regulations (14 CFR) Parts 91,121, 125, and 135. The operations specifications (OpSpecs), standard operating procedures (SOPs), and other FAA-approved documents. Brazilian regulations also address manufacturers and operators in a similar context for Brazil's cases (ANAC, 2005).

CFIT fatal and non-fatal accidents

In IATA (2018), CFIT accidents have accounted for 6 % of total accidents in commercial aviation between 2008 and 2017. Although CFIT accidents have shown fewer absolute numbers in the past decades, the outcomes are almost catastrophic and involve fatalities to passengers or flight crews (IATA, 2018). As a result, IATA and industry representatives have assessed CFIT as one of the highest priority topics for safety intervention in the face of fatality risk.

Several contributing factors may occur individually and more frequently in combination to result in CFIT accidents. The analysis and assignment of contributing factors, classified as latent conditions, environmental, and airline threats, may help foresee the problem from a broader perspective and develop risk mitigation strategies. Table 3 lists some significant contributing factors related to CFIT accidents.

Table 3
Frequent Contributing Factors for CFIT (2008 – 2017).

Latent Conditions	**Percentage**
Regulatory oversight	72 %
Technology and equipment	54 %
Safety management	46 %
Flight operations	31 %
Environmental Threats	**Percentage**
Meteorology	51 %
Navigation aids	51 %
Ground-based navigation aid malfunction or not available	49 %
Poor visibility, IMC	46 %
The undesired Aircraft States	**Percentage**
Flight towards terrain	56 %
Vertical, Lateral, Speed Deviation	49 %
Unnecessary weather penetration	18 %
Unstable approach	10 %
Continued landing after an unstable approach	5 %

Note: Adapted from "IATA Controlled Flight Into Terrain Accident Analysis Report," 2018, p. 22. Copyright by International Air Transport Association.

A CFIT event definition is in its nature associated with descent scenarios, as approach, final approach, and landing. Even though unfavorable or adverse meteorological conditions may be present during a given flight's approach and landing phases, there is no indication (nor is it necessary to) that the same prevailing conditions existed during the previous flight phases. Poor visibility, deteriorating meteorological conditions, or accidental entrance into IMC may impair the pilot's ability to maintain adequate orientation and control of the aircraft flight path during the visual traffic pattern in a VFR procedure. It is crucial to interpret the taxonomy outlined in Table 3, considering that the contributing factors do not occur in isolation.

The overall contributing factors indicated as latent conditions and environmental threats, in the form of low visibility, IMC, and lack of visual references, point to the need to implement instrument, precision approach procedures, or Performance-Based Navigation (PBN) approaches as an essential method to reduce the risk of CFIT accidents (Ashford, 2013). ICAO sets out VFR minimum for the various classes of airspace, which countries, by and large, have adopted with some slight variations to suit their circumstances (Ashford, 2013).

As a combination of several factors is usually the case to build up a potential CFIT event, one or more of the environmental threats, coupled with inadequate training, may contribute to inappropriate adjustments and corrections on the aircraft's flight path to an unstable approach.

Likewise, unstable approaches are also crucial components of CFIT accidents. They may influence the flight crew's attention and divert it away from the approach procedure to maintain better aircraft control in that flight phase. The most common definition of a stabilized approach, based on recommendations from ICAO and IATA's body of requirements under IATA Operational Safety Audit (IOSA) provisions, states that a safe approach requires the aircraft's flight path angle, landing gear and flaps configuration, and airspeed to be stabilized before a certain altitude threshold is reached.

Unless all the mentioned flight parameters are complied with, the approach becomes unstable and requires flight crew action. A go-around is then initiated. Therefore, evaluating airports with TAWS events history based on Flight Operations Quality Assurance (FOQA) or other means provided by air transport carriers may prove an essential metric of risks related to unstable approaches and CFIT that affect candidate airports eligible for instrument procedures.

The implementation of PBN procedures has been considered an essential means to address unstable approaches in VFR-only airports. It may prevent the need to rely solely on the visual approach procedure (Brasil, 2020). Also, adequate obstacle separation areas corresponding to IFR procedures must comply with any PBN procedure designed for a given airport, per ICAO Doc 8168 recommendations and DECEA regulations about instrument design approach procedures (DECEA, 2018; ICAO regulations, 2007).

A report published by IATA about unstable approaches also addresses the benefits of PBN procedures as an effective technological measure to reduce inconsistent practices, as PBN provides flight crews with vertical and lateral guidance from the initial descent phase to the aircraft's touchdown on the runway, with defined descent profile and adequate terrain separation (IATA, 2017).

Instrument approach procedures are essential to provide higher safety levels in the landing operations in specific locations with VFR-only airports. No vertical or lateral flight path guidance chart or navigation database is published to the flight crew (ICAO, 2019).

Moreover, cost-effectiveness can be attained by analyzing possible locations that can receive "RNAV Visual" procedures or the v-RNP (RNP APCH procedures for Visual Runways). Positive flight path guidance to the flight crew may offer safer operations than no guidance at all.

Methodology

This research involves basic and applied research, as fundamental air navigation concepts are discussed and applied to VFR-only airports' operational environments. A quantitative approach analyzes TAWS alerts and traffic volume figures (number of flight operations) into airports in the Brazilian landscape. Analyses of the significance of TAWS alert data in VFR-only and IFR airports are provided, along with the historical data of flight cancellations or diversions caused by adverse meteorological conditions. In this study, technical research procedures cover the bibliography, applicable regulations, guidance material related to the topic, and experimental methods of collecting TAWS alerts data. This approach characterizes ex-post-facto, as data and other relevant information are based on past events.

CAST recommends that the evaluation of airports with the highest risks of unstable approaches, including those certified as VRF-only, be identified with a significant history of TAWS warnings from the Flight Data Monitoring database (CAST, 2018). A preliminary analysis of airports based on TAWS alerts clusters is conducted, and data visualization software with geolocation tool (Tableau®) is used to visualize the TAWS "hotspots". Graphic visualization of the identified "hotspots" may scale the problem's scope in the Brazilian scenario. Airports' population covers the traffic volume observed in Brazil's most relevant air carriers operating under RBAC / FAR 121. Sample delimitation considers TAWS alerts events time histories. Data is collected from the air carriers' FOQA database in a 1-year timeline, from January 2019 to October 2019.

The proposed method to analyze FOQA data to capture unstable approaches is proper. It may provide precise means to break down essential flight parameters related to a "stable approach window" and the flight path along with the descent profile. The parameters include descent slope, descent rate, airspeed, thrust setting and adjustments, terrain proximity warnings, and aircraft landing gear and flap configurations.

Current data related to 2020 may not be helpful due to the worldwide reductions in commercial flight operations caused by the covid-19 pandemic, causing air carriers to reduce or temporarily cease operations in several airports significantly. Data collected contains airport identification, geographic location coordinates of TAWS alert events, the nature of TAWS alerts by type (Caution or Warning), and arrival runway designations.

The determination of VFR-only airports with a higher number of TAWS alerts associated with a traffic volume history provides a list of ranked candidates to receive instrument approach procedures. Also, TAWS alerts observed in VFR procedures into IFR airports may even rank in the candidate airports list to receive a further analysis from implementing other instrument approach and landing procedures or revising existing policies. A list of the recorded TAWS parameters that compose the database is described in Table 4. This study parameters of primary focus are the geographic coordinates of the TAWS alerts, destination airport, flight phase during which the alert is detected, and the type of landing procedure performed (VFR or IFR). Using metric criteria (Index), we can indicate the number of TAWS alerts per number of flight operations. The appropriate ranking method considers that listing the absolute numbers of TAWS for the airports in the database shall be analyzed about traffic volume for adequate prioritization of the candidate airports. As a result, a metric criterion, namely Index, indicates a rate of TAWS alert events per number of flight operations at a given airport is an adequate parameter. The Index receives a dimensionless number as a correction factor (1000) to facilitate its interpretation in order of magnitude and comparison of candidate airports illustrated in Equation 1.

$$Index = \frac{number\ of\ TAWS\ alerts}{number\ of\ flight\ operations}\ x\ 1000$$

Table 4
TAWS: description of recorded parameters.

Parameter	Description
Event Date	Date of the year
Flight Phase	Flight phase during which the alert occurred
Alert Type	Warning or Caution
Departure Airport	(ICAO Code)
Departure Runway	(ICAO Code and RWY Code)
Destination Airport	(ICAO Code)
Flight Procedure	VFR or IFR
Landing Runway	(ICAO Code and RWY Code)
Latitude	Geographic coordinate
Longitude	Geographic coordinate
Altitude (QNH)	Altitude at which the alert occurred.

Note: It is extracted from the Brazilian Commercial Safety Team (BCAST), CFIT Working Group, confidentiality and study purposes.

Outcomes

TAWS events database is provided from the three currently most relevant Brazilian air carriers, considering the number of flight operations in one year from January 1st, 2019, to October 31st, 2019.

TAWS events

An overview of the number of TAWS events is described in Table 5, detailed by the flight phase. Most TAWS events are observed for the final approach, followed by landing and approach flight phases.

As expected, TAWS events during take-off and climb are commonly rare. Most initial climb and departure phases occur in normal conditions and are carried out in Standard Instrument Departure procedures.

Table 5
TAWS events per flight phase (January 2019 – October 2019).

Flight Phase	**Number of Events**	**Percentage**
Initial climb after take-off	2	0.17 %
Enroute climb after take-off	5	0.43 %
Descent	2	0.17 %
Approach	26	2.24 %
Final approach	1079	93.02 %
Landing	46	3.97 %
Total	1160	100 %

Note. It is extracted from the Brazilian Commercial Safety Team (BCAST), CFIT Working Group, for confidentiality and study purposes.

Therefore, further study of the approach and landing scenarios is highlighted as VFR and IFR approach procedures in the considered database may arise.

Table 6 details the contribution of TAWS alerts observed in VFR and IFR flight rules during the approach, final approach, and landing phases.

Table 6
TAWS events per flight rule: VFR and IFR (January 2019 – October 2019).

Flight Phase	**Number of Events**	**VFR**	**IFR**
Approach	26	0	26
Final approach	1079	976	103
Landing	46	46	0
Total	1151	1022	129

Note. Extracted from the Brazilian Commercial Safety Team (BCAST), CFIT Working Group, confidentiality and study purposes.

As indicated in Table 6, the most significant contribution to the total number of TAWS alert events in VFR procedures is observed for the final approach and landing phases. Thus, the suggestion is coherent with the expectation that, as the flight progresses to land under VFR rules, the exposition to terrain clearance risk may increase during the visual traffic pattern.

It is important to note that the total number of TAWS alerts observations in VFR procedures covers all airports in the analysis database, including IFR certified but received flights performing a VFR procedure to land. The analysis is then detailed further to consider and separate the VFR-only airports from the entire airport database, described in Table 7.

Table 7
Airports in the database for which VFR landing procedures were performed.

IATA / ICAO Code	**Landing Certification**
AFL / SBAT	IFR
BEL / SBBE	IFR
BSB / SBBR	IFR
CGB / SBCY	IFR
CGH / SBSP	IFR
CGR / SBCG	IFR
CKS / SBCJ	IFR
CNF / SBCF	IFR
CWB / SBCT	IFR
CXJ / SBCX	IFR
FLN / SBFL	IFR
FOR / SBFZ	IFR
GIG / SBGL	IFR
GRU / SBGR	IFR
GYN / SBGO	IFR
IOS / SBIL	VFR
MAO / SBEG	IFR
MCZ / SBMO	IFR
OAL / SSKW	VFR
POA / SBPA	IFR
PVH / SBPV	IFR
RAO / SBRP	IFR
REC / SBRF	IFR
ROO / SBRD	IFR
SDU / SBRJ	IFR
SLZ / SBSL	IFR
SSA / SBSV	IFR
VCP / SBKP	IFR
VDC / SBVC	IFR
VIX / SBVT	IFR
XAP / SBCH	IFR

Note: Adapted from (DECEA, 2020).

As Table 7 indicates, SBIL and SSKW are the first strong candidates to receive instrument procedures since they are VFR-only airports and contained in the detected TAWS alerts database.

The Tableau® visualization of geographic locations of TAWS alerts identified in the collected data is depicted in Figure 1. The "hotspots" indicate a scatterplot of TAWS alerts' geographic coordinates and may contain several superimposed points related to alert events detected in the database within the analysis timespan. The examples highlighted by the numbered circles detail further.

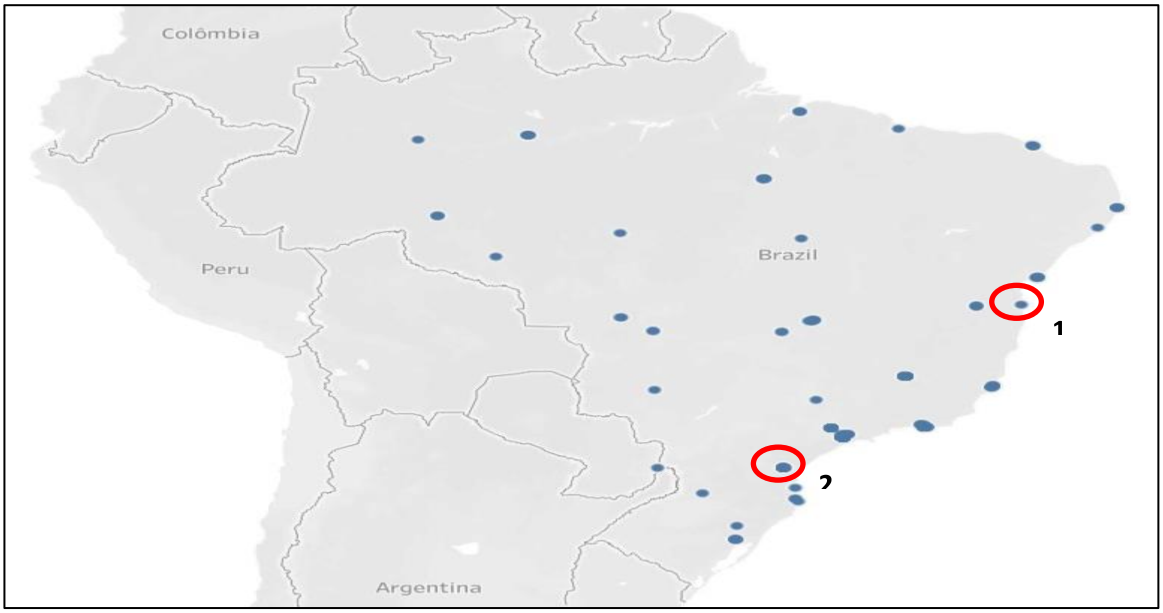

Figure 1. "Hotspots" of TAWS alerts collected from the study database.

For example, in Figure 1, red circle #1 refers to Ilhéus Airport (IATA Code IOS) in Bahia State, and red circle #2 refers to Curitiba Airport (IATA Code CWB) Paraná State.

Enlarged pictures of those locations with further detail are illustrated in Figure 2 for IOS and Figure 8 for CWB. While IOS presents one TAWS alert point detected in the analysis timespan, IOS is a VFR-only airport. Its candidacy to receive instrument procedures, therefore, remains relevant within the scope of this study.

The blue dot in Figure 7 identifies the TAWS alert event location. It refers to an alert detected close to the runway in the short final approach phase to land.

Figure 2. TAWS alert identified for Ilhéus Airport (IOS), RWY 11.

The case for Curitiba shows in Figure 3 several TAWS alert events detected in various points along the final approach path, most of which for Runway 33. That characteristic indicates unstable approaches and suggests difficulties in maintaining the correct final approach glideslope to the runway.

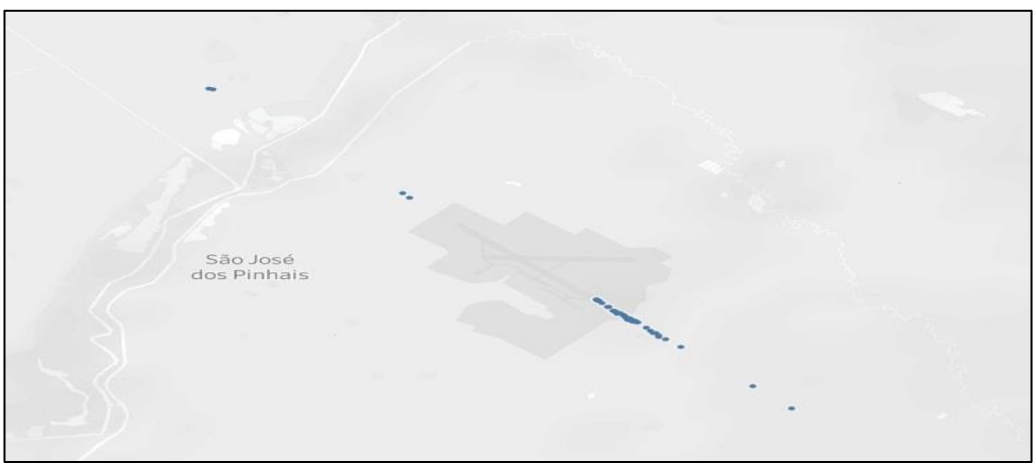

Figure 3. TAWS alert identified for Curitiba Airport (CWB), RWY 15/33.

As discussed previously, the collected database contains TAWS alerts observed in VFR operations in destination airports that are IFR-certified. Figure 4 depicts the number of TAWS alerts during VFR operations, including IFR-certified airports, listed by IATA Codes.

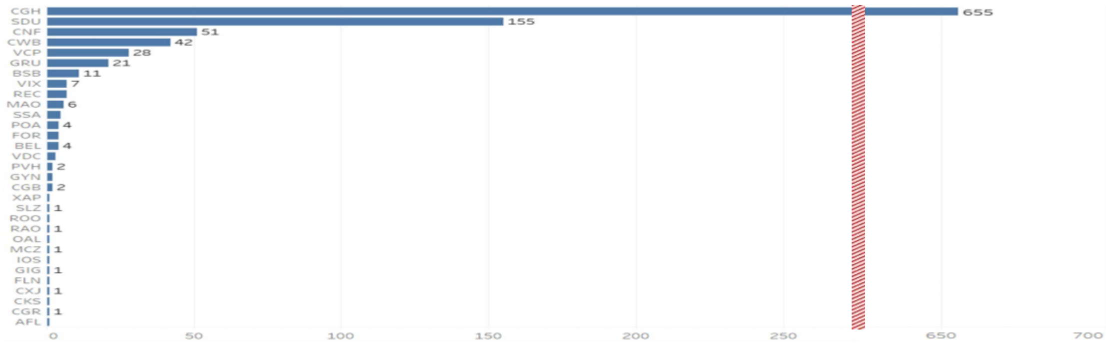

Figure 4. Quantity of TAWS alerts in VFR operations, including IFR-certified airports (January 2019 – October 2019).

The red marking in Figure 4 indicates the brake on the horizontal axis scale to accommodate the significantly higher number of TAWS alerts related to CGH airport than the other airports.

In this sense, based on the absolute numbers of TAWS alerts observed in this study's timespan, Figure 4 indicates the stronger candidate IFR-certified airports for detailed analysis to receive instrument approach and landing procedures.

The results indicated in Table 7 and Figure 4 are cross-checked with flight operations traffic volume related to those airports in the study period.

The total number of the Brazilian leading carriers' flight operations into those airports is described in Figure 5, considering VFR and IFR procedures.

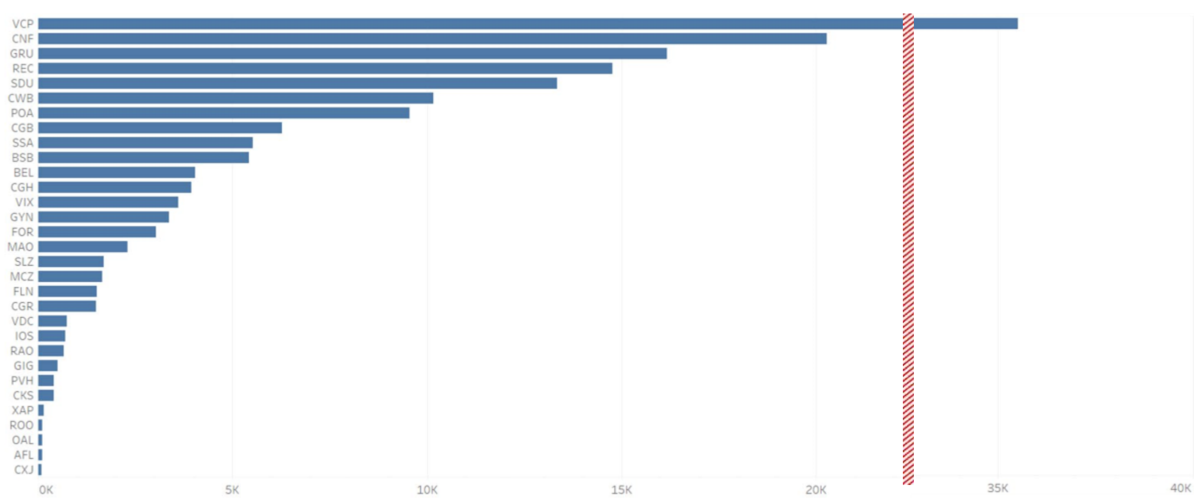

Figure 5. Traffic volume: quantity of flight operations - VFR and IFR - (January 2019 – October 2019).

A relation between the results presented in Figures 4 and 5 can be established using the application of metric criteria (Index) to indicate the number of TAWS alerts per number of flight operations based on the index formula.

The Index receives a dimensionless number as a correction factor (1000) to provide an exact comparison between airports to be ranked in the priority list to receive instrument approach and landing procedures.

Therefore, the index factor application (Figure 6) indicates that the airports showed higher TAWS alerts per thousand flight operations in the study period.

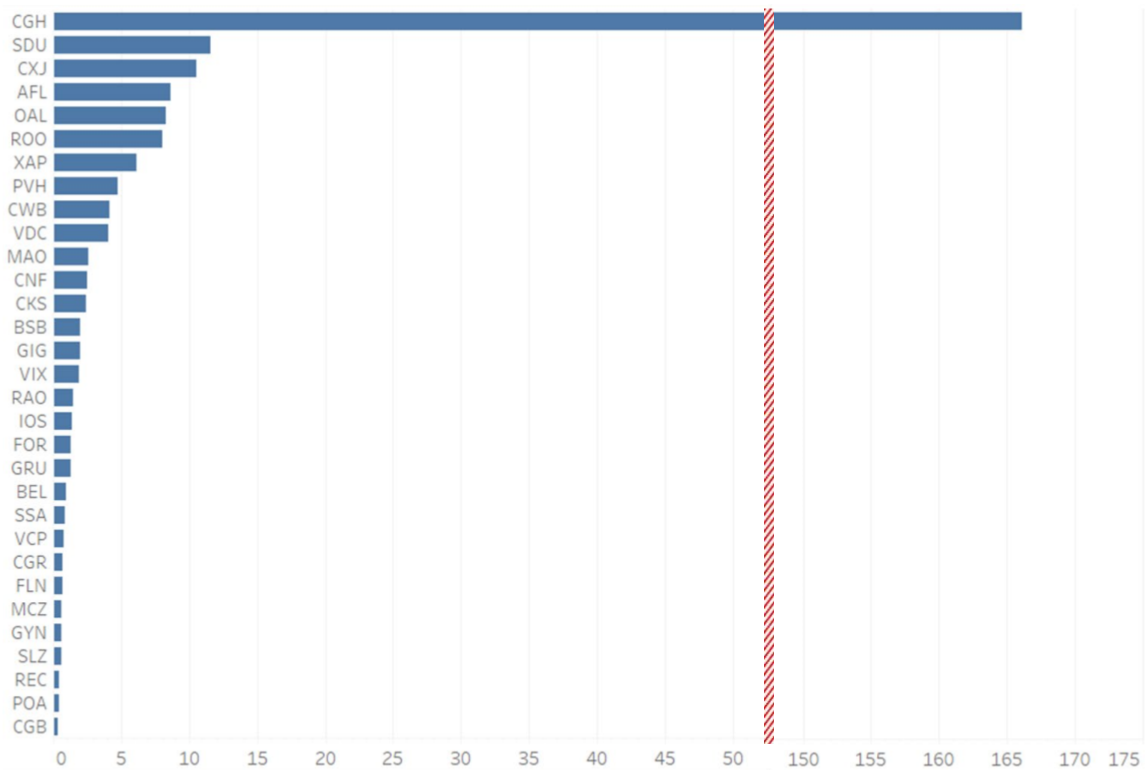

Figure 6. Index: Number of TAWS alerts per flight operation [x1000].

The results are shown in Figure 6 already indicate the airports of more significant concern to receive instrument approach and landing procedures for prioritization purposes. Therefore, applying the Index criteria refines the rank of airports to be further analyzed by DECEA and ICA as its institute in charge of developing and implementing navigation procedures.

Regarding the frequency of diversions due to weather, for example, as discussed previously, the most significant causes for flight cancellations and diversions in VFR airports are adverse weather conditions at the destination. Therefore, the underlying condition may already be addressed in the TAWS alert analysis for those airports.

Nevertheless, an evolution of the ranking method may include a detailed analysis of possible correlations of TAWS alerts and weather diverts in a given set of VFR airports.

As for IFR airports that make up the ranking list, existing IFR procedures may have limited room for further improvements to address meteorological minimums, as RNP AR procedures, for example, would require additional certification to aircraft as well.

For the cases of VFR-only airports, RNP procedures for Visual Runways can be applicable. For IFR-certified airports, revisions of current instrument procedures or implementing the v-RNP type's additional procedures can also be applicable.

The 20 airports of primary concern, ranked by the Index criteria, are summarized in Table 8.

Table 8
Candidate Airports to receive a further analysis of instrument procedures.

# Rank	Airport (IATA Code)	# Rank	Airport (IATA Code)
1	CGH	11	MAO
2	SDU	12	CNF
3	CXJ	13	CKS
4	AFL	14	BSB
5	OAL	15	GIG
6	ROO	16	VIX
7	XAP	17	RAO
8	PVH	18	IOS
9	CWB	19	FOR
10	VDC	20	GRU

Finally, it is essential to notice that the ranking method also captured OAL and IOS airports. They were previously mentioned as potential candidates to receive instrument procedures since they are VFR-certified only.

Conclusions and Recommendations

This study investigated significant aspects of the safe and efficient landing procedures to airports in the Brazilian landscape by analyzing TAWS alert events gathered from the central Brazilian air carriers operating domestic flights.

A ranking method was developed to identify "hotspots" of TAWS alerts, evaluated for IFR and VFR-only airports. The prioritization of airports eligible to obtain instrument approach and landing procedures furthermore contemplates the history of traffic volume, in terms of the number of operations into those airports, to offer valuable metrics of comparison between candidate airports. Implementing instrument procedures successfully offers applicable separation with ground terrain and lateral and vertical guidance to preserve stable approaches, decreasing CFIT risk. As depicted in our results, PBN procedures enhance meteorological minimums, grant higher accessibility to those airports, and reduce flight cancellations and diversions to alternate airports caused by adverse meteorological conditions. That is too a significant economic benefit to amplified connectivity and growth of the national commercial air transportation network.

This study illustrates that a suitable prioritization method to rank current VFR-only airports to be provided with instrument approach procedures, or additional exploration in the case of IFR airports, entails analyzing TAWS events during approach and landing, combined with the traffic volumes at a given airport.

This study's limitation is the unavailability of traffic volume information detailed by type of operation (VFR or IFR). A leading-edge method may separately consider the number of VFR operations about the candidate airports identified by the TAWS alert events.

Recommendations

DECEA is currently reviewing the method as a systematic process to identify, analyze and rank airports, in terms of TAWS alerts by the number of operations, to be provided with PBN procedures for approach and landing and, more specifically, the viability of the application of v-RNP (RNP APCH for Visual Runways).

A detailed investigation of the nature of the TAWS alerts (whether they are "caution", "warning", related to aircraft configuration or the approach flight path) in the detected "hotspots" for IFR airports may provide a better understanding of the effectiveness of existing IFR procedures. Thus, future research may include a more detailed analysis of TAWS alerts for each runway at a given airport. In addition, since the TAWS "hotspots" are related to approach and landing procedures to a specific runway, the ranking method may be refined with the analysis to prioritize specific runways of interest.

Additional concerns to the TAWS alert event analysis also involve the flight crews' measures to behave correctly and rapidly a missed-approach procedure or evasive maneuver once a TAWS alert is uncovered throughout approach or landing. For airports with added complex surrounding terrain environments, assessing the viability of a go-around maneuver under VFR rules might develop into a significant contributor or impose a given airport's priority to receive an instrument approach procedure. Hence, additional research may also involve examining the complexity of existing missed approach procedures considered in the ranking method.

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Contributory Factors of Fatigue Among Collegiate Aviation Pilots: An Ordinal Regression Analysis

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Fatigue is a pervasive safety hazard in aviation affecting several aspects of a pilot's' ability to safely perform their jobs. Several factors can contribute to fatigue, including inadequate sleep, stress, long work hours, excessive workload, and inadequate nutritional habits. In addition to flight training, some factors including academic, social, part-time work, and emerging time management skills are unique for Title 14 Code of Federal Regulations (CFR) Part 141 collegiate aviation pilots. By utilizing the Collegiate Aviation Fatigue Inventory (CAFI-II) at eight flight programs (n = 422), the current study examined factors such as fatigue training received, time spent working/studying and socializing, and enrollment level. Ordinal regression was used to assess the odds ratios of fatigue among demographic study groups. Notable results indicated approximately fifty percent of respondents reported not having fatigue training, Juniors and Seniors reported a less frequency of fatigue training when compared to the other two enrollment levels, and they also had a higher probability of flying while fatigued. The researchers suggested improved targeted training as well as recommendations for fatigue risk management strategies.

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Introduction

Fatigue is the "physiological state of reduced mental or physical performance capability resulting from sleep loss, extended wakefulness, circadian phase and/or workload (mental and/or physical activity) that can impair a person's alertness and ability to adequately perform safety-related operational duties" (International Civil Aviation Organization, 2016, p. 2-1). From an aviation accident risk perspective, the National Transportation Safety Board (NTSB) (2016) has determined that "fatigue degrades a person's ability to stay awake, alert, and attentive to the demands of safely controlling a vehicle, vessel, aircraft, or train" (p.1). Center for Disease Control and Prevention (CDC) guidance indicates an individual's mental performance with 17 to 19 hours of being awake is similar to having a Blood Alcohol Level (BAC) of 0.05% and being awake for 24 hours is like having a BAC level of .10%. The latter is above the legal limit for driving in all states (CDC, 2017). According to the Title 14 Code of Federal Regulations (CFR) 91.17, no person may act or attempt to act as a crewmember of a civil aircraft while having a BAC level of .04% or greater. Regardless of the BAC level, the CFR 91.17 also prohibits anyone from acting as a crewmember while under the influence of alcohol (Electronic Code of Federal Regulations, 2021). Due to the detrimental effects of fatigue while operating a vehicle, the NTSB has continued to include reducing fatigue related accidents on their most wanted list (NTSB, 2020). The NTSB (2020) issued a statement, "we are calling for a comprehensive approach to combatting fatigue in transportation, focusing on research, education, and training" (p.1).

Research intersecting fatigue and aviation is not novel. Numerous studies have been conducted with scheduled service and military operations (Caldwell et. al, 2009; Gander, et. al, 2013; Gawron, 2016; Gore, et. al, 2010; Hartzell, 2014; Lee & Kim, 2018; Rabinowitz et. al, 2009). The research has included causes of fatigue, fatigue measurement and prediction, consequences of fatigue, and fatigue mitigation strategies (Bendak & Rashid, 2020). Despite the plethora of studies relating to fatigue among commercial airline pilots and military aviators, there has not been a similar body of literature on flight students and instructors in collegiate flight programs in the United States. This has given an impetus for more studies in this fledgling area of aviation safety.

The NTSB, International Civil Aviation Organization (ICAO), and the Federal Aviation Administration (FAA) have provided resources and guidance to the aviation community for the purpose of safety promotion efforts (NTSB, 2021; FAA, 2020; ICAO, 2016). Despite these laudable efforts, there are areas for improvement regarding the guidance and training efforts. Most fatigue mitigation guidance on fatigue is directed towards maintenance technicians, Part 121 (scheduled service), Part 135 (on-demand), and flight attendants (FAA, 2010a, 2010b, 2012, 2014). The Aircraft Owners and Pilots Association (AOPA), provides fatigue mitigation guidance for the general aviation (GA) community in the U.S. through periodic publications (AOPA, 2020). Though this is positive for safety promotion and training efforts, AOPA's guidance is generally directed towards the broader GA community which includes all flight operations except for scheduled service and military operations (AOPA, 2018a, 2020).

Traditionally, fatigue training in the collegiate aviation environment utilizes guidance from these sources. Often, fatigue lessons are delivered during ground school, academic courses such as human factors, aviation physiology, crew resource management, and basic aviation safety. During the practical flight examination, the FAA Flight Standards Service requires the assessment of pilot's knowledge and their ability to demonstrate the understanding of the recognition, causes, effects, and corrective actions of aeromedical and physiological issues including fatigue (FAA, 2018a). The reference study source is document FAA-H-8083-2 (Risk Management Handbook). In addition to training and education to meet certification standards, regulations are used to mitigate the consequences of fatigue.

Extensive regulations such as Federal Aviation Regulation (FAR) Part 117, which mandates flight and duty limitations as well as rest requirements for flight crews do not apply to the flight training environment (Electronic Code of Federal Regulations, 2020a). The only regulation that pertains to "duty time" for collegiate aviation pilots is the FAR 61.195. The FAR 61.195 limits Certified Flight Instructor (CFI) flight time to eight hours per 24-hour period (Electronic Code of Federal Regulations, 2020b).

Many collegiate aviation pilots including flight instructors are full-time students enrolled in 12 credit hours or more during the Fall and Spring semesters. In addition to flight training, these collegiate aviation pilots are expected to participate in student organizations, research projects, studying, social activities, and often have jobs while being employed as flight instructors (Keller et al., 2019). According to Beattie et al. (2019), students who are successful within the academic environment treat it like a full-time job and spend an average of 30 hours a week completing class-related activities including studying. If this is the standard to achieve academic success, it is necessary to understand the schedules and nuances of collegiate aviation pilots. A combination of the activities mentioned above are all known reasons that reduce sleep quantity, quality, and overall performance.

Further, fatigue can cause a decrease in academic performance resulting in a lower grade point average (Beattie et al., 2019; Satti et al., 2019). An excessive workload may negatively impact their goals of having a healthy lifestyle (McDale & Ma, 2008; Mendonca et al., 2019). Many collegiate aviation pilots fall within the 18-22 age range, and it may be the first time managing their lives independent of parental oversight. This scenario can present challenges in their development of time and stress management skills and predispose them to increased risk of mental, emotional, and physical fatigue (Abrams, 2015; Caldwell et al., 2009; Worley, 2018). Increased research into the effects of fatigue on this pilot population has become more imperative because of the safety implications to flight operations. Therefore, a comprehensive examination of fatigue among collegiate pilots is essential as part of safety promotion efforts within collegiate aviation programs"

Extant literature recommends organizations utilize a multidimensional approach beyond prescriptive regulations to identify, address, and mitigate the risks of fatigue within flight operations (Caldwell 2017; Dawson & McCulloch, 2005; ICAO, 2016). Effective Safety

Management System (SMS) processes such as the assurance and promotion aspects can enhance voluntary safety reporting and incident reporting, vital for management decision-making as well as policy improvements on fatigue (FAA, 2016).

Fatigue is the product of several factors ranging from physiological to emotional needs yet organizational factors (e.g., organizational pressures) could add to the complexity of fatigue management during flight operations (Caldwell, 2009). Different types of aviation operations offer their own complexity, whether it be early departures and/or late arrivals, crossing multiple time zones, working extended duty days, non-standard work hours, and rotating schedules. The investigation of previous aircraft accidents has indicated that fatigue identification and management is complex (NTSB, 2014a, 2014b; Transportation Safety Board of Canada, 2018). The effective management of fatigue during flight activities requires an approach that addresses physiological, organizational, and operational factors.

The ICAO standards and recommendations support two methodologies for managing fatigue in aviation: prescriptive and performance-based approaches, the latter by implementing a Fatigue Risk Management Systems (FRMS). ICAO defines FRMS as a "data-driven means of continuously monitoring and managing fatigue related safety risks, based upon scientific principles, knowledge and operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness" (2016, p. XVI). FRMS is a safety tool that seeks to achieve a realistic balance between safety and productivity. Effective FRMS is multi-faceted, incorporating reactive, proactive, and predictive methodologies that are based on operational experience and science (Rangan et al., 2020). According to Caldwell et al. (2019), the FRMS framework has been continuously adopted throughout the transportation industry.

In the U.S., The FAA has recommended air carriers and other aviation operators should develop and implement a science based FRMS (FAA, 2013). FRMS allows aviation operators to use their resources more efficiently and to leverage their operational flexibility while ensuring an acceptable level of safety (Caldwell et al., 2019). Other benefits of an effective FRMS include workload balance to mitigate fatigue, fatigue identification and management, educational efforts, and the management of fatigue risks to a level that is higher than a prescriptive approach.

There have been recommendations for fatigue risk mitigation strategies to be based on the knowledge gleaned from scientific inquiries and data-driven analysis (ICAO, 2016). Interestingly, FRMS utilizes the SMS tenets and processes to manage the hazard of fatigue and ICAO SARPs recommends that if the aviation service provider has a mature SMS, they can use the existing SMS processes to address the provisions of an FRMS through process integrations and alignments (ICAO, 2016). Though SMS is now mandated for Part 121 certificated carriers in the U.S., it is not required for collegiate aviation programs (FAA, 2016). However, some are actively engaged in the voluntary FAA SMS program for certificate holders not under the mandate of 14 CFR Part 5 which has components that could be beneficial for fatigue policy improvement (Adjekum, 2014; FAA, 2016).

ICAO recommends fatigue mitigation strategies to be based on the knowledge gleaned from data-driven analysis and suggests five primary methods for proactive fatigue risk identification namely: self-reported measures, surveys, performance data, research studies, and the analysis of time worked (ICAO, 2012; ICAO; 2016). The following section will highlight fatigue literature including recent fatigue research that pertains to collegiate aviation students.

Literature Review

Fatigue

Fatigue is a multifaceted and complex phenomenon (Avers & Johnson, 2018). According to Kloss et al. (2011), the negative effect of inadequate sleep is significant on human performance. A reduction of cognitive performance can be attributed to the interaction of deficient sleep quality, hours of being awake, and time of day or circadian rhythms (James et al., 2018). Related cognitive deficiency results from the interaction of multiple factors including sleep history, time awake, and time of day or circadian rhythms (Caruso, 2014; Simon et al., 2017; Van Dongen, 2000). In conjunction with a healthy lifestyle, an individual should aim to achieve between 7 and 9 hours of sleep each night for optimal performance (ICAO, 2016; National Sleep Foundation, 2021). Sleep is valuable in two primary ways. The body needs time for restoration and information processing. Throughout the time of being awake the body encounters stress from physical, mental, and emotional standpoints. Therefore, sleep permits restoration and repair (Barger, et al., 2018). Regarding information processing, the body repairs neural pathways to regular levels during sleep cycles (ICAO, 2020).

The adverse consequences of fatigue on pilot performance are well researched and documented within the broader aviation environment. Previous research (Marcus & Rosekind, 2017) and the investigation of aircraft accidents (NTSB, 2014a, 2014b) have indicated that it is difficult to determine fatigue as a causal factor during the investigation of an accident or incident. However, Rosekind (2015) found out that fatigue was a contributing factor in approximately 20 % of aviation accidents between 2001 and 2012. Even though data suggest that the General Aviation (GA) accident rate has been declining in the U.S., the 28th Nall Report indicated GA accounted for 95% of all aviation accidents during the last 10 years up till 2018 (FAA, 2018b; AOPA, 2018).

Approximately 73% of these GA accidents had some form of human error listed as a probable cause or contributing factor. Moreover, flight instruction activity accounted for 14% of all general aviation accidents in the United States. Fatigue may be an underlying condition for accidents and incidents at a much higher number than reported. Even with the challenges of listing fatigue as a probable cause, the NTSB has released more than 50 fatigue related recommendations since 1970 (NTSB, 2018). In addition to incidents and accidents, a more common outcome is poor performance. For instance, sleep deprivation among college students leads to a decrease in cognitive performance, i.e., Grade Point Average (GPA), a decrease in satisfaction, and an increase in negative interpersonal interactions. Moreover, acute and chronic fatigue can have deleterious effects on an individual’s quality of life (Kloss, 2011).

Job demands or excessive workload is a significant predictor towards fatigue thus reducing cognitive and behavioral performance (Fan & Smith, 2017). Studies of diverse groups of workers in High Reliability Organizations (HROs) show that work scheduling practices can create conditions that exacerbate the risk of fatigue-related cognitive impairment. The ICAO

Document 9966 (2016) also suggests that work schedules can have an impact on time on duty (fatigue causal factor). Yet, schedules may not allow periodic extended opportunities for recovery. Moreover, "rotating schedules is that at certain times, such as on the night shift, an individual will be working when their circadian drive for sleepiness is high, and their performance is at its poorest" (p. 2.26). Fatigue training has been shown to be one effective countermeasure. A systematic review of fatigue training and performance outcomes has indicated improvements in safety and health outcomes of individuals (Barger et. al, 2018). One objective of the current study is to understand the impact of pilot workload, social activities, and formal fatigue awareness training on fatigue management among collegiate flight students.

Fatigue in Collegiate Aviation

In the United States, collegiate aviation programs are one of the main sources of producing professional pilots (Mendonca, et al., 2019). Empirically based assessments of the behaviors of collegiate pilot training populations that predisposes them to fatigue, and of the associated safety risks are essential. Such assessments provide findings for promoting desirable safety behavioral outcomes in the collegiate pilot training environment. Levin et al. (2019) found the leading causes of fatigue among collegiate aviation pilots were insufficient resting time and an inadequate work-life balance. The researchers also noted that half of the respondents did not consider themselves to have consistent healthy eating, exercise, and stress management habits. In another quantitative survey-based assessment of fatigue in collegiate flight programs, Romero et al. (2020) suggested that respondents knew about the correct strategies for combating fatigue but had challenges managing high academic workloads and ensuring regular sleep patterns essential for quality sleep.

Mendonca et al. (2019) distributed the Collegiate Aviation Fatigue Inventory-I (CAFI-I) to collegiate aviation pilots and results indicated 51% of the respondents had previously continued with a flight despite being extremely fatigued. Seventy-eight percent of the participants reported they committed errors and did not always give their best effort during flight training activities due to fatigue. Keller et al. (2019) presented participants with six vignettes on flight scenarios which entailed sleep deprivations, stress, mental and physical fatigue. Respondents were asked to qualitatively provide desirable or appropriate alternatives to the scenarios. For instance, one scenario told the story of a 14-hour day that included physical and mental fatigue then a long night flight and respondents were supposed to make a “Go/ No Go” decision as well as answer why. Almost half of the thirty-five participants responded with a “Go” decision.

The qualitative analysis in the Keller et al. (2019) study found that some participants struggled to communicate desirable alternatives, lacked knowledge of the human limitations, and expressed succumbing to external pressures such as staying on schedule to finish their flight course. However, during other scenarios some responses articulated desirable decision-making processes and expressed viable alternatives. Despite the positive responses, there were enough undesirable responses within the dataset the authors suggested fatigue training was lacking (Keller et al., 2019). Keller et al. (2020) examined self-reported sleepiness and fatigue provided evidence that collegiate aviation pilots had the highest median of fatigue at 08:00 Hrs. Instead of a desirable reporting of fully awake and refreshed, respondents indicated perceptions of feeling of "a little tired, less than fresh" throughout the entire study (Keller et. al., 2020). Mendonca et. al. (2021), found that 60 % of respondents felt fatigued during their flight activities.

A clearer understanding of fatigue among collegiate aviation pilots, may provide the flight training community a pathway for safer and more efficient operations. The researchers of this study distributed the Collegiate Aviation Fatigue Inventory-II (CAFI-II) to eight collegiate programs in the United States through convenience sampling methods. The CAFI-II was developed to determine fatigue awareness, causes of fatigue, lifestyles, workload, and impact of fatigue on flight training activities (Keller et al., 2021). Though collegiate aviation pilots are typically 18-22 years old, diversity of experiences can be found at each enrollment level, particularly with workload. Another aim of the current study was to determine which collegiate aviation pilot demography had the highest propensity to fly fatigued. Additionally, understanding if students perceive they have received fatigue training or not may have implications on fatigue mitigation efforts. Therefore, the research objectives for this study were:

1. To determine the frequency of formal fatigue training received by respondents during their enrollment in collegiate aviation programs.
2. To determine times spent on academic, employment and social activities.
3. To determine whether enrollment levels, fatigue training status and total flight hours are significant predictors of reported frequency of fatigue during flight training.

The following section will discuss the sample population, research instrument, procedures, research questions, and data analyses.

Methodology

Participants

All eight universities are in the Midwestern region of the United States and represented small, medium, as well as large university flight programs. Initial notifications of the study were sent to the points of contact including Faculty, Chairs, and Chief Flight Instructors within each program. The research instrument was then forwarded to the pilot group. All eight programs are accredited by the Aviation Accreditation Board International (AABI) and are certified under Federal Aviation Regulation Part 141. All participants in this study were collegiate aviation pilots including instructors who were identified as students. The researchers sought collegiate aviation pilots, aged 18 years or older, who had previously flown in the last 6 months, and were currently enrolled in a collegiate aviation flight training program. The estimated number of pilots enrolled in the eight programs was 700.

Research Instrument

As stated earlier in this paper, the Collegiate Aviation Fatigue Inventory (CAFI) was a modified version of a survey published by McDale and Ma (2008). Data from CAFI-I was instrumental in the publication of three scholarly papers (Keller et al., 2019; Levin et al., 2019; Mendonca et al., 2019). During its development, the CAFI underwent content validity checks by six Subject-Matter Experts (SMEs) (Mendonca et al., 2019). The researchers made modifications to the survey based on feedback provided by the SMEs. Subsequently, the team conducted beta testing with 24 participants who were students enrolled in a collegiate aviation program at a Midwestern University in the U.S. The Mendonca et al. (2019) study utilized a Principal Component Analysis (PCA) (n = 122). The analyses revealed an overall Kaiser-Meyer-Olkin (KMO) measure of 0.78, with individual KMO measures all greater than 0.6. Bartlett's Test of Sphericity was statistically significant ($p < .0005$). The PCA yielded the following three components: the fatigue awareness subscale consisted of eight items and a Cronbach's Alpha of .867, the causes of fatigue subscale consisted of 11 items with an alpha score of .793, and the lifestyle subscale consisted of 7 items with an alpha score of .734. The reliability and consistency of the CAFI was found to be acceptable, with a total of 26 items and an overall alpha score of .754 and further results were reported in the Mendonca et al. (2019) study.

For this study, the researchers made minor revisions to the CAFI to create the CAFI-II. Revisions included changing the multiple-choice range questions in the demographic section of 'age' and 'approximate total logged flight time' to "fill in the blank" slot option. Similar revisions were made to questions in the lifestyle section, which surveyed the number of hours the participant spent on various listed activities. These revisions allowed participants to report quantitative data more accurately instead of a predetermined scale range. A factor analysis was not run for the current study.

The final version of CAFI-II consists of eight sections. The first section had the required IRB consent form. The second section of the survey was the demographics section. The third section of the survey was the fatigue awareness section. Respondents were provided with a list of fatigue symptoms and were asked to rate their applicability via a five-point Likert Scale (Never – Always) question. The fourth section of the survey was the causes of fatigue section. Similarly, participants were presented with a list of situations that may encourage the onset of fatigue. Participants were asked via a 5-point Likert Scale (Never – Always) question to rate their applicability based on personal experiences.

The fifth section of the survey involved lifestyle choices. Respondents were given a list of lifestyle choices and had to rate their applicability on a 5-point Likert Scale (Strongly disagree – Strongly Agree) question. The sixth section of the survey contained personal solutions that participants may undertake to reduce or mitigate fatigue. In this section, participants were told to rank (one being most applicable and ten being the least) among a given list of situations, which they felt was the best solution that they have taken to mitigate the effects of fatigue.

The seventh section of the survey asked participants whether they felt that fatigue had an impact on their flight training. Participants were presented with a five-point Likert Scale (Never – Always) question. There were open-ended style questions that queried the participant's typical weekly schedule, including hours spent on the weekends for different types of chores, social activities, and hours spent on the weekdays for social activities. The eighth section of the survey asked about the participant's circadian rhythms. In this section, participants were presented with different times of the day (early morning 6:00 am – 9:00 am) and using a 7-point Likert scale (Fully alert – completely exhausted) question, the participants had to rate what their fatigued state was typically like during those times of the day. The survey can be found in Appendix A.

After IRB approval the survey was distributed to the collegiate aviation programs through email using an anonymous Qualtrics® survey link. Three reminders were sent throughout the data collection period. The data collection period was the end of Fall 2019 and the beginning of the Spring 2020 semester. Results and discussions related to specific questions in this study were presented and conclusions proffered.

Data Analysis

All data collected were anonymous and downloaded from Qualtrics then imported into IBM SPSS 26®. Participant's workload and socializing hours as well as fatigue training received were reported using descriptive statistics. An ordinal logistics regression test was selected to understand the predictors, enrollment level, fatigue training received, and reported total flight hours. Ordinal logistic regression is used to predict an ordinal dependent variable given one or more independent variables. More specifically, the test can determine which independent variable will significantly affect the dependent variable and determine how well the model predicts the dependent variable (Kleinbaum & Klein, 2010).

The predictor variables for this study were enrollment level, fatigue training received, and approximate total flight hours. Enrollment categories were First-Years, Sophomores, Juniors, and Seniors. The dependent variable was the survey item "fatigue impacts my flight training activities". The participants selected from a ranked scale: 'Never', 'Rarely', 'Sometimes', 'Often', and 'Always'. Specifically, the research questions for this study were:

1. How many participants have received fatigue training while enrolled in their flight training program?
2. What are the reported typical hours spent on working (work and study) and socializing?
3. Do the independent variables enrollment level, fatigue training received (Yes or No), and total flight hours predict the reported frequency of fatigue during flight training?

Results

Demographics

Demographic information was collected as part of the survey, including gender, enrollment level, highest certificate held, approximate total logged flight time, and name of their institution. Not all participants respond to the demographic items and all percentages were rounded to the nearest tenth. Seventy-eight percent of respondents were male while 21.7% were female (n = 373). The youngest participant age was 18 years old while the oldest respondent was 40 years old. The mean age was (M = 20.58, Mdn = 20, SD = 2.627). Most of the participants were Student or Private Pilots and had 200 hours or less of flight time. The demographic fit the ideal target group for this study. Table 1 details the distribution of the demographics.

Table 1
Summary of Participant's Demographics

Institution	(n)	Percent
Institution 1	98	26.6%
Institution 2	67	18.2%
Institution 3	51	13.9%
Institution 4	39	10.6%
Institution 5	36	9.8%
Institution 6	34	9.2%
Institution 7	23	6.3%
Institution 8	20	5.4%
Total	**368**	**100%**
Gender	**(n)**	
Female	81	21.7%
Male	292	78.3%
Total	**373**	**100%**
Age	**(n)**	**Percent**
18-21	304	81.5%
22-25	65	17.4%
26-29	3	.8%
30+	1	.3%
Total	**373**	**100%**
Enrollment Level	**(n)**	**Percent**
First-Years	72	19.3%
Sophomores	90	24.1%
Juniors	105	28.2%
Seniors	106	28.4%
Total	**373**	**100%**
Highest Certificate Held	**(n)**	**Percent**
Student Pilot	99	26.5%
Private Pilot	157	42.1%
Commercial Pilot	52	13.9%
Certified Flight Instructor	65	17.4%
Total	**373**	**100%**
Approximate Total Flight Time	**(n)**	**Percent**
0 - 100	144	38.6%
100 - 200	112	30.0%
201 - 300	62	16.6%
301 - 400	26	7.0%
401 - 500	12	3.2%
501 - 600	4	1.1%
601 - 700	4	1.1%
701 - 800	1	.3%
801 - 900	0	0%
901 - 1000	1	.8%
1001+	2	.5%
Total	**373**	**100%**

Note. The percentages were rounded to the nearest tenth.

Research Question One

> *How many participants received fatigue training while enrolled in their flight training program?*

Two hundred and ninety-seven (n = 297) individuals responded to this question. Forty-nine percent responded that they had received fatigue training during their academic or flight training course work while 50.2% responded they had not. Each of the eight-flight training programs had respondents indicate they did not receive fatigue training. The percentages contributing to the 50.2% (did not receive fatigue training) ranged from 3.4% to 9.8%. The range of "did not receive fatigue training" overall frequencies and percentages of student responses are shown in Table 2. To further understand the frequency of received training the researchers elected to separate the data by enrollment level. First-Years and Sophomores had a higher percentage of receiving fatigue training while Juniors and Seniors had a higher percentage of not receiving fatigue training. These results can be found in Table 3. Figure 1 shows the data in a column chart.

Table 2
Overall Responses

Response	**Count**	**Percent**
Yes	148	49.8%
No	149	50.2%
Total	297	100%

Note. Percentages are rounded to the nearest whole number.

Table 3
Responses by Enrollment Level

		Yes	**No**	**Total**
First-Years	Count	39	17	56
	% within Enrollment Level	69.60%	30.40%	100.00%
	% of Total	13.10%	5.70%	18.90%
		Yes	**No**	**Total**
Sophomores	Count	37	20	57
	% within Enrollment Level	64.90%	35.10%	100.00%
	% of Total	12.50%	6.70%	19.20%
		Yes	**No**	**Total**
Juniors	Count	34	53	87
	% within Enrollment Level	39.10%	60.90%	100.00%
	% of Total	11.40%	17.80%	29.30%
		Yes	**No**	**Total**
Seniors	Count	38	59	97
	% within Enrollment Level	39.20%	60.80%	100.00%
	% of Total	12.80%	19.90%	32.70%
		Yes	No	Total
	Total Count	148	149	297
	% of Total	**49.80%**	**50.20%**	**100.00%**

Note. Percentages are rounded to the nearest tenth.

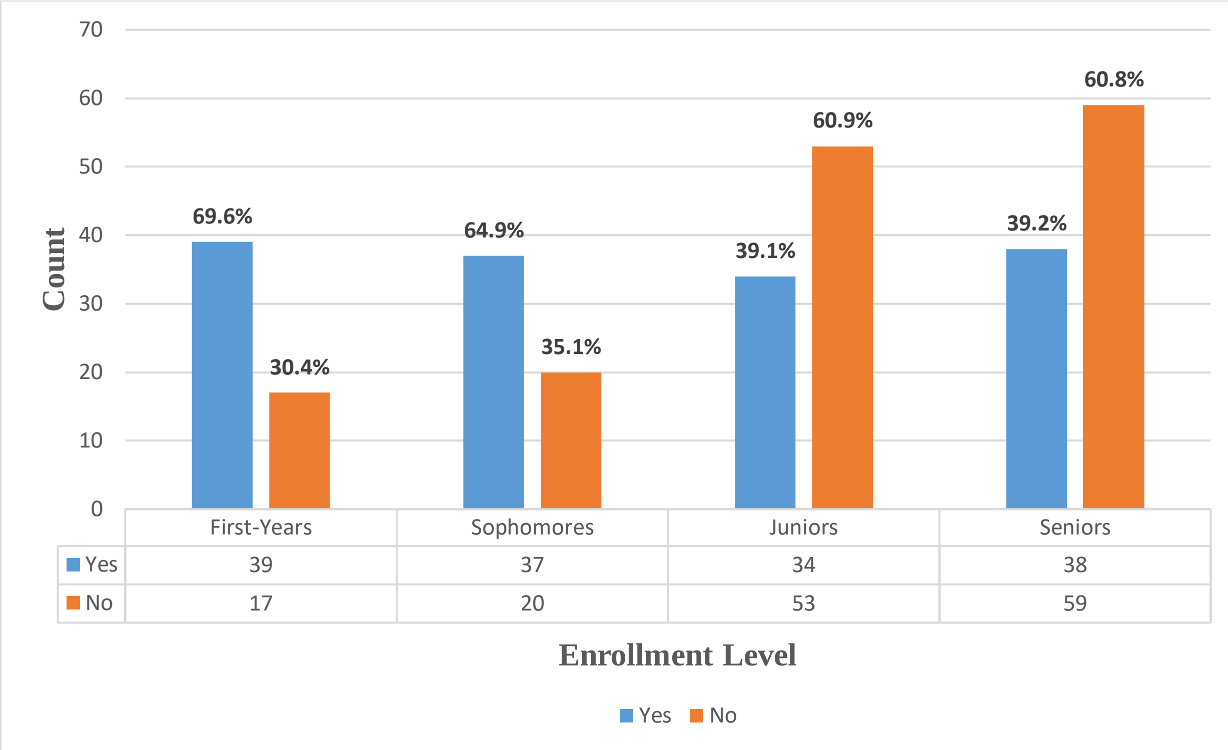


Figure 1. Enrollment Level and Count of Responses for Receiving Fatigue Training.

Note. Percentages are from within the enrollment level.

Research Question Two

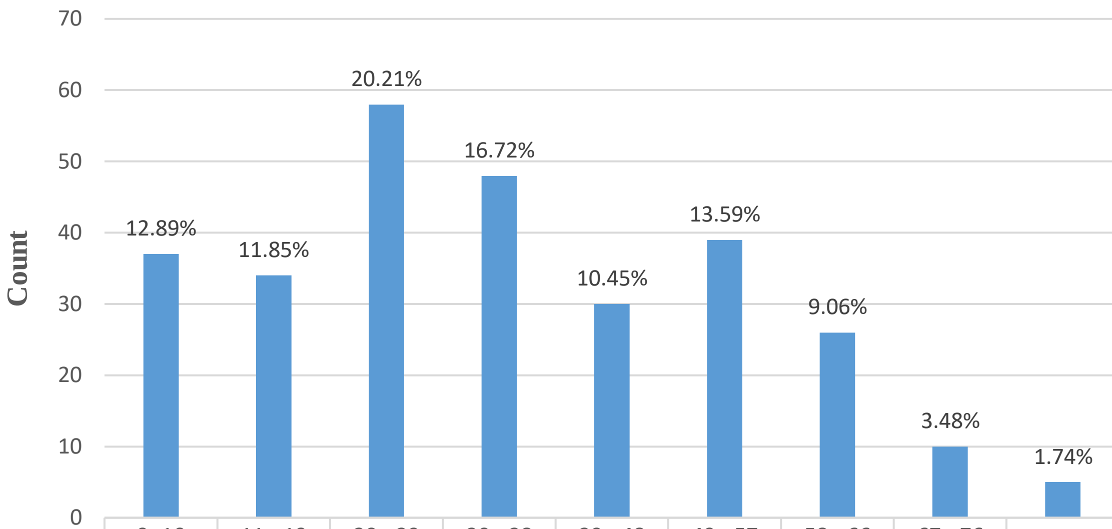
What are the reported typical hours spent working, studying, and socializing?

There were 282 responses for the survey item that requested hours worked per week Monday through Sunday. The prompt within the survey item asked to participants to include time spent working as well as studying. Results showed the mean hours worked per week was close to 33 hours (M = 33.09, Mdn = 30, SD = 19.014). The minimum reported hours worked per week was zero while the maximum was reported as 78 hours per week (see Table 4).

Table 4
Descriptive Statistics for Hours Worked per Week

Item	**Hours Worked Monday-Sunday**
N	282
Mean	33.09
Median	30.00
Mode	0
Std. Deviation	19.014
Variance	361.529
Minimum	0
Maximum	78

The hours worked in a week were binned into ranges to access the counts using a feature within IBM SPSS 26®. Approximately 45% of respondents to the survey item reported working and studying between 0 and 29 hours per week. Approximately 41% reported working and studying between 30 and 57 hours per week while approximately 14.28% reported working and studying between 58 and 78 hours per week. Figure 2 shows the hour ranges, counts, and percentages from the total count.

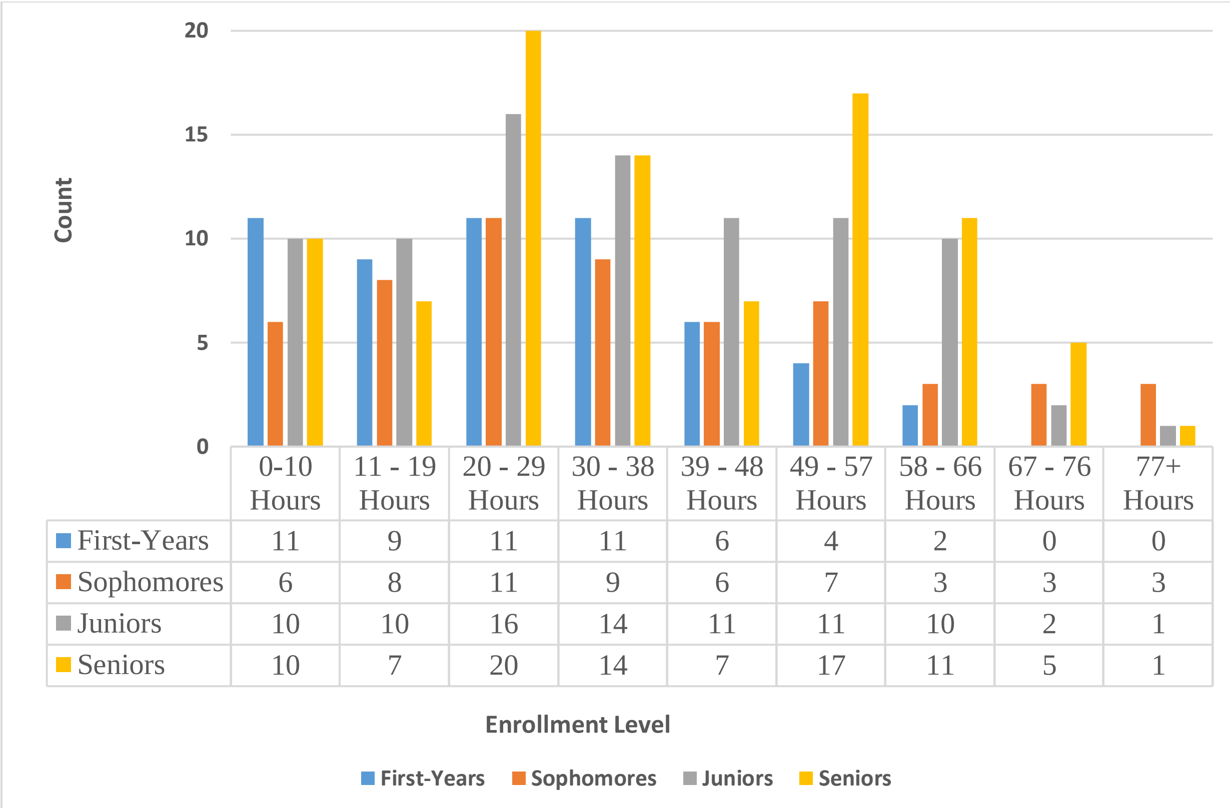


	0 -10 Hours	11 - 19 Hours	20 - 29 Hours	30 - 38 Hours	39 - 48 Hours	49 - 57 Hours	58 - 66 Hours	67 - 76 Hours	77+ Hours
Count	37	34	58	48	30	39	26	10	5

Figure 2. Range of Hours Worked Per Week.

Note. Percentages are from the total responses to the question (N = 282). The range consists of hours worked per week Monday-Sunday.

To further understand the participants' workload, the researchers broke down the hours by enrollment level and hours worked. Results indicated Juniors and Seniors worked more hours per week than First-Years and Sophomores. However, Juniors and Seniors accounted for more of the survey respondents. In fact, there were 49 more responses from Juniors and Seniors. Reported hours worked per week by enrollment level is found in Figure 3.



	0-10 Hours	11 - 19 Hours	20 - 29 Hours	30 - 38 Hours	39 - 48 Hours	49 - 57 Hours	58 - 66 Hours	67 - 76 Hours	77+ Hours
First-Years	11	9	11	11	6	4	2	0	0
Sophomores	6	8	11	9	6	7	3	3	3
Juniors	10	10	16	14	11	11	10	2	1
Seniors	10	7	20	14	7	17	11	5	1

Figure 3. Range of Hours Worked per Week by Enrollment Level.

Respondents were also asked to provide the amount of time in hours spent socializing. Two hundred and ninety-two responses were obtained (n = 292). Results showed the mean hours spent socializing per week was close to 15 hours (*M* = 15.38, *Mdn* = 12, *SD* = 12.324). The minimum hours reported was zero hours while the maximum was 69 hours. Table 5 shows the descriptive statistics for hours worked per week.

Table 5
Descriptive Statistics for Hours Spent Socializing Per Week.

Item	Hours Socializing Monday-Sunday
N	292
Mean	15.38
Median	12.00
Mode	8
Std. Deviation	12.324
Variance	151.872
Minimum	0
Maximum	69

Once again, the researchers utilized SPSS 26® to bin the hours into ranges to assess the counts. Approximately 46% of respondents to the survey item reported socializing between zero and 10 hours per week. Approximately 46% reported socializing between 11 and 32 hours per week while 8.21% reported socializing between 33 and 69 hours per week. Figure 4 shows the hour ranges, counts, and percentages from the total count. Similar to the hours worked analyses, the researchers included the hours by enrollment level and hours spent socializing. Results indicated Juniors and Seniors socialized more hours than First-Years and Sophomores in almost all of the range categories. Hours spent socializing per week by enrollment level is found in Figure 5.

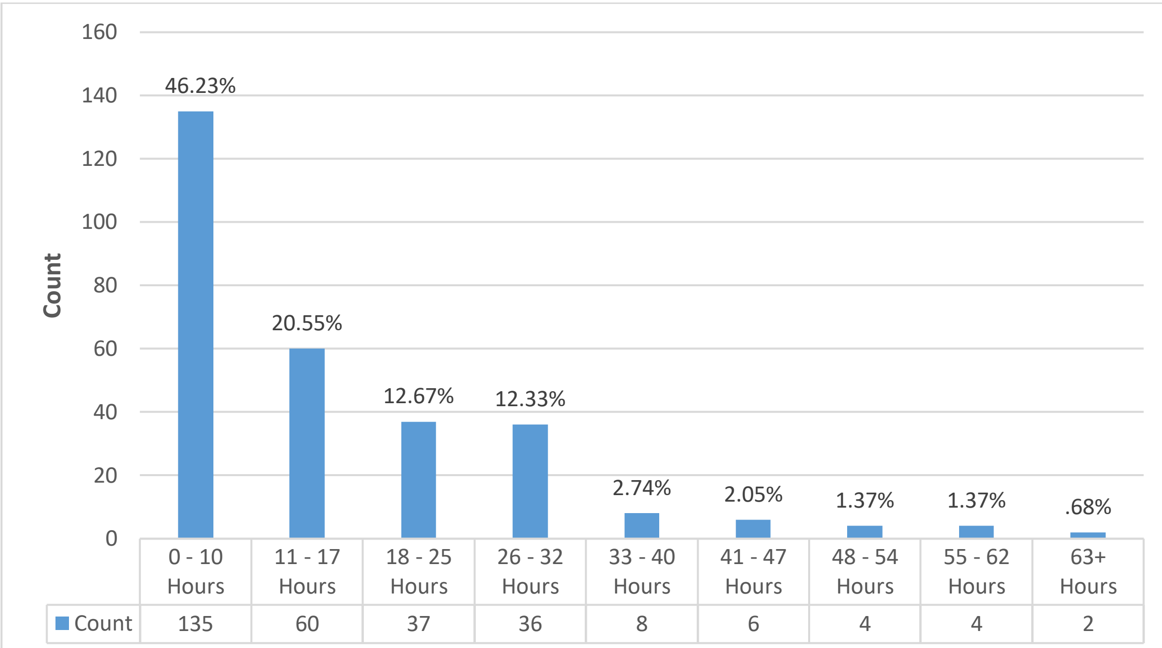


Figure 4. Range of Socializing Per Week.

Note. All responses combined reported hours spent socializing Monday-Sunday.

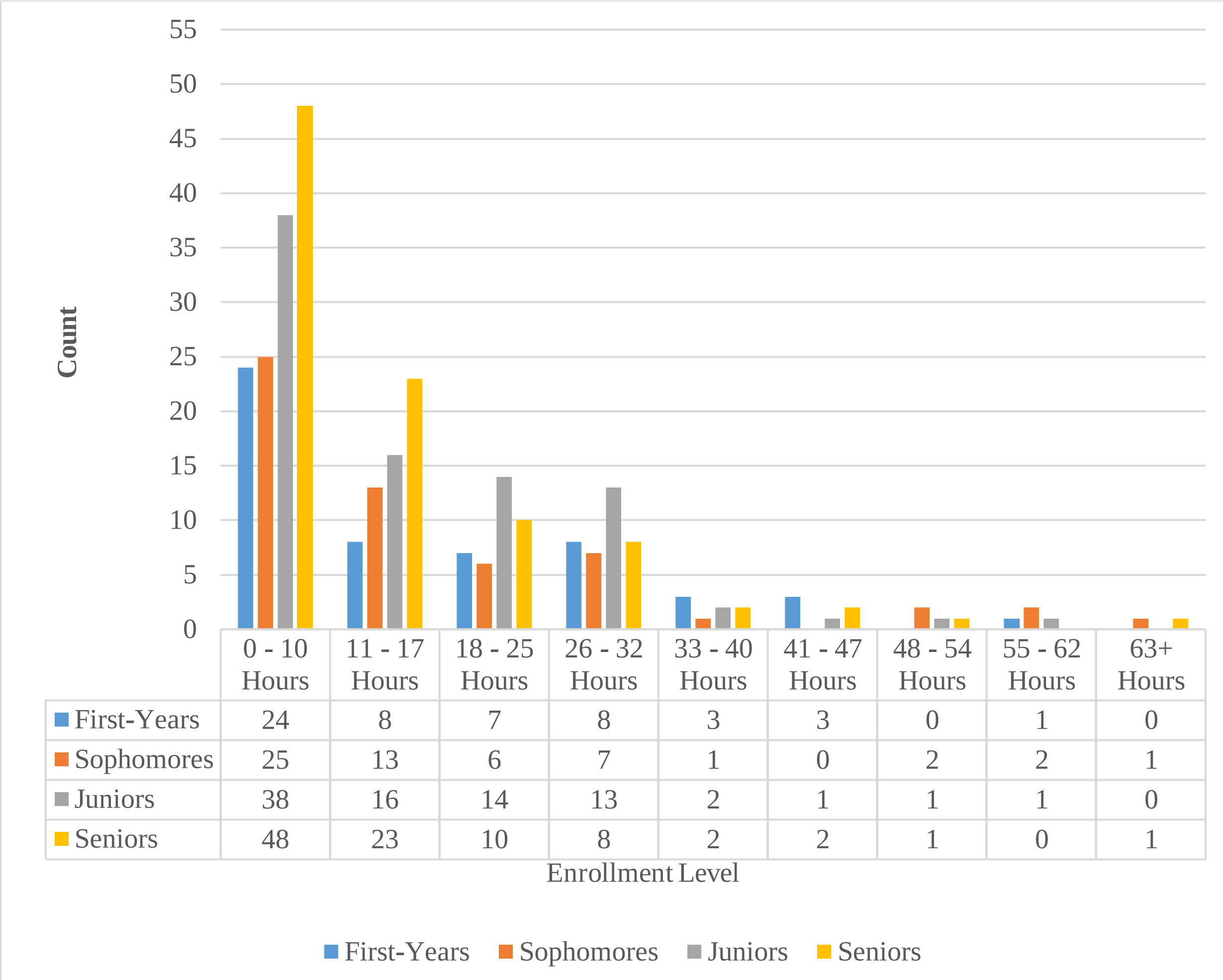


Figure 5. Range of Socializing per Week by Enrollment Level.

Research Question Three

Do the independent variables enrollment level, fatigue training received (Yes or No), and total flight hours predict the reported frequency of fatigue during flight training?

The null hypothesis for this research question is H_o: Enrollment level, fatigue training, and approximate total flight hours do not predict the frequency of fatigue during flight training activities.

A cumulative odds ordinal logistic regression with proportional odds was run to determine the effect of enrollment level, fatigue training, and flight time, and the reported frequency that fatigue impacts flight training activities. See Table 6 for an overall distribution of variables and sample size.

Table 6
Variables and Descriptive Statistics

		n	Marginal Percentage	* Scale Combined	n	Percent
Fatigue During Flight Training Activities	Never	23	7.9%	No	169	57.9%
	Rarely	146	50.0%			
	Sometimes	94	32.2%	Yes	123	42.1%
	Often	22	7.5%			
	Always	7	2.4%			
Enrollment Level	First-Years	55	18.8%			
	Sophomores	56	19.2%			
	Juniors	86	29.5%			
	Seniors	95	32.5%			
Fatigue Training	Yes	146	50.0%			
	No	146	50.0%			
Total		292	100.0%			

Note. For the scale combined column, Never and Rarely=No while Sometimes, Often, and Always=Yes

An ordinal regression has four assumptions that need to be met. The researchers chose to use $p < .05$ as the cutoff value for significance for all tests. The first assumption requires an ordinal dependent variable. Question #16, "*fatigue impacts my flight training activities",* was a Likert scaled item and had the following options as a response; 'Never', 'Rarely', 'Sometimes', 'Often', and 'Always'. The second assumption requires at least one independent variable. Once again, the independent variables were, enrollment level, fatigue training received, and flight time. Flight time was measured at the continuous level and established in the analysis as a covariate. The third assumption tested for multicollinearity. To test for multicollinearity, the researchers utilized the linear regression test within SPSS®. The linear regression test yielded *Tolerance* values that were greater than 0.1. The Tolerance value for enrollment level was .652, received fatigue training was .936, while flight hours was .618. All three Variance Inflation Factor (VIF) values were less than ten. These findings indicated there was no issue with collinearity.

To check the assumption for proportional odds, the researchers performed a Full Likelihood Ratio test. The results of the test generated the Test of Parallel Lines. To pass this assumption, the Test of Parallel lines should be statistically not significant, $p > .05$. As assessed by the full likelihood ratio test, the assumption as met, $\chi2(15) = 21.843$, p = .112. Most cells were sparse with zero frequencies in 772 (76.1%) of cells therefore deviance goodness-of-fit test was used. Results indicated the model was a good fit to the observed data, $\chi2(803) = 543.387$, p = .677. Table 7 shows the goodness-of-fit results. The final model statistically significantly predicted the dependent variable over and above the intercept-only model, $\chi2(5) = 17.769$, p = .003. Table 8 shows the model fitting information.

Table 7
Goodness-of-Fit Test Statistics

	Chi-Square	df	Sig.
Pearson	864.838	803	.064
Deviance	543.387	803	.677

Table 8
Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	621.825			
Final	604.056	17.769	5	.003

The next step was to determine which variable(s) were significant predictors on frequency of fatigue impacting flight training reported by participants. The Test of Model effects indicated enrollment level and fatigue training received were the only significant variables in the model. The variable enrollment level was, $\chi 2(3) = 12.134$, $p = .007$ while flight training received was, $\chi 2(1) = 3.883$, $p = .049$. Data for the Test of Model Effects is shown in Table 9.

Table 9
Test of Model Effects

Variable	Type III		
	Wald Chi-Square	df	Sig.
Enrollment Level	12.134	3	0.007
Training Received	3.883	1	0.049
Total Flight Time	0	1	0.992

With four categories of enrollment, there were six comparisons that needed to be made. These comparisons are First-Years vs Seniors, Sophomores vs Seniors, Juniors vs Seniors, Juniors vs First-Years, Sophomores vs Juniors, and First-Years vs Sophomores. The reference category in the first run only provided three of the comparison. To obtain all the comparisons the researchers had to recode and rerun the enrollment categories. The parameter estimates output shows the initial and consecutive pairwise comparisons and can be found in Appendix B. The following section will provide interpretation of these comparisons.

Two of the comparison provided statistically significant results, Seniors vs First-Years and Juniors vs First-Years. Juniors and Seniors had higher odds of falling in a higher frequency category of the dependent variable- "*fatigue impacts my flight training activities*". The odds of Seniors reporting a higher frequency of fatigue impacting their flight training was 3.95, 95% CI [1.77, 8.83] times higher than that of First-Years with a statistically significant effect, $\chi 2(1) = 11.24$, $p < .001$.

The comparison for Juniors vs First-Years was determined in the second run of the analyses with the categories recoded and reordered. The odds of Juniors reporting a higher frequency of fatigue impacting their flight training was 3.00, 95% CI [1.45, 6.18] times higher than that of First-Years with a statistically significant effect, $\chi 2(1) = 8.85$, $p < .001$. The remaining comparison were not statistically significant but are reported in the following paragraphs.

The odds of Seniors reporting a higher frequency of fatigue impacting their flight training was 2.05, 95% CI [0.99, 4.25] similar to Sophomores and was not statistically significant effect, $\chi 2(1) = 3.74$, $p = .05$. The odds of Seniors reporting a higher frequency of fatigue impacting their flight training was like Juniors and was not statistically significant, .076, 95% CI [.42, 1.36], $\chi 2(1) = 0.86$, $p = .35$. Regarding Sophomores vs Juniors, the odds of Sophomores reporting a higher frequency of fatigue impacting their flight training was 1.56, 95% CI [0.80, 3.84] similar to that of Juniors and not statistically significant effect, $\chi 2(1) = 1.68$, $p = .20$. The First-Years vs Sophomores comparison can be found in the third run of the data. The odds of First-Years reporting a higher frequency of fatigue impacting their flight training was slightly lower and not statistically significantly different when compared to Sophomores, 0.52, 95% CI [.25, 1.09], $\chi 2(1) = 3.04$, $p = .08$.

Participants were asked if they had received fatigue training during their flight training program. The odds of reported fatigue training recipients experiencing a higher frequency of fatigue during flight activities was 1.583, 95% CI [1.002, 2.499] times that of fatigue training non-recipients with a statistically significant effect, $\chi 2(1) = 3.883$, $p = .049$. This is an interesting result. Participants were also asked to provide their approximate total flight hours. This continuous variable was added to the model as a covariate. Reported total flight hours did not indicate a significant effect, $\chi 2(1) = 0.00$, $p = .992$.

Discussions and Conclusions

The purpose of this study was to gain a clear understanding of fatigue training provided to collegiate aviation pilots, their typical workload and time spent socializing, and factors that may lead respondents to indicate a higher frequency of fatigue while conducting flight training activities. The first question answered in this study pertained to fatigue training among the respondents. The responses to "*have you received fatigue training during your enrollment in the flight program*" were almost evenly split between "yes" and "no". This is a concerning finding considering the insidious nature of fatigue and its deleterious effects during flight operations. While the authors recognize that many flight programs incorporate human factors training into their curriculum, the responses indicate some of the fatigue training and education may not be meeting critical learning outcomes of identifying fatigue risk factors and application of effective mitigation strategies during flight operation activities.

As part of the practical standards for pilots in the U.S., the Airmen Certification Standards (ACS) requires the assessment of pilot's knowledge and ability to demonstrate an understanding of the recognition, causes, effects of aeromedical and physiological issues such as fatigue including the relevant corrective actions (FAA, 2018a). Some collegiate aviation programs use informal discussion-based format for lessons on fatigue. Other collegiate aviation programs also introduce concepts on fatigue through aviation safety and human factors courses that analyzes accident case- studies. There may be a need to review curriculum to include more comprehensive and data-driven content analyses on fatigue risk management education and recommended by ICAO SARPs.

Though it is a challenge to control student behavior outside of the classroom or flight deck and simulator laboratories, increasing the intentionality of fatigue training may promote desirable safety behaviors (Barger et. al, 2018). These behaviors can include the ability to understand the leading causes of fatigue, signs, and symptoms, best practices for sleep preparation, how to handle disruptions, workload management, as well as fatigue related decision-making before and during flight operations i.e., talking with an instructor.

Integrated fatigue training using Safety Management System processes such as safety promotion can be productive. This can be done by incorporating fatigue training as part of the continuous improvement efforts of safety required in a functional SMS of an organization. Additionally, collegiate programs with SMS can utilize other components of SMS namely; Safety Policy, Risk Management, and Safety Assurance to enhance fatigue management. The SMS policy must have provisions that spells out fatigue as one of the safety risks that needs to be managed and who will have responsibilities and accountabilities for fatigue management in the program. It will also highlight leaderships commitment to provide resources to mitigate the adverse effects of fatigue in flight operations. Risk management tools can be used to identify and recommend effective controls for fatigue. Data on fatigue in an organization can be used for periodic evaluation of the effectiveness of any fatigue management plan adopted. Finally, collegiate aviation programs with a voluntary SMS program can adopt and integrate commercial airline FRMS components that can be beneficial for fatigue policy improvement.

Understanding workload is imperative to fatigue mitigation efforts and the second research question of this study queried hours spent working and socializing. The average reported time working and studying per week was 30 hours while the average time socializing was 15 hours per week. Romero et al. (2020), reported approximately 77 % of collegiate aviation respondents were enrolled in 12 credits or more per academic semester and another research finding suggests that academically successful students' study approximately 30 hours per week (Beattie et al., 2019).

It is highly recommended that fatigue risk matrices that provides guidance on quantifying the risk associated with student's workload be developed in Part 141 training programs. As noted in the results section of this study, Juniors and Seniors work and socialize more than First-Years and Sophomores. This provides evidence that fatigue training should be different for these groups. A future research direction may focus on how hours spent flying, time of flight slot, time spent studying, and working part time jobs influences fatigue management among this collegiate pilot population. Future research can also track pilot's workload in detail in terms of period of the semester.

For the final research question, the researchers included enrollment level, fatigue training received, and reported total flight hours as independent variables. Results from the ordinal regression analyses indicated Juniors and Seniors were two to three times more likely to report a higher frequency of fatigue when compared to First-Years and Sophomores. The results also indicated that Juniors and Seniors reported higher hours of work and socializing. These findings seem intuitive since Juniors and Seniors may be more engaged in leadership roles in extramural campus associations/activities and that can adversely affect time management needed for quality sleep. At this student academic level in the universities sampled some of the respondents can live outside the dormitories and are free to engage in more socializing and may engage in unhealthy eating habits which are fatigue risk factors and adversely affect quality sleep.

As upperclassmen, many collegiate aviation pilots turn 21 which allows them to legally visit bars and spend copious amounts of time in nightclubs. Some may also have changes in family lifestyles i.e., married, engaged to partners, and or having kids. These factors may be more disruptive to effective time management and quality sleep schedules. Others may be engaged in excessive and extraneous shift work to pay for college upkeeps and that can affect rest cycles especially night shifts that could have detrimental effects on circadian rhythms. Some may also be CFIs and undergraduate students while working extra jobs and combining academic loads with family responsibilities. These are some of the psycho-social factors that can potentially explain the differences observed from the findings. Adjekum (2014) in a study on safety culture in collegiate aviation suggests peer to peer advocacy for personal safety by peers advocating and encouraging lifestyles among themselves that minimizes fatigue risk factors. The findings from that study encouraged submission of safety reports on fatigue related flight events by collegiate aviation pilots and informal safety meetings moderated by peers where feedback from safety office is discussed.

Further, results indicated Juniors and Seniors had the lowest reported fatigue training. Evidence indicates those who said “yes” for having received fatigue training were 1.5 times more likely to report higher levels of fatigue. This may be due to the fact they are more aware of their fatigue and human limitation but still choose to meet the demands of the day. Specificity and recency of the type of fatigue training may be helpful in future studies. Some of the academic-based fatigue training tends to be done during the first and second years of enrollment. That may create a knowledge gap in terms of any formalized training on fatigue apart from the briefs required during flight operations with CFIs. It may be expedient to have higher levels courses in fatigue risk management which can be part of recurrent crew resource management or safety management system courses. Routine data collection and analysis on fatigue risk factors utilizing behavioral and subjective measures such as brief fatigue inventories and technology will improve organizational fatigue mitigation and management efforts (Shahid et al., 2012). Further, organizations can account for students assigned to instructors, track cancellations due to fatigue, use additional workload data such as credit hours in progress, limit late flights with early morning starts (particularly in the summer), and foster an environment that encourages work life balance.

The authors acknowledge some limitations to the study. This study utilized convenience sampling methods which inhibit generalization to the larger pilot population. All responses were from four-year university programs and did not include two-year community colleges. It is assumed that respondents were truthful and accurate when answering the survey items. There may have been cases of social desirability biases in the responses where respondents may not provide answers that makes them feel bad in social standings. Despite the limitations of this study, the results may be valuable to collegiate aviation program leaders, pilots, regulators, and human factors and aviation safety scholars.

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Appendix A

Demographics
Age:
Gender:
Enrollment status:
Highest Certificate Held:
Approximate total logged flight time:
Institution

Fatigue Awareness
Please rank the accuracy of the statement describing your overall experienceduring all of your flight activities.

	Never	Rarely	Sometimes	Often	Always
I have struggled to stay awake during a flight.					
I have remarked (out loud or to myself) about how tired I was but proceeded with the flight anyway.					
I have overlooked mistakes during a flight because of reduced judgment caused by fatigue.					
I have felt disinterest during flight activities because I was fatigued.					
I have not given my best effort due to fatigue.					
I have felt heightened irritation during a flight because I was fatigued.					
My abilities to carry out tasks requiring concentration have been decreased due to fatigue.					

What symptoms cause you to realize you are fatigued?

Causes of Fatigue
Please rank the accuracy of each statement describing contributing factors which may have led to fatigue during flight activities.

	Never	Rarely	Sometimes	Often	Always
Flying during night (sunset through sunrise).					
Flying a long cross-country (2.5 hours or over).					
Working a long day.					
Stress caused by family or other psychological conditions.					
Poor scheduling of flight lessons (e.g., too early, too late, or too many).					
Poor scheduling of academic classes.					
Lack health or fitness.					
Personal activities or other commitments (e.g., 2nd job).					
Academic activities (e.g., midterms, student organizations, etc.).					
Quality of sleep (restlessness or interrupted sleep).					
Not of enough sleep.					

Please comment on other factors that contributed to fatigue:

Lifestyle

Given each item, please select the accuracy of the statement describing your current lifestyle.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I have a healthy academic and life balance.					
I regularly exercise.					
I maintain a healthy diet.					
I am good at workload management.					
I am good at stress management.					
I get adequate sleep every night (quantity and quality).					
I prepare well to get adequate sleep (i.e., limit electronic device use, caffeine, disruptions, noise, etc.)					

In your experience what are the most significant factors that inhibit your quality/quantity of sleep?
Personal Solutions

Please read through the entire list then rank (click and drag) in order the following personal solutions to mitigate fatigue, 1 being the most important and 10 being the least important. You can provide factors that are not listed in the comment box below.

Reduced workload
Scheduled breaks
More sleep
Efficiency in scheduling of classes and flight activities
Management of sleep preparation
Self-awareness of fitness to fly
Guaranteed rest for a given amount of flying time
Physical exercise
Healthy eating habits
Better management of non-work issues

What other personal solution(s) do you find important?

Based on your overall experience during all of your flight activities.

	Never	Rarely	Sometimes	Often	Always
Fatigue impacts my flight activities.					

How many hours do you typically work per week Monday-Friday? (include studying, working, student organizations, etc.) (e.g., 1, 2, 3)

How many hours do you typically work per weekend Saturday-Sunday? (include studying, working, student organizations, etc.) (e.g., 1, 2, 3)

How many hours do you typically socialize per week Monday-Friday (e.g., 1, 2, 3)

How many hours do you typically socialize per weekend Saturday-Sunday? (e.g., 1, 2, 3)

Have you ever received fatigue training during your academic or flight training course work? Yes or No

What specific method do you use to ensure you are fit to fly?

Please identify in general your fatigue level during the specified time periods. We may be able to understand of your preference for morning or evening.

	Fully alert	Very lively but not at peak	Ok, somewhat fresh	A little tired, less than fresh	Moderately tired, let down	Extremely tired, very difficult to concentrate	Completely exhausted, unable to function effectively
Early morning (6am-9am)							
Morning (9am-noon)							
Early afternoon (noon-3pm)							
Afternoon/early evening (3pm-6pm)							
Evening (6pm-9pm)							
Night (9pm-6am)							

Please provide any comments that would help improve the survey (unclear items, length of survey, areas that were not addressed, etc.) Thank you for your feedback and participation.

Appendix B

Parameter Estimates

	Parameter	B	Std.Err	95% Wald CI Lower	95% Wald CI Upper	Wald Chi-Square	df	Sig.	Exp (B)	95% Wald CI Lower	95% Wald CI Upper
Threshold	Fatigue=.00	-2.80	0.38	-3.54	-2.05	54.25	1	0.00	0.06	0.03	0.13
	Fatigue=1.0	0.10	0.32	-0.53	0.73	0.10	1	0.76	1.11	0.59	2.08
	Fatigue=2.0	2.04	0.36	1.35	2.74	32.97	1	0.00	7.72	3.84	15.51
	Fatigue=3.0	3.56	0.48	2.61	4.51	54.15	1	0.00	35.31	13.67	91.25
Enrollment Level	First-Years	-1.37	0.41	-2.18	-0.57	11.24	1	**0.00**	0.25	0.11	0.57
	Sophomores	-0.72	0.37	-1.45	0.01	3.74	1	0.05	0.49	0.24	1.01
	Juniors	-0.28	0.30	-0.86	0.31	0.86	1	0.35	0.76	0.42	1.36
	Seniors	0[a]							1.00		
Fatigue Training	Yes=.00	0.46	0.23	0.00	0.92	3.88	1	**0.04**	1.58	1.00	2.50
	No=1.00	0[a]							1.00		
Flight Hours	Flight Hours	7E-6	0.00	0.00	0.00	0.00	1	0.99	1.00	1.00	1.00
				Comparison2							
Enrollment Level	Sophomores	0.66	0.38	-0.08	1.39	3.04	1	0.08	1.93	0.92	4.03
	Juniors	1.10	0.37	0.37	1.82	8.85	1	**0.00**	3.00	1.45	6.18
	Seniors	1.37	0.41	0.57	2.18	11.24	1	**0.00**	3.95	1.77	8.83
	First-Years	0[a]							1.00		
				Comparison 3							
Enrollment Level	Juniors	0.44	0.34	-0.23	1.11	1.68	1	0.20	1.56	0.80	3.04
	Seniors	0.72	0.37	-0.01	1.45	3.74	1	0.05	2.05	0.99	4.25
	First-Years	-0.66	0.38	-1.39	0.08	3.04	1	0.08	0.52	0.25	1.09
	Sophomores	0[a]							1.00		
				Comparison 4							
Enrollment Level	Seniors	0.28	0.30	-0.31	0.86	0.86	1	0.35	1.32	0.73	2.37
	First-Years	-1.10	0.37	-1.82	-0.37	8.85	1	**0.00**	0.33	0.16	0.69
	Sophomores	-0.44	0.34	-1.11	0.23	1.68	1	0.20	0.64	0.33	1.25
	Juniors	0[a]							1.00		

Note. The parameter estimates were rounded to the nearest hundredth. Significance levels were rounded to the nearest hundredth. Bold indicates the significant results at .05.

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Maintenance of Composite-Based Aircraft Components and Structures through the Perspective of Aviation Maintenance Technicians in the United States

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For the last three decades, the field of aircraft construction and manufacturing has been experiencing a significant change as the material of choice for aircraft construction has been continuously transitioning from metal to composite materials. This underlying change to the way aircraft structures and components are manufactured is propelled by composite materials' intrinsic design and operational advantages. Nevertheless, as new technologies are introduced into the aviation industry, it is crucial to consider how all aspects thereof are affected, most importantly to ensure that safety is not compromised. As a critical part of the aviation industry and a key factor influencing the safety thereof, maintenance activities and certified aviation maintenance technicians (AMTs) need to be considered when evaluating the impact of the introduction of composite materials in the aeronautical field. Consequently, the conducted study specifically focuses on aircraft maintenance activities, especially as it pertains to the interaction of certified AMTs with composite materials. The goal of the study was to highlight and understand the opinions and perceptions of AMTs on composite materials and how, from a front-line perspective, aviation maintenance activities have changed with the introduction of novel materials. The input gathered from AMTs is a tool to understand potential pitfalls, deficiencies in training and resources, and safety threats from a maintenance perspective that may stem from the increased use of composite materials. With this purpose, certified maintenance technicians in the United States were surveyed and their responses were analyzed to identify recurring themes in the topics presented. Responses indicated issues related to formal composite-centered AMT training, knowledge, and resources available for composite maintenance.

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The use of composite materials has continuously increased throughout the last decades, making them now a common material of choice for the construction of commercial aircraft primary structures (Haresceugh et al., 1994). Composite materials are used to manufacture a variety of parts and structures of a wide range of aircraft across manufacturers as they present a collection of advantages when compared to aluminum and other traditional aircraft materials. Among others, composite materials allow for lighter, more fuel-efficient and environmentally friendly aircraft constructions due to their comparative light weight and ability to be shaped into aerodynamically efficient parts, while simultaneously presenting excellent mechanical properties (Gopal, 2016; Hadcock, 1998; Haresceugh et al., 1994; Kassapoglou, 2013). Examples of civil, transport-category aircraft in which composite materials are used for the manufacture of parts and structures include the Boeing B737, B777 and B787 models, as well as the Airbus A220, A320, A350 and A380 models (Airbus, 2019; Gopal, 2016; Hiken, 2017; Kassapoglou, 2013; Soutis, 2005). In each aircraft, the exact composite material application and use are different. On the A320, the control surfaces, vertical and horizontal stabilizers are manufactured out of composite materials (Kassapoglou, 2013; Soutis, 2005). Similarly, composite sandwich materials were used for the manufacture of the horizontal stabilizer of the B737 **(**Kassapoglou, 2013). On the B777, composite materials were originally employed for the construction of the main floor beams, control surfaces and tail assembly (Kassapoglou, 2013). However, on the B777X, similar to the A220, A350 and B787, the use of composite materials is expanded and used for the manufacture of the wings (Airbus, 2019; Hiken, 2017; Kassapoglou, 2013; Soutis, 2005). On the A380, composite materials account for around 25% of the aircraft's weight, as composites are used for the manufacture of fuselage sections floor beams, the center wing box, and the aft pressure bulkhead (Kassapoglou, 2013; Soutis, 2005). On more recently designed aircraft, such as the B787 and A350, the aircraft fuselage is constructed solely out of composite materials. In addition, the center wing box and wings of the B787 and A350, respectively, are built as all-composite structures (Gopal, 2016; Kassapoglou, 2013). On these two aircraft, composite materials account for approximately 50% of the structural weight (Gopal, 2016; Kassapoglou, 2013; Soutis, 2005).

However, with the increased use of composite materials in aircraft structures, it is crucial to consider the maintenance characteristics of these materials and their impact on conventional maintenance activities. As is highlighted in a variety of maintenance-related documentation published by the Federal Aviation Administration (FAA, 1998, 2016, 2018a), the tools and methods used for composite material inspection, maintenance, and repair significantly vary compared to those used for the maintenance of traditional aircraft materials, such as aluminum. These changes and shifts in aviation maintenance practices and their impact on the work of aviation maintenance technicians need to be recognized, especially as the use of composite materials is continuously increasing. Properly performed maintenance activities are critical for the continuing safety of the aviation industry (FAA, 2018b), and thus it is critical to consider all aspects and elements that can impact these activities. Aviation maintenance technicians conducting and performing the maintenance and repair activities are a key element of aviation maintenance, and by extension of the safety thereof. Therefore, it is necessary to analyze and assess how the significant maintenance changes introduced by the increased use of composite materials impacts aviation maintenance technicians.

Literature Review

Composite Materials in Aviation Maintenance and Technician Education

Literature suggests that traditional aviation maintenance technician (AMT) education is not sufficient to meet the challenges of modern aviation, which includes the maintenance of composite-based aircraft structures (Haritos & Macchiarella, 2005). The use of composite materials for the manufacture of primary, structural aircraft components has introduced additional obstacles to aircraft maintenance and repair activities. First, the inspection of composite structures is more complex and difficult than the inspection of metallic structures due to the inherent manufacturing intricacy thereof (Kroes & Sterkenburg, 2013). Second, the damage type, failure modes, and damage propagation observed in aircraft composite structures present differences when compared to the damage found on metallic structures, subsequently requiring a different approach to aircraft maintenance, and specifically inspection activities (Hobbs, Brasil, & Kanki, 2009; Sterkenburg & Wang, 2013; Werfelman, 2007). For instance, while the inspection of metallic structures heavily relies on visual inspections, the inspection of composite structures frequently requires the further use of non-destructive testing (NDT) techniques, such as ultrasound, thermography and x-ray, as composite damage may not always be visually identified (Kroes & Sterkenburg, 2013; Ostrom & Wilhelmsen, 2008; Werfelman, 2007). By extension, NDT methods frequently require separate, additional and specific training and certification, which adds further complexity to the process of aircraft composites inspection (Kroes & Sterkenburg, 2013). Similar to the inspection, the repair of damaged or failed aircraft composite-based structures differs from techniques used to repair metallic structures and methods used for non-structural composite repairs. Consequently, further adjustments to standard, existing repair processes and procedures are required (Mitchell, Poudel, Li, Chu, & Mattingly, 2013).

As a crucial part of the aviation industry, the training and education of individuals involved in the maintenance and repair of aircraft need to be re-evaluated and adjusted to meet the novel requirements set by the evolving nature of aircraft construction. However, the training and education requirements in the field of composite maintenance have been vastly criticized as the requirements therefore are not standardized and fail to represent the needs of the industry (Hobbs et al., 2009).

In the United States, the FAA regulates the training requirements for aviation maintenance technician (AMT) certification under the Code of Federal Regulations (C.F.R.). When evaluating the curriculum required to be taught at AMT schools (Title 14 C.F.R. Part 147 Appendix C, 2017) it can be observed that comparatively old and outdated technology – such as wood, dope and fabric inspection, construction and repair – is required to be taught extensively, while novel technology – such as composite inspection and repair – is less prevalent. Even though basic composite education is mandated, extensive courses covering composite repairs and NDT are only optional, with their inclusion left up to the discretion of each AMT school (FAA, 2015). Consequently, standardization issues, as introduced by Hobbs et al. (2009), as well as a workforce not educated to meet the requirements of modern aviation – as hypothesized by Haritos and Macchiarella (2005) – emerge.

To address the above-mentioned, theoretically studied, shortcomings in AMT education as well as to address the potential impact on aviation maintenance activities, a study focused on aviation technicians' perceptions, attitudes, and opinions with regards to composite aircraft maintenance and repair was conducted.

Surveys in Aviation

In an effort to increase the safety of the maintenance activities themselves and of the aviation industry, aviation maintenance technicians and mechanics are frequently surveyed and interviewed regarding their attitudes and opinions on a variety of issues. Most commonly, these surveys and interviews are focused around the areas of maintenance manuals and technical publications, training, procedures, human factors, safety management systems and safety culture.

Human factors in relation to aviation technical manuals were studied by Chaparro & Groff (2002) and Chaparro, Groff, Chaparro, and Scarlett (2002) as they aimed to identify, through a combination of techniques, human factors issues that are related to aviation maintenance technical manuals. As part of the study, a survey was employed consisting of a questionnaire and interviews to determine the perceptions of maintenance technicians on the quality and usability of the maintenance documentation used, and to compare the maintenance documentation across aircraft manufacturers. Further in the area of technical publications, Zafiharimalala, Robin, and Tricot (2014) explored how maintenance documentation is used by aviation maintenance technicians, employing a survey to understand how and when maintenance technicians use said documentation as well as the reasons for which technicians do not use the maintenance documents. In addition to human factors related to maintenance manuals and the actual use of these manuals, avantgarde approaches to technical publications, such as 3D aircraft maintenance manuals, are also researched and explored. A study conducted by Wang and Leib (2014) investigated the usefulness and acceptance of 3D maintenance manuals, compared to traditional manuals, as seen by front-line aviation technicians.

The relationship and interaction amongst maintenance technicians and pilots, especially in the area of maintenance discrepancy reporting, has been explored and studied by surveying both pilots and maintenance technicians. To understand maintenance discrepancy reporting policies and practices, as well as the opinions of aviation professionals with respect to the effectiveness of said practices and the training in the area, Mattson, Petrin and Young (2001) surveyed a group of pilots and maintenance technicians. Similarly, Munro, Kanki, & Jordan (2008) explored factors that influence logbook entries as well as the impact on these entries if it is known that they may be read by regulatory agencies. In the research, Munro et al. (2008) used a survey to identify factors influencing the level of detail of the description of discrepancies in a logbook and the frequency of direct discussions of these discrepancies between pilots and mechanics. The survey consisted of a combination of yes-no, multiple choice and rank-order questions, and Likert-type scales.

Georgiou (2009) and Hackworth et al. (2007) explored human factors in aviation maintenance activities by surveying, among others, aviation maintenance technicians. While Georgiou (2009) aimed to investigate human factors related to aviation maintenance activities and their impact on safety, Hackworth et al. (2007) focused on the impact and difference between regulatory and voluntary approaches to maintenance human factor programs. Georgiou (2009) employed a survey to identify the human factor types that impact the performance of aviation mechanics and the extent to which these human factors impact the safety of the industry. The survey items from Hackworth et al. (2005) fall in the following categories: demographics, human factor metrics, organizational policies, error management, fatigue management, human factors training, motivation for a human factors program, and proactive human factors support.

Safety is a critical aspect in all areas of the aviation industry, including aviation maintenance organizations. Thus, a vast volume of research is centered around the implementation of safety management systems (SMS) in aviation maintenance activities, the safety culture of aviation maintenance organizations, and risk perception factors. Kearns and Schermer (2017) employed a survey with the aim to determine the attitudes and perceptions of aviation professionals on SMS, and differences therein based on gender and/or nationality. Similarly, McDonald, Corrigan, Daly, and Cromie (2000) explored the relationships between safety culture and SMS aspects through a variety of techniques, including interviews and surveys. Patankar (2003) analyzed an accident-free aviation organization to determine the factors that may have contributed to its positive safety record. Through questionnaires distributed to flight operations personnel, maintenance personnel as well as other employees of the organization, Patankar (2003) aimed to measure the safety attitudes of the employees as well as their opinions on the factors contributing to the exceptional safety record. Kim and Song (2015) focused specifically on the safety culture of a maintenance organization in Korea, with the purpose of using the results to improve further SMS implementations. The survey consisted of a variety of Likert- and nominal-scale elements, as well as free-response questions for safety proposal descriptions. Lastly, safety and risk can, and may, be perceived differently by every individual. For example, Chionis and Karanikas (2018) compared the opinions and attitudes of professional aviation maintenance personnel, engineers, and trainees through a survey. The survey consisted of questions about risk perception factors and scenarios for which the participants had to select a course of action.

As can be seen through the literature described, aviation maintenance technicians are mainly surveyed on procedural, managerial, safety, and human factor related aspects. Conversely, the perceptions, attitudes, and opinions of maintenance technicians in areas related to technical aspects, such as modifications to aircraft, for example through the increased use of composite materials and their impact on the maintenance activities, are not represented in existing literature. Nevertheless, such surveys can be beneficial to properly understand how industry professionals are impacted by considerable changes that impact their activities, as is shown by a variety of studies performed on pilots. With the implementation of glass cockpits and the further automation of flight, pilots have experienced substantial changes to their activities in the last decades. Thus, to understand how these changes impact pilots themselves, aircraft operation and the effect on safety, a variety of studies focusing on pilots' perceptions, opinions, attitudes, performance, and interactions with these systems have been performed.

Studies by Casner (2008), McClumpha, James, Green, and Belyavin (1991), Mosier and Fischer (2012), Sherman, Helmreich, and Merritt (1997), and Weyer (2016) focused on pilots' beliefs, attitudes, and perceptions with respect to automation and glass cockpits. By presenting pilots with a variety of scenarios and asking them to judge automation elements thereof, Mosier and Fischer (2012) studied how variations in automation as well as context and task features impact professional pilots' perceptions regarding workload, task management, situation awareness, automation cross-checking, and automation-related errors. Casner (2008) and McClumpha et al. (1991) focused specifically on pilots' attitudes towards advanced cockpit systems and advanced technology aircraft, respectively. Casner (2008) aimed to assess pilots' advanced cockpit system attitudes and beliefs, identify relationships between experience and attitudes, compare the attitudes of general aviation pilots and airline pilots, and recognize differences in impact perceptions. Similarly, McClumpha et al. (1991) studied pilots' attitudes and impressions on the design, reliability, skills, training, workload, flight management system, output and feedback, as well as crew interaction elements of advanced technology aircraft. With the purpose of identifying obstacles to the efficient human-automation interaction and to understand the distribution of roles in digital cockpits, Weyer (2016) analyzed and assed the confidence of pilots on human-automation interaction and collaboration, as well as the factors that influence this confidence. Furthermore, the impact of nationality, professional culture, and organizational differences on the pilots' attitudes towards automation were assessed and explored by Sherman et al. (1997).

In addition to perceptional and attitude-focused surveys and research, studies on the interaction between pilots and the advanced and automated systems have been performed by Casner (2009) and Sarter and Woods (1992, 1994). Sarter and Woods (1992) studied the impact of flight-deck automation on the performance of pilots by analyzing the interaction between pilots and the Flight Management System (FMS). Specifically, Sarter and Woods (1992) asked pilots to provide descriptions of issues encountered with the FMS, but also observed the transition process of flight crews to glass cockpit aircraft, while focusing on the pilots' interactions with the FMS and communications between the crew and instructors. To further understand pilot-automation interaction and performance, Sarter and Woods (1994) studied pilots' mode awareness and ability to apply flight context knowledge and understanding by observing and analyzing pilot-FMS interaction and pilots' reactions to hypothetical events during simulated flights. Additionally, the effect advanced cockpit systems can have on pilot workload and errors was studied by Casner (2009), who analyzed the effect of navigation equipment, control method, as well as flight and navigation instrumentation on error and workload.

Through these studies, an increased and more comprehensive understanding of the impact that advanced cockpit and automated systems have on pilots is obtained. The results can be used to identify, amongst others, issues, complications and pitfalls in the implementation of the advanced systems, gaps in knowledge and training, the impact on safety, as well as possibilities for further improvement thereof. Due to the lack of similar research with regards to aviation maintenance technicians' knowledge, opinions, attitudes, and perceptions of composite materials, it can be challenging to identify issues and difficulties presented by the maintenance of composite-based airframes and structures, and potentially to devise future improvements in the area. The impact of the scarce literature in the area is further magnified when considering the implications of aircraft maintenance on the safety of the aviation industry.

Methodology

To understand the practical implications of the introduction of composite-based structures into the lifecycle of aircraft, specifically focusing on potential challenges to maintenance and repair activities, aviation maintenance technicians (AMTs) in the United States were surveyed. Specifically, the purpose of the conducted survey was to answer the following research questions:

1. What are the opinions, attitudes, perceptions, and knowledge of AMTs in the United States regarding composite maintenance and repairs?
2. What are the similarities and differences between composite and metal maintenance and repair activities with regards to the opinions, attitudes, perceptions, and knowledge thereof of AMTs in the United States?

Through the results of the survey, potential shortcomings in mandated AMT education, as well as difficulties and safety issues arising from the introduction of composite materials into aircraft construction were aimed to be identified.

Survey Design

References from the literature were used to design the survey. Specifically, elements and survey formats from Casner (2008), Chaparro et al. (2002), Hackworth et al. (2007), and Mattson et al. (2001) were included into the survey design developed. Overall, the survey was divided into three main sections: (1) demographic questions, (2) questions related to the opinions and perceptions of AMTs with regards to composite materials, and (3) composite material knowledge questions. While the demographic information is used to categorize the responses and obtain an understanding of the background of the survey respondents, the questions related to opinions/perceptions and composite knowledge are used to gain insight into the relationship between AMTs and composite materials in the United States. Furthermore, the survey elements presented in the second section of the survey – questions related to opinions and perceptions – are divided into two types: (1) Likert-scale ranking and (2) open-ended questions. On one hand, the Likert-type scale is used to allow AMTs to indicate their agreement/disagreement with statements related to composite maintenance activities and repairs. On the other hand, the open-ended questions are used as a tool for AMTs to narrate their personal opinions and perceptions on composite materials in aviation maintenance and repairs. The third section of the survey – composite material knowledge questions – is used to test the composite-related theoretical knowledge AMTs have. Specifically, these questions were retrieved from a test guide (Aviation Supplies & Academics [ASA], 2018) for the FAA airframe and powerplant (A&P) examination – an FAA-regulated exam that is to be passed by AMTs to obtain the mechanics' certificate and perform certain types of maintenance on U.S.-registered aircraft (FAA, 2020). The full survey, outlining the questions, is presented in the *Appendix*.

Survey Participants and Distribution

The target population for the surveys included FAA-certified aviation mechanics, with either the airframe rating (referred to as "A") or the combined airframe and powerplant ratings (referred to as "A&P"). As the survey was intentionally kept broad to reflect the diversity of the aviation industry in the United States, the target population was not further narrowed down. Consequently, all AMTs with "A" or "A&P" ratings, regardless of factors such as occupational status, experience, or background, were included in the survey. Related demographic elements were collected via the survey questionnaire (as reflected in the *Appendix*), but were solely used to frame the responses in context rather than to further refine the scope of the survey. Therefore, the only participation pre-requisite was for participants to have either an "A" or "A&P" rating.

To reach the largest number of eligible participants while still representing the diversity of the aviation industry, a Facebook™ group was used for the distribution of the survey per an Institutional Review Board (IRB) approved procedure. The group in question has approximately 27,000 members and is used as a platform for AMTs to discuss aviation-related content, primarily focusing on aviation maintenance/repair topics. The survey was maintained on the group for one month, while group members were introduced, invited, and reminded of the possibility to participate in the survey twice – once per week during the first two weeks. As aforementioned, the group participants were informed of the only pre-requisite to participate – if the pre-requisite was met, group members could voluntarily decide to participate.

Results

After the one-month period, 92 responses to the survey were recorded. However, not all the responses included complete answers to the questionnaire. Only the survey responses that included complete, full answers to at least the Likert-scale rating section of the questionnaire were considered for the analysis of the opinion/perception element of the study. Similarly, to evaluate the theoretical knowledge of composite materials of AMTs, only responses that included answers to all the knowledge questions were analyzed. Through this filtering, the responses break down as follows (see Figure 1):

- Responses with at least opinions/perceptions Likert-scale rating section complete: 50
- Responses including answers to open-ended questions: 38
- Responses with complete answers to knowledge questions: 18

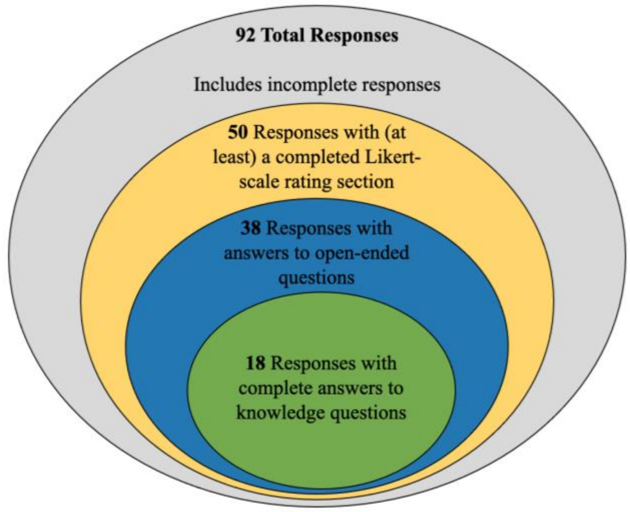


Figure 1. Venn Diagram with breakdown and results of response filtering.

During the analysis, each of the above three elements: Likert-scale rating, open-ended questions and knowledge questions, were analyzed separately.

Demographic Results

For the demographic analysis, the 50 responses which included – at least – a complete Likert-scale rating section were considered. Under the demographic analysis, the following elements are evaluated: employment information, AMT experience, educational background, certification and licenses, age, as well as background/experience with composite materials. Table 1 highlights and summarizes the demographic information obtained.

The majority of the survey respondents are employed at an airline maintenance department, followed second by entire-aircraft repair stations. With regards to positions held, more than half of the respondents indicated that they practice as mechanics/technicians, with the responses reflecting a variety of backgrounds, including – but not limited to – overhaul technicians, structural technicians, and line mechanics. However, there was also representation from the quality control (QC), maintenance control, and managerial positions among the respondents. The participants' experience as aviation maintenance technicians is approximately evenly distributed among all year categories, with the lowest experience being one (1) year and the highest experience being 45 years – both indicated by one participant, respectively.

Table 1
Demographic Information

Demographic Element	Frequency	Percentage
Employment Organization		
Airline Maintenance Department	18	36%
General Aviation/Business Aircraft	4	8%
Maintenance School/Training Facility	3	6%
Manufacturer	2	4%
Military/Government	8	16%
Repair Station – Entire Aircraft	12	24%
Other	3	6%
Current Employment		
Mechanic/Technician/A&P/AMT	33	66%
Mechanic/Technician – Lead or Manager	7	14%
Maintenance Control	1	2%
Instructor	2	4%
Inspection/Quality Control	1	2%
Other	6	12%
Years with Experience as Aviation Maintenance Technician		
0 – 5 Years	13	26%
+5 – 10 Years	15	30%
+10 – 30 Years	11	22%
30+ Years	11	22%
Highest Level of Education Completed		
High School/GED	2	4%
Trade School	11	22%
Associate's Degree	1	2%
Some College	17	34%
Bachelor's Degree	17	34%
Graduate Degree	2	4%
Certificates Held		
Mechanic: Airframe Rating	1	-
Mechanic: Airframe & Powerplant	21	-
Inspection Authorization (IA)	12	-
Mechanic/IA + FCC License	15	-
Mechanic/IA + Pilot's License/Certificate	8	-
IA + Designated Airworthiness Rep.	1	-
Mechanic + Repairman	1	-

The formal education levels represented in the sample range from High School/General Education Diploma (GED) to Graduate degrees, with both extremes representing four percent of the participants. Some form of college education as well as a Bachelor's degree are the most frequent educational levels of the survey participants. Trade school education (i.e., vocational school and/or technical school) follows third – a path that allows for formal aviation maintenance technician training. Lastly, to evaluate the licenses and certificates held by the participants – a crucial factor in the field of aviation maintenance – a non-mutually exclusive list was created, as licenses and certificates can be held in any combination. Therefore, Table 1 does not include percentages for this category. As it was a requirement to participate in the survey, all respondents indicated that they have a mechanic's license with the airframe or the airframe and powerplant ratings. However, a large portion of the participants had additional licenses/certificates, including the inspection authorization (IA), a combination of pilot certificates and licenses, as well as licenses from the Federal Communications Commission (FCC). Additionally, the sample included a Designated Airworthiness Representative (DAR) as well as a certified repairman – both FAA-regulated certifications. Furthermore, aviation maintenance technician training as well as composites-specific training were evaluated separately. Table 2 provides an outline of the type – and when applicable, duration – of aviation maintenance and composite training received.

Of the 50 respondents, 45 received their aviation maintenance training at a technical school, such as a four-year college program or trade school. This training was received, on average, for 1.94 years, with extremes of 0.5 and one year (potentially indicating an early termination of the educational programs) to four years (i.e., as observed in most college-level programs). Fifteen participants received aviation maintenance training through a military program, lasting – on average – slightly below five years. A total of 13 participants received aviation maintenance training through another source – potentially through on-the-job (OTJ) training or through experience. However, it is important to note that the three indicated forms of training can be completed in combination. Therefore, specific combinations of the three main types of training were observed among the survey respondents.

Table 2
Specific Training Information

Aviation Maintenance Training		
Training Source	**Number of Responses**	**Average Duration of Training**
Technical School	45	1.94 Years
Military	15	4.76 Years
Other	13	5.54 Years
Combination: Tech./Military	13	-
Combination: Tech./Military/Other	3	-
Aircraft Composite Materials Education		
Type of Education	**Source of Education**	**Number of Responses**
Formal	Certification Training	18
	Employer	6
	Independent/Voluntary	1
Informal	Experience	17
No composites training/education	-	8

Observing aircraft composites material training and experience specifically, similar trends can be observed. Half of the respondents indicated that they received formal education in the field of aircraft composite materials, with certification training – as for instance FAA-regulated AMT training – being the most popular form of education. While a few individuals indicated that either a current or a formal employer sponsored/provided composites training, one participant completed specific training in the field on a voluntary basis.

Approximately 80% of the survey respondents – specifically 41 of the 50 respondents – have experience working with composite aircraft/materials. The form of the experience, however, varies, as shown in Table 3. The list provided in Table 3 is non-mutually exclusive, so that each category can be indicated more than once per respondent. The most frequent source of experience is performing maintenance and repairs (or minor field repairs) on composite aircraft, followed by experience gained through education and/or training. A comparatively small number of respondents indicated gaining experience from a manufacturing and/or design engineering environment, while one participant indicated having worked with composite materials on experimental aircraft.

Table 3
Composites-Specific Experience

Experience Type	Number of Responses
Educational/Training Context	18
Maintenance, repairs, and overhauls	33
Manufacturing	7
Others – Minor Field Repairs	1
Others – Design Engineering	1
Others – Experimental Aircraft	1

Perceptions and Opinions Results

The results obtained from the second section of the questionnaire, relating to the opinions and perceptions of AMTs with respect to composite materials, are divided into two sections. First, the results from the Likert-scale rating statements are presented in terms of the frequency of responses. Second, the results from the open-ended questions are analyzed through basic, essential qualitative analysis to identify reoccurring themes among the responses.

Likert-Scale Results

A total of 25 Likert-scale ranking questions were employed in the survey, with a six-point scale ranging along the strongly disagree (1) to strongly agree (6) spectrum. The detailed ranking statements are found in the complete questionnaire in the *Appendix.* Figures 2 through 5 below visually represent the statements to be ranked and their relative rankings.

Questions 18, 19, and 27 as well as questions 13, 14, 30, and 31 are related to the training and understanding, respectively, of aircraft maintenance technicians in the fields of both, metal and composite aircraft repair/maintenance. The opinions and perceptions of the survey participants in these areas are reflected in Figure 2. With individual exceptions, it can be seen that, overall, technicians believe that their training has prepared them better for the maintenance and repair of metal airframes. Similarly, while 37 respondents agree in some form that their training was adequate for a career focused on metal-based aircraft, only 24 respondents claim the same for a career focused on composite-based aircraft. Moreover, the most frequent rating for the statement “My training and education have adequately prepared me to work with composite aircraft structures” is a 2 on the used Likert-scale, thus reflecting disagreement, while the same statement but for metal aircraft is most frequently rated as a 6 – “Strongly agree”. The differences in metal- and composite-oriented training and education further affect the understanding of the respective disciplines. The distribution of respondents indicating an understanding of the consequences of damages to metal aircraft structures is clearly left-skewed, highlighting that only a few mechanics do not believe that they understand the consequences of metal failures. Evaluating the same statement but focusing on the understanding of composite failures and the consequences thereof, it can be seen that the shape of the distribution changes. The majority of the respondents indicated that they agree with the following statement: “I fully understand the consequences of damages to aircraft composite structures”. However, comparatively, the number of respondents that indicated that they do not agree with the above statement is greater in reference to composite structures than to metal structures. Similarly, most respondents noted that they understand elements related to metal aircraft maintenance. However, a different response pattern was observed in reference to composite aircraft maintenance. Specifically, in reference to composite aircraft maintenance, the responses along the disagree-agree spectrum are more equally distributed.

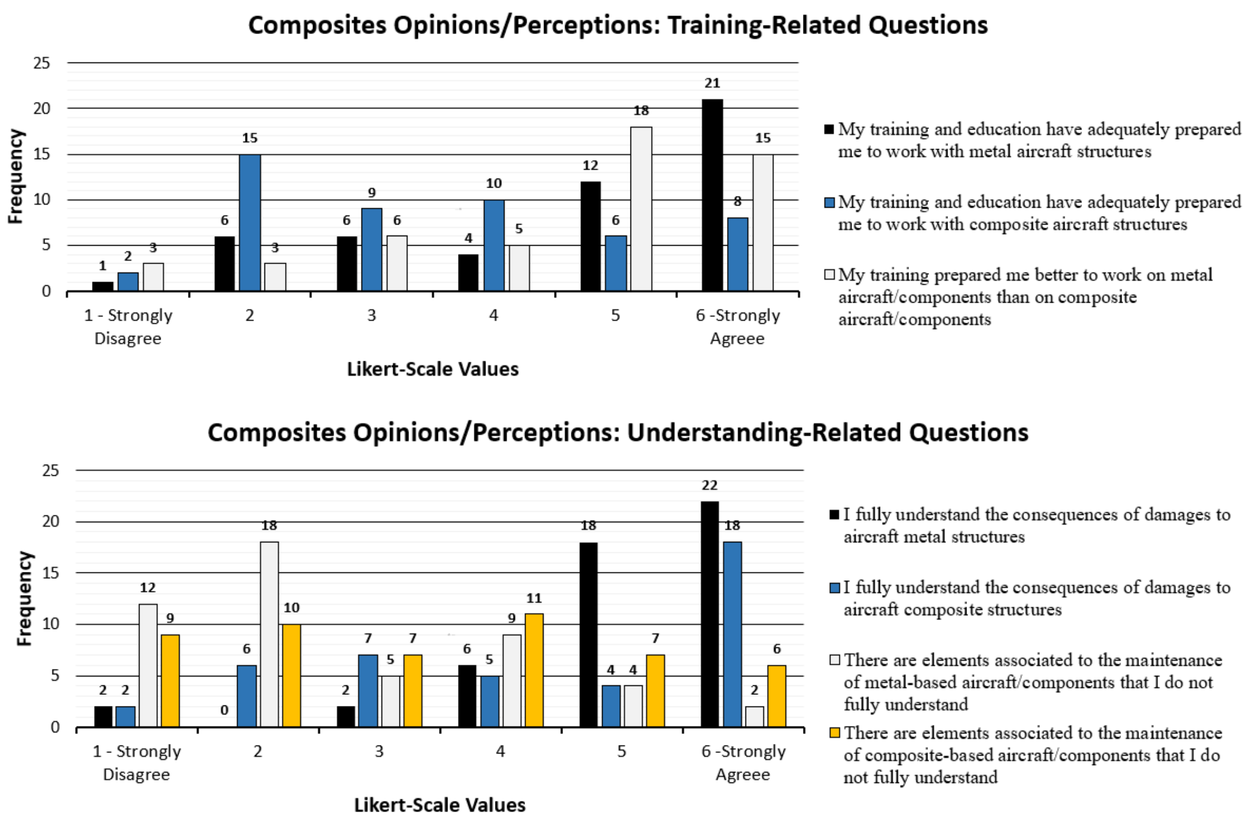


Figure 2. Responses on training and understanding of metal/composite aircraft maintenance.

Differences in the responses were also observed when evaluating maintenance-related elements such as time, confidence, and ease. Specifically, questions 13, 20, 21, 22, 23, 24, and 25, as shown in Figure 3, related to the aforementioned topics. The majority of the respondents, specifically 31, indicated that more time is required to perform repair activities on composite aircraft than on metal aircraft, with 18 respondents strongly agreeing that composite repairs are more time consuming than metal repairs. With regards to confidence, similar trends in answers are observed for metal and composite repairs. For both, metal- and composite-based aircraft/components, a left-skewed distribution is observed, indicating that more responses are recorded in the "agree" section of the Likert-scale. Nevertheless, the extremes of both distributions differ. On one hand, for metal aircraft, 22 respondents indicated that they "strongly agree" with the indicated confidence statement. On the other hand, for composite aircraft, a lower number – specifically 10 respondents – indicated a strong agreeance with the statement presented. This trend is similarly highlighted by the blue series on the graph, as six participants indicated that they feel more confident performing maintenance/repairs on metal aircraft.

Considering the actual difficulty of performing maintenance activities on metal- and composite-based aircraft, participants' responses converged toward the center of the Likert-scale range. Combined, 19 participants – 38% of the responses – indicated small agreement and disagreement with metal-based aircraft being easier to work on than composite-based aircraft.

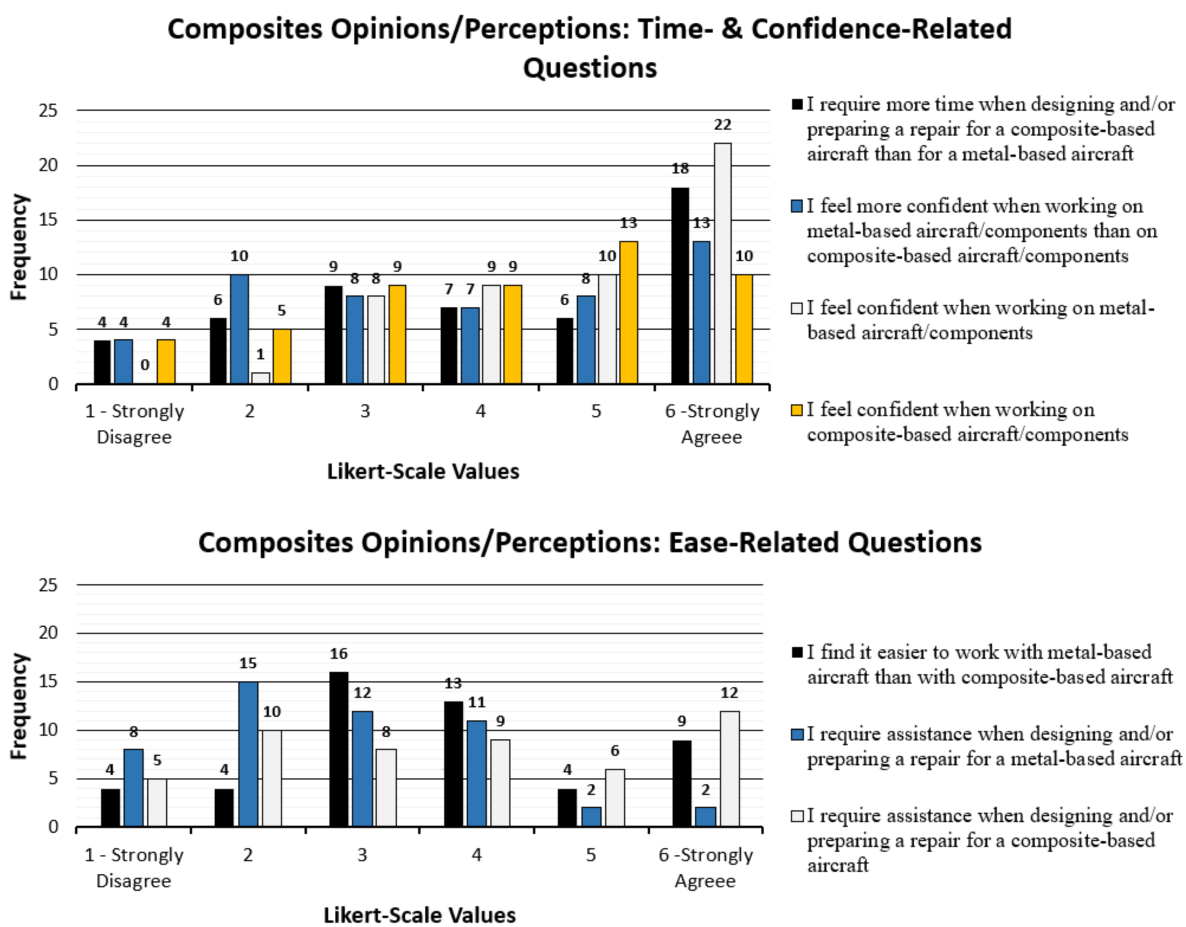
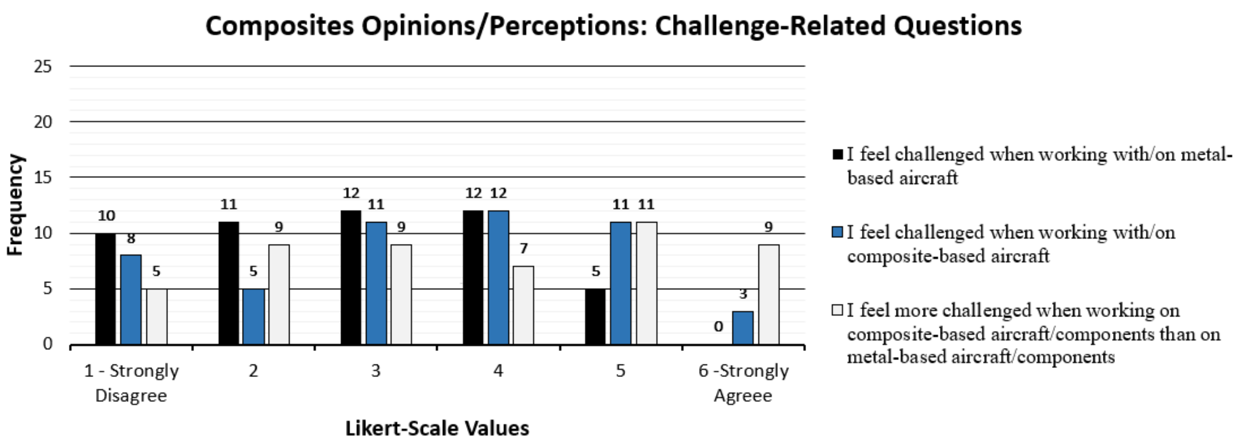


Figure 3. Responses on time, confidence and ease of metal/composite aircraft maintenance.

Moreover, the responses are approximately evenly split across the agree-disagree spectrum: 24 responses are on the disagreement side while 26 responses are on the agreement side. However, the responses start differing when focusing on the need/requirement for assistance during the repair process. The majority of the participants indicated a certain degree of disagreement with the following statement: "I require assistance when designing and/or preparing a repair for a metal-based aircraft", resulting in a right-skewed distribution. However, the same statement in reference to composite-based aircraft yields a more even distribution. Even though the mode is located at the Likert-scale value of "6 – Strongly agree" with 12 responses, the responses are approximately evenly distributed along the spectrum: 23 responses fall along the disagreement spectrum while 27 responses fall along the agreement spectrum.

Challenges encountered, detectability of errors, as well as the errors made when performing maintenance and repair activities on metal- and composite-based aircraft are evaluated under questions 16, 17, 26, 34, 35, 36, and 37. The results obtained from the Likert-scale rating to these questions are visually represented in Figure 4. At a first glance, the distribution of the three challenge-related statements appears to be even, equally distributed on the scale, and similar for metal and composite aircraft. However, small but notable differences can be appreciated. For instance, with regards to the first statement – "I feel challenged when working with/on metal-based aircraft" – the responses are approximately evenly distributed among ratings "1" through "4", but drastically decrease in the two upper-limit ratings. No participants indicated maximum agreement – "6 – Strongly agree" – to said statement. The distribution of the answers to "I feel challenged when working with/on composite-based aircraft" is similar to the statement for metal-based aircraft, with slight differences towards the extremes of the scale. Specifically, fewer participants selected the two extreme ratings on the "disagree" end of the scale, while more participants selected the two extreme ratings on the "agree" end of the spectrum. These minute differences indicate a slight increase in the level of challenge when performing maintenance/repair activities on composite structures and components. This minute difference is similarly reflected and synthesized in the third statement: "I feel more challenged when working on composite-based aircraft/components than on metal-based aircraft components". As was observed in previous instances, the answers are approximately evenly distributed on the disagree-agree spectrum. Nevertheless, the "agree" spectrum, indicating more challenges when working on composite-based aircraft components, was selected by 27 participants. More divergence in responses is observed evaluating the rankings for the error-related statements. Participants indicated that errors are more quickly/easily recognizable in metal-based aircraft/components. Specifically, with regards to metals, 43 responses are found on the "agree" spectrum, while only 18 responses are found on the "agree" spectrum for composites. When evaluating the frequency of errors made on metal and composite aircraft, respectively, a different distribution of responses was obtained dependent on the directionality of the statement presented. First, when the statement is phrased indicating more errors being made on metal aircraft – the series in white on the second graph in Figure 4 – the distribution is right-skewed, indicating that most respondents do not believe that more errors are made on metal aircraft. However, when the statement is phrased indicating more errors being made on composite aircraft – the series in yellow on the second graph in Figure 4 – the distribution is approximately symmetrically distributed with a peak around rating "3". Moreover, 26 of the responses fall on the "disagree" side of the spectrum, conflicting with the previous responses obtained.

Lastly, in Figure 5, statements with regards to the demand experienced by mechanics (corresponding to questions 28, 29, 32, and 33) are evaluated. Three statements (black, blue, and white series) reflect a similarly right-skewed shape, while the last statement – yellow series – is centered and approximately evenly distributed along both sides of the spectrum. For both, metal and composite aircraft maintenance/repairs, answers were more frequent on the "disagree" end of the spectrum. Furthermore, "1 – Strongly disagree" was the most frequently selected ranking for both statements. Combined, these two characteristics indicate that the majority of mechanics do not feel highly overwhelmed while performing maintenance/repair activities on either form of structure. However, it is important to note that, for composite aircraft, 13 participants indicated a certain degree of feeling overwhelmed, while only two participants indicated the same for metal aircraft. With regards to mental demand, a slight right-skew is observed for metal aircraft. For the statement "Working on metal-based aircraft/components is mentally demanding", 19 participants indicated that they agree therewith, with three indicating that they "strongly agree". The mode for this statement, with 12 responses, concentrates along the rankings of "2" and "3", both on the "disagree" end of the spectrum.



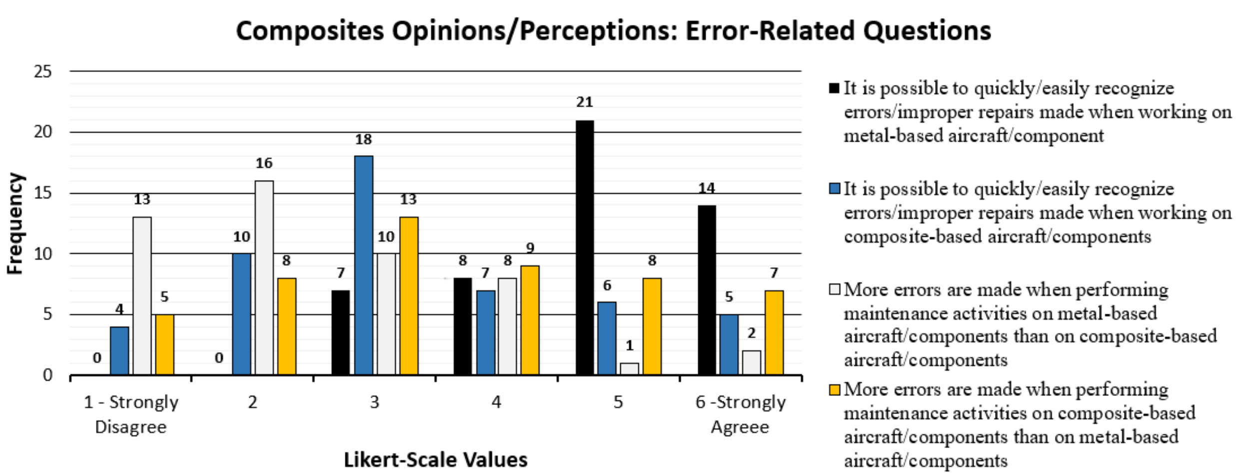


Figure 4. Responses on challenges and errors of metal/composite aircraft maintenance.

The same statement but worded for composite aircraft resulted in a distinct shape. The mode thereof, with 13 responses, concentrates along the rankings of "3" and "4", with a slight majority of the responses (26 specifically) being recorded on the "agree" end of the spectrum. The differences in the distribution of the answers are indicative of higher levels of mental demand being experienced, on average, when performing repair and maintenance activities on composite-based aircraft/components.

Open-Ended Questions

As mentioned above, the results from the 10 open-ended questions included in the questionnaire are categorized and grouped by reoccurring themes, with the purpose of identifying trends in opinions and perceptions. Table 4 highlights the reoccurring themes categorized as well as the frequency of the respective categories.

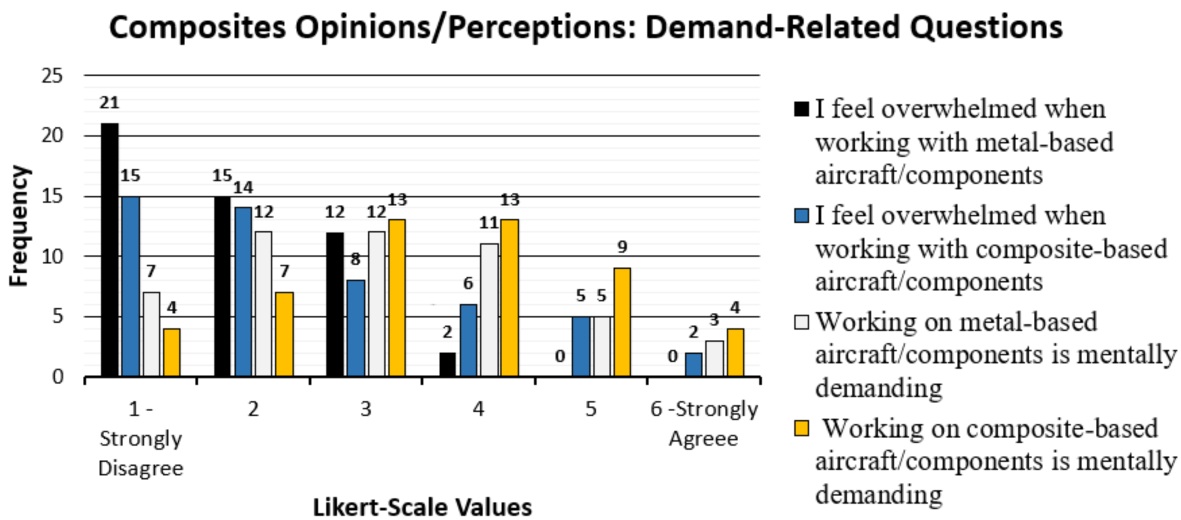


Figure 5. Responses on demand of metal/composite aircraft maintenance.

A larger number of participants indicated a preference for working on metal-based aircraft/components than on the composite counterpart. Specifically, two reasons for this difference are explained to be the comparative simplicity and ease of working with metallic-based structures as well as more background knowledge, training, experience, and confidence mechanics have – or have gathered – with regards to metal-based aircraft/component maintenance/repair activities. However – even with the majority of participants indicating a preference for metal-based maintenance/repair activities – some responses highlighted a preference for composite-based maintenance/repair activities, while six participants indicated that they do not have a preference.

To understand the divergence in opinions with regards to the preference, two elements were studied. First, opinions with regards to the likes and dislikes of each, metal- and composite-based maintenance and repair activities were gathered. Second, opinions related to elements that complicate and add difficulty to each material's respective maintenance/repair activities were obtained. For both materials, elements related to the actual repair processes, material characteristics, as well as the knowledge, training, experience of the workforce were frequently quoted as both benefits and drawbacks. However, more nuanced but less frequently-quoted elements present salient differences. For instance, working with composite materials has been quoted by participants to be more flexible, where mechanics enjoy the properties composite materials present, the modern technology used, and the challenges presented. On the other hand, maintenance/repair activities on metal structures are quoted to present benefits in the form of availability of resources as well as reduced time requirements to complete said repairs. Furthermore, when evaluating composite repairs specifically, trends emerge that were not indicated for metal-based repairs. Themes related to identifying damages, setting-up a repair, controlling the variables influencing the repair, and validating the repair were more represented in the responses related to composite structures. However, as aforementioned, these results do not indicate that maintenance and repair activities on metallic structures are not accompanied by challenges or do not present difficulties. Instead, they intend to highlight differences that affect the maintenance/repair activities of composite-based aircraft/components specifically. The following quote from one participant summarizes the responses to the open-ended questions: "Composite maintenance requires greater knowledge of material performance, care, and environmental control. Metal maintenance is so established that it is relatively easy to find expertise and to train others, and is far less nuanced".

Table 4
Summary of Open-Ended Questions

Question/Topic		Themes	Frequency
Preference: Working with metal- vs. composite-based aircraft/ components?	Preference for *composites*	Experience, training, & background	2
		More detailed instructions	1
	Preference for *metal*	Simplicity/Ease	5
		Less chemicals	1
		Experience, training, confidence, & background	8
		More satisfying to work with	1
		Equipment availability and requirements	2
	No preference		6
Working with metal-based aircraft/ components	Likes	Familiarity, simplicity, and ease of use	11
		Damage resistance and identification	5
		Availability of resources	2
		Work/repair/material-related elements	16
		Time (quicker to repair)	2
	Dislikes	Accessibility	4
		Work/repair/material-related elements	11
		Health and safety aspects	5
		Complexity/difficulty in repairs	2
Working with composite-based aircraft /components	Likes	Work/repair-related elements	5
		Manufacturing/repair processes	6
		Material characteristics	7
		Ease and flexibility	5
		Challenge and learning	3
	Likes	Modern technology	1
	Dislikes	Maintenance/Repair processes	9
		Specialty tools	2

Question/Topic		Themes	Frequency
Working with composite-based aircraft /components (ctd')		Reduced experience/knowledge	3
		Airworthiness aspects/Repair validation	2
		Messiness	5
		Health aspects	4
Difference: Metal- vs. composite-based aircraft/ components maintenance	Composite maintenance has a higher standard of quality (more knowledge, care, and control)		2
	Different forms of deterioration and damage		1
	Different tooling and maintenance/repair techniques		6
	Different training		1
	Metal repairs are more permanent		1
	Metal maintenance/repair requires more skill		1
	No difference between the two types of maintenance		2
Difficulties during maintenance	Metal-based aircraft	Accessibility	10
		Fastener-related issues	5
		Potential for dents and cracks	4
		Metal characteristics (i.e. corrosion)	5
		Time and precision requirements	2
		Tooling issues	3
		Repair requirements (i.e. positioning, sealing)	2
		Size/weight of components/tooling	1
		Knowledge, experience, confidence, & training	4
		Unable to form complex repair shapes in field	2
		Maintenance documentation	1
	Composite-based aircraft	Failed/Improper repairs	5
		Need for specific products/materials/tools	7
		Environmental control concerns	5
		Damage creation and identification	4
		Complex lay-ups	3
		Hard to identify and correct mistakes	2
		Work area set-up	1
		Detail orientation	1
		Knowledge, experience, confidence & training	5
		Health hazards	1
		Messiness	2

Knowledge Question Results

The results from the knowledge questions are presented in Table 5 and Figures 6 and 7, highlighting the number and percentage of correct responses to the knowledge questions included in the questionnaire (refer to the *Appendix).* As indicated previously, 18 participants provided full responses to the knowledge questions.

Observing the histogram in Figure 6 as well as the results summarized in Table 5, it can be seen that precisely half of the questions were answered correctly by more than 50% of the participants, while the remaining half were answered correctly by less than 50% of the participants. However, no single question was answered correctly – or incorrectly – by all the participants. The mode – with six questions – is a score range from 10% to 20%. The category with the highest score range – 90% to 100% – includes four questions with a correct answer rate of 94.44% (17 correct answers from 18 respondents).

Table 5
Summary of Knowledge Question Results

Question	Correct Answers	Percentage Correct	Question	Correct Answers	Percentage Correct
1	16	18.89%	**15**	7	18.89%
2	16	18.89%	**16**	11	18.89%
3	9	50%	**17**	11	50%
4	4	22.22%	**18**	14	22.22%
5	2	11.11%	**19**	11	11.11%
6	11	61.11%	**20**	15	61.11%
7	6	33.33%	**21**	11	33.33%
8	13	72.22%	**22**	12	72.22%
9	12	66.67%	**23**	14	66.67%
10	17	94.44%	**24**	16	94.44%
11	17	94.44%	**25**	16	94.44%
12	15	83.33%	**26**	13	83.33%
13	13	72.22%	**27**	15	72.22%
14	5	27.78%	**28**	14	27.78%

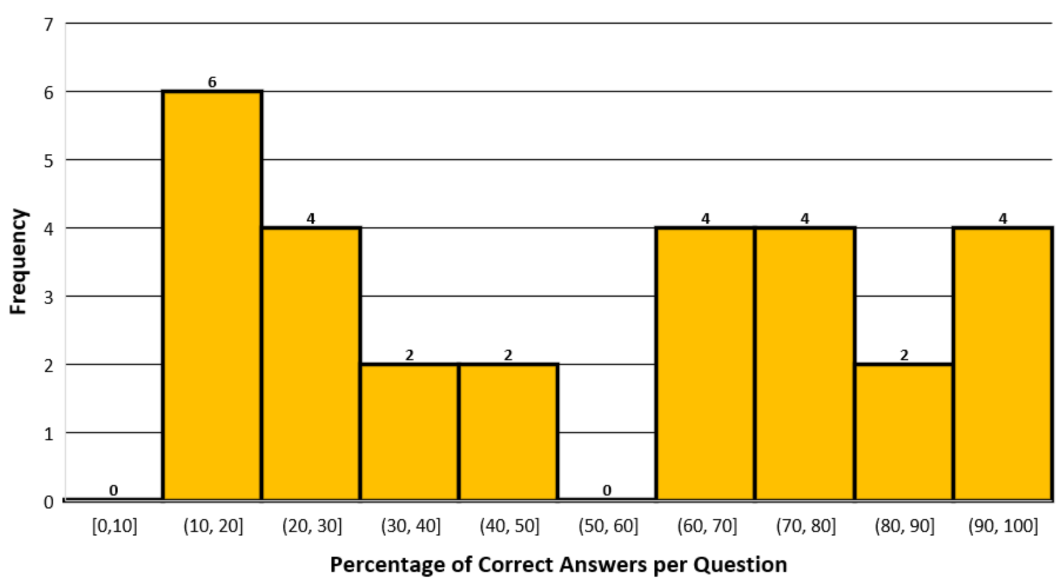


Figure 6. A&P knowledge questions results: Correct answers per question.

Figure 7 highlights the distribution of test scores obtained. The lowest score obtained was 42.86%, corresponding to 12 out of 28 questions being answered correctly. The highest score obtained was a 96.43%, corresponding to 27 out of 28 questions being answered correctly. The two most frequent scores were 64.29% (18 out of 28 questions correct) and 78.57% (22 out of 28 questions correct), each occurring three times. The average score equals 66.87%. Adhering to FAA passing scores, where a 70% or higher is required to obtain a passing grade (FAA, 2015) only eight participants (less than half) would have passed the test presented.

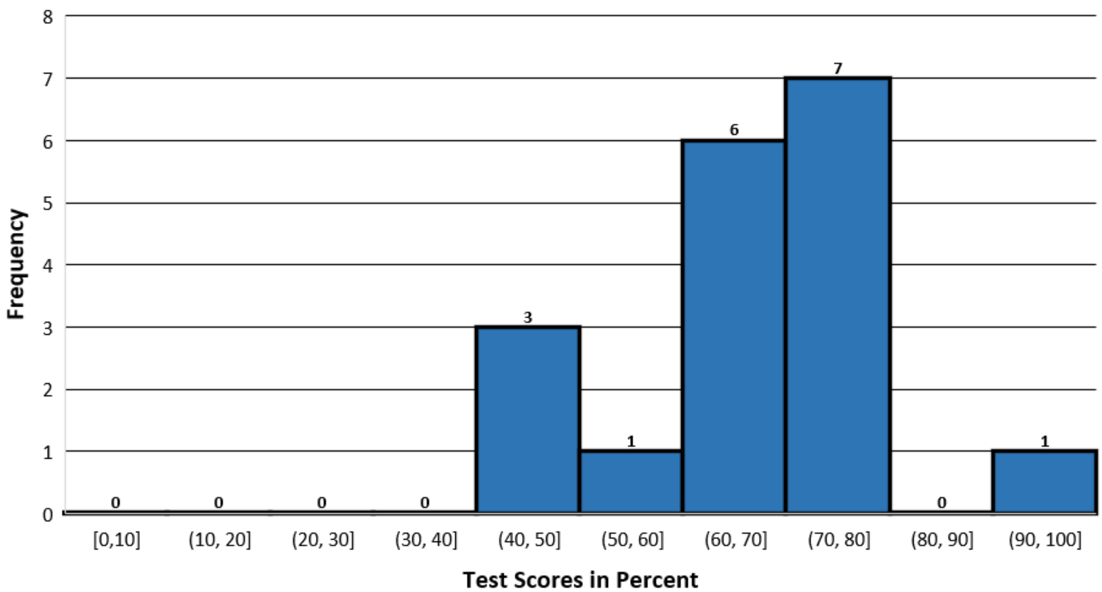


Figure 7. A&P knowledge questions results: Test scores.

Discussion

With developments in technology, it is crucial to adapt and adjust the underlying systems and procedures that support the technological improvements throughout their lifecycle. In the case of composite materials and their application in the aviation industry, activities including maintenance and repair of airframes, structures, and components need to be adjusted to meet the needs of the changing aircraft composition. As a pivotal element of maintenance and repair activities, aircraft mechanics – and more specifically A&P certified technicians – require the appropriate training and resources to upkeep the composite aircraft fleet.

Considering education specifically, even though 41 participants (~80% of the respondents) have experience working with composite materials, only 25 participants (50% of the respondents) received formal education in the field. Further exacerbating these results, the respondents to the survey indicated that there is a gap between the training of composite- and metal-based maintenance/repair activities, where the training received better prepares individuals for a career maintaining a metal-based fleet rather than a composite-based fleet. When evaluating the FAA-mandated curriculum for technician education (Title 14 C.F.R. Part 147 Appendix C, 2017), the context for the discrepancies in training perception can be understood. The curriculum mandated and prescribed by the FAA prioritizes instruction on principles of wood/dope- and metal-based aircraft repair and maintenance, while topics related to composite materials are scarce in content with the individual AMT schools being responsible for further composite in-depth education (Title 14 C.F.R. Part 147 Appendix C, 2017). As introduced by Hobbs et al. (2009) and mirrored by the results of this study, the training requirements do not accurately represent or meet the needs and demands of the aviation industry. Examples of suggested additional composite-related areas of education include, but are not limited to, repair techniques for glass fiber, carbon fiber, Kevlar and boron reinforced composites, introduction to the tooling and equipment required for composite repair activities, as well as composite-specific nondestructive inspection coursework (FAA, 2015).

The repercussion of reduced, or limited, formalized training in the area of aircraft composite materials is further reflected in safety-critical aspects. First, participants indicated a comparatively higher understanding of, and confidence in, maintenance/repair-related aspects for metal-based aircraft than for composite-based aircraft. Second, relating to challenges felt during maintenance activities, a slight but notable skew towards composite maintenance/repairs being perceived as more challenging is observed, as indicated in literature by Kroes and Sterkenburg (2013). Moreover, in terms of error-recognizability, participants indicated that maintenance/repair errors on metal aircraft are easier to identify than on composite aircraft – a further threat to safety. These trends are also reflected in both, the open-ended perception/opinions questions posed as well as the composites knowledge questions. Training, knowledge, confidence, and experience – specifically, the lack thereof – was frequently quoted as a disadvantage, downside, and aspect adding difficulty to composite-based maintenance activities. As above-mentioned, less than half of the participants that provided full answers to the knowledge questions would have met the FAA standard 70% passing score on the knowledge questions – further indicating reduced knowledge in the topical area. These results must be further considered in relation to the demographic data described in Tables 1, 2, and 3. More than half of the respondents (specifically 80%) have experience working on composites, and 90% indicated completing their training at an AMT school. In theory, the education provided should have equipped technicians with the tools and knowledge to be knowledgeable in, and confident with, the materials encountered in the industry. Furthermore, AMTs working with composites are expected to be familiar with the basics thereof. However, the knowledge test results do not reflect these expectations. There are two potential explanations for the results obtained. First, the knowledge questions are not reflective of the composite-related knowledge taught at technical institutions or of the composite-related maintenance activities and repairs performed in the industry. Second, AMTs are not sufficiently familiar with the topic of composite-related maintenance and repair activities. Similarly, the fact that composite maintenance/repairs are perceived to be more challenging was identified by participants as well, even though the challenge was identified as a positive element. Lastly, difficulties identifying damage in composite structures and a more complex repair validation process were indicated by respondents as additional challenges in the open-ended questions, lining up with the results from the Likert-scale rating questions.

Lastly, in addition to downsides pertaining to elements such as composite knowledge, education, and challenges, the maintenance/repair industry appears to not be prepared to perform the required maintenance/repair activities on composite structures. As was indicated by Ostrom and Wilhelmsen (2008), Kroes and Sterkenburg (2013), and Werfelman (2007) composite maintenance and repair activities require a different set of tools, equipment, and resources.

However, per the responses obtained in the open-ended segment of the questionnaire, the required resources, such as specialized tools, are not always available, adding further challenges to the tasks at hand.

Limitations and Future Work

The main limitation present in the conducted study is the low response rate, specifically to the open-ended questions section. Moreover, the categorization of the qualitative results – specifically the responses to the open-ended question – was based on the knowledge and experience of the authors, potentially adding subjectivity into the study. Therefore, the generalizability of the results obtained needs to be carefully considered. Similarly, even though – as provided by the demographics results – the respondents were from a variety of backgrounds, the sample is only representative of the aircraft maintenance technician workforce in the United States, adding further limitations to the generalizability.

It is suggested for future research to expand the study to aircraft maintenance technicians employed in different countries or that received AMT training and certification from aviation regulatory authorities outside of the United States. Subsequently, different training and certification regulations can be compared and evaluated in the area of composites education, while expanding the generalizability of the results. Moreover, future research efforts should focus on methods to address the shortcomings of composite-related AMT education highlighted in the study. Specifically, a cooperative research approach including representatives from AMT schools, regulatory agencies, as well as technicians performing composite repairs is recommended to meet the needs of the industry and bridge the gap identified by the results obtained in the presented study.

Conclusion

The study conducted aimed to identify the opinions and perceptions of airframe/airframe & powerplant certified mechanics in the United States on the topic of composite-based aircraft maintenance and repair activities. As the use of composite materials increases in the aviation industry, the related maintenance activities need to be adjusted accordingly. However, antiquated mandated training together with more intrinsically complicated structures and a lack of resources, complicate the maintenance of composite-based aircraft structures.

The results from the performed study indicate that aircraft maintenance technicians' training in the area of composite aircraft maintenance/repair is not adjusted to the current needs of the industry. In turn, the understanding of composite damages and respective repair mechanisms is decreased (as shown through the opinion/perception and knowledge questions), increasing the challenges faced by mechanics and presenting potential safety hazards. Adding thereto is the inability of certain existing maintenance/repair facilities to sustain the maintenance/repair activities of composite-airframes due to a lack of specific resources. Therefore, for composite-based maintenance activities to reach the maturity level of metal-based maintenance activities, changes in the required training are necessary while the respective maintenance/repair facilities need to be overhauled to include the resources to sustain the maintenance/repair activities of composite structures.

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Appendix
DISTRIBUTED SURVEY

Demographic Questions

1. Select the type of organization in which you work:

    ____ Airline Maintenance Department

    ____ Repair Station (Entire aircraft)

    ____ Repair Station (Components only)

    ____ Manufacturer

    ____ General Aviation/Business Aircraft Operations

    ____ Military/Government Fixed Base Operator

    ____ Other Military/Government

    ____ Maintenance School/Training Facility

    ___ Other (specify):

2. State your job title:

3. Years in current position:

4. Years with experience as an aviation maintenance technician:

5. Select the highest level of education completed:

    ____ High School graduate/GED

    ____ Trade School

    ____ Some college

    ____ Bachelor’s degree

    ____ Graduate degree

    ____ Other (specify):

6. Indicate the type and years (in numerical form) of maintenance training you received. If you did not receive one of the listed types, insert "0" in the respective field:

   ____ Technical School - ____ years

   ____ Military - ____ years

   ____ Other - ____ years

7. FAA certification:

   ____ None

   ____ Yes

8. Licenses or certificates currently held (check all that apply):

   ____ Airframe

   ____ Powerplant

   ____ Inspection Authorization

   ____ Private

   ____ Commercial

   ____ FCC

   ____ Other(s) (specify):

   ____ None

Indicate your age:

   ____ Under 25

   ____ 26 – 35

   ____ 36 – 45

   ____ 46 – 55

   ____ 56 – 65

____ 65 +

9. List up to five of the aircraft you currently work on and indicate the length of time you have worked on them

Aircraft	Specialty area (i.e. avionics, airframe, engines, ALL, etc.)	Time worked on aircraft

10. Have you received formal education in the area of aircraft composite materials?

____ No

____ No, but gained through experience

____ Yes – As part of/provided by (Select all that apply):

____ Certification training (i.e. Part 147 curriculum)

____ Current or previous employer

____ Independent/Voluntary additional training

____ Other (specify):

11. Do you have experience working with composite aircraft or materials?

____ No

____ Yes - ____ Years - Type of experience (Select all that apply):

____ Educational/Training context
____ Manufacturing
____ Maintenance, repairs, and overhauls
____ Other (specify):

Opinions and Perceptions

Ranking Statements

Rate the following statements using the given scale:

12. I find it easier to work with metal-based aircraft than with composite-based aircraft

1 Strongly disagree	2	3	4	5	6 Strongly agree

13. I fully understand the consequences of damages to aircraft metal structures

1 Strongly disagree	2	3	4	5	6 Strongly agree

14. I fully understand the consequences of damages to aircraft composite structures

1 Strongly disagree	2	3	4	5	6 Strongly agree

15. I feel challenged when working with/on metal-based aircraft

1 Strongly disagree	2	3	4	5	6 Strongly agree

16. I feel challenged when working with/on composite-based aircraft

1 Strongly disagree	2	3	4	5	6 Strongly agree

17. My training and education have adequately prepared me to work with metal aircraft structures

1	2	3	4	5	6

Strongly disagree	Strongly agree

18. My training and education have adequately prepared me to work with composite aircraft structures

1	2	3	4	5	6
Strongly disagree					Strongly agree

19. I require more time when designing and/or preparing a repair for a composite-based aircraft than for a metal-based aircraft

1	2	3	4	5	6
Strongly disagree					Strongly agree

20. I require assistance when designing and/or preparing a repair for a metal-based aircraft

1	2	3	4	5	6
Never					Very frequently

21. I require assistance when designing and/or preparing a repair for a composite-based aircraft

1	2	3	4	5	6
Never					Very frequently

22. I feel more confident when working on metal-based aircraft/components than on composite-based aircraft/components

1	2	3	4	5	6
Strongly disagree					Strongly agree

23. I feel confident when working on metal-based aircraft/components

1	2	3	4	5	6
Strongly disagree					Strongly agree

24. I feel confident when working on composite-based aircraft/components

1	2	3	4	5	6
Strongly disagree					Strongly agree

25. I feel more challenged when working on composite-based aircraft/components than on metal-based aircraft/components

1	2	3	4	5	6
Strongly disagree					Strongly agree

26. My training prepared me better to work on metal aircraft/components than on composite aircraft/components

1	2	3	4	5	6
Strongly disagree					Strongly agree

27. I feel overwhelmed when working with metal-based aircraft/components

1	2	3	4	5	6
Never					Very frequently

28. I feel overwhelmed when working with composite-based aircraft/components

1	2	3	4	5	6
Never					Very frequently

29. There are elements associated to the maintenance of metal-based aircraft/components that I do not fully understand

1	2	3	4	5	6
Strongly disagree					Strongly agree

30. There are elements associated to the maintenance of composite-based aircraft/components that I do not fully understand

1 Strongly disagree	2	3	4	5	6 Strongly agree

31. Working on metal-based aircraft/components is mentally demanding

1 Strongly disagree	2	3	4	5	6 Strongly agree

32. Working on composite-based aircraft/components is mentally demanding

1 Strongly disagree	2	3	4	5	6 Strongly agree

33. It is possible to quickly/easily recognize errors/improper repairs made when working on metal-based aircraft/component

1 Strongly disagree	2	3	4	5	6 Strongly agree

34. It is possible to quickly/easily recognize errors/improper repairs made when working on composite-based aircraft/components

1 Strongly disagree	2	3	4	5	6 Strongly agree

35. More errors are made when performing maintenance activities on metal-based aircraft/components than on composite-based aircraft/components

1 Strongly disagree	2	3	4	5	6 Strongly agree

36. More errors are made when performing maintenance activities on composite-based aircraft/components than on metal-based aircraft/components

1	2	3	4	5	6
Strongly disagree					Strongly agree

<u>Open-Ended Questions</u>

37. Do you prefer working with metal- or composite-based aircraft/components?

    a. Why?

38. What aspects of working with metal-based aircraft/components do you like?

39. What aspects of working with metal-based aircraft/components do you dislike?

40. What aspects of working with composite-based aircraft/components do you like?

41. What aspects of working with composite-based aircraft/components do you dislike?

42. In your opinion, how do maintenance activities of metal- and composite-based aircraft/components differ from each other?

43. List some difficulties you experience/have experienced when performing maintenance activities on metal-based aircraft

44. List some difficulties you experience/have experienced when performing maintenance activities on composite-based aircraft

45. List some factors that, in your opinion, complicate the maintenance of composite-based aircraft

46. List some factors that, in your opinion, complicate the maintenance of metal-based aircraft

Knowledge Questions

1. Metal fasteners used with carbon/graphite composite structures *(ASA 8053)*
    a. May be constructed of any of the metals used in aircraft fasteners
    b. Must be constructed of materials such as titanium or corrosion resistant steel
    c. Must be constructed of high strength aluminum-lithium alloy

2. Sandwich panels made of metal honeycomb construction are used on modern aircraft because this type of construction *(ASA 8054)*
    a. Has a high strength to weight ratio
    b. May be repaired by gluing replacement skin to the inner core material with thermoplastic resin
    c. Is lighter than single sheet skin of the same strength and is more corrosion resistant

3. (1) When performing a ring (coin tap) test on composite structures, a change in sound may be due to damage or transition to a different internal structure
   (2) The extent of separation damage in composite structures in most accurately measured by a ring (coin tap) test *(ASA 8055)*
    a. Both No. 1 and No. 2 are true
    b. Only No. 1 is true
    c. Only No. 2 is true

4. Which of these methods may be used to inspect fiberglass/honeycomb structures for entrapped water? *(ASA 8056)*
   1. Acoustic emission monitoring
   2. X-Ray
   3. Backlighting
    a. 1 and 2
    b. 1 and 3
    c. 2 and 3

5. When repairing puncture-type damage of a metal faced laminated honeycomb panel, the edges of the doubler should be tapered to *(ASA 8058)*
    a. Two times the thickness of the metal
    b. 100 times the thickness of the metal
    c. Whatever is desired for a neat, clean appearance

6. One of the best ways to assure that a properly prepared batch of matrix resin has been achieved is to *(ASA 8059)*
    a. Perform a chemical composition analysis
    b. Have mixed enough for a test sample
    c. Test the viscosity of the resin immediately after mixing

7. How does acoustic emission testing detect defects in composite materials? *(ASA 8060)*
    a. By picking up the “noise” of any deterioration that may be present

   b. By analyzing the ultrasonic signals transmitted into the parts being inspected
   c. By creating sonogram pictures of the areas being inspected

8. What precaution, if any, should be taken to prevent corrosion inside a repaired metal honeycomb structure? *(ASA 8061)*
   a. Prime the repair with a corrosion inhibitor and seal from the atmosphere
   b. Paint the outside area with several coats of exterior paint
   c. None. Honeycomb is usually made from a manmade or fibrous material which is not susceptible to corrosion

9. One method of inspecting a laminated fiberglass structure that has been subjected to damage is to *(ASA 8062)*
   a. Strip the damaged area of all paint and shine a strong light through the structure
   b. Use dye-penetrant inspection procedures, exposing the entire damaged area to the penetrant solution
   c. Use an eddy current probe on both sides of the damaged area

10. When inspecting a composite panel using the ring test/tapping method, a dull thud may indicate *(ASA 8063)*
    a. Less than full strength curing of the matrix
    b. Separation of the laminates
    c. An area of too much matrix between fiber layers

11. The length of time that a catalyzed resin will remain in a workable state is called the *(ASA 8065)*
    a. Pot life
    b. Shelf life
    c. Service life

12. A category of plastic material that is capable of softening or flowing when reheated is described as *(ASA 8066)*
    a. Thermoplastic
    b. Thermocure
    c. Thermoset

13. Superficial scars, scratches, surface abrasions, or rain erosion on fiberglass laminates can generally be repaired by applying *(ASA 8069)*
    a. A piece of resin-impregnated glass fabric facing
    b. One or more coats of suitable resin (room-temperature catalyzed) to the surface
    c. A sheet of polyethylene over the abraded surface and one or more coats of resin cured with infrared heat lamps

14. Composite fabric material is considered to be the strongest in what direction? *(ASA 8072)*
    a. Fill
    b. Warp
    c. Bias

15. What reference tool is used to determine how the fiber is to be oriented for a particular ply of fabric? *(ASA 8073)*
    a. Fill clock (or compass)
    b. Bias clock (or compass)
    c. Warp clock (or compass)

16. The strength and stiffness of a properly constructed composite buildup depends primarily on *(ASA 8074)*
    a. A 60% matrix to 40% fiber ratio
    b. The orientation of the plies to the load direction
    c. The ability of the fibers to transfer stress to the matrix

17. Which fiber to resin (percent) ratio for advanced composite wet lay-ups is generally considered the best for strength? *(ASA 8075)*
    a. 40:60
    b. 50:50
    c. 60:40

18. What is the material layer used within the vacuum bag pressure system to absorb excess resin during curing called? *(ASA 8076)*
    a. Bleeder
    b. Breather
    c. Release

19. Proper pre-preg composite lay-up curing is generally accomplished by *(ASA 8077)*
    1. Applying external heat
    2. Room temperature exposure
    3. Adding a catalyst or curing agent to the resin
    4. Applying pressure
    a. 2 and 3
    b. 1 and 4
    c. 1, 3, and 4

20. When repairing large, flat surfaces with polyester resins, warping of the surface is likely to occur. One method of reducing the amount of warpage is to *(ASA 8078)*
    a. Add an extra amount of catalyst to the resin
    b. Use short strips of fiberglass in the bonded repair
    c. Use less catalyst than normal so the repair will be more flexible

21. When making repairs to fiberglass, cleaning of the area to be repaired is essential for a good bond. The final cleaning should be made using *(ASA 8079)*
    a. MEK (methyl ethyl ketone)
    b. Soap, water, and scrub brush
    c. A thixotropic agent

22. Fiberglass laminate damage not exceeding the first layer or ply can be repaired by *(ASA 8081)*
    a. Filling with a putty consisting of a compatible resin and clean, short glass fibers
    b. Sanding the damaged area until aerodynamic smoothness is obtained
    c. Trimming the rough edges and sealing with paint

23. Fiberglass damage that extends completely through a laminated sandwich structure *(ASA 8082)*
    a. May be repaired
    b. Must be filled with resin to eliminate dangerous stress concentrations
    c. May be filled with putty which is compatible with resin
24. Fiberglass laminate damage that extends completely through one facing and into the core *(ASA 8083)*
    a. Cannot be repaired
    b. Requires the replacement of the damaged core and facing
    c. Can be repaired by using a typical metal facing patch

25. Repairing advanced composites using materials and techniques traditionally used for fiberglass repairs is likely to result in *(ASA 8084)*
    a. Restored strength and flexibility
    b. Improved wear resistance to the structure
    c. An unairworthy repair

26. The preferred way to make permanent repairs on composites is by *(ASA 8085)*
    a. Bonding on metal or cured composite patches
    b. Riveting on metal or cured composite patches
    c. Laminating on new repair plies

27. The part of a replacement honeycomb core that must line up with the adjacent original is the *(ASA 8087)*
    a. Cell side
    b. Ribbon direction
    c. Cell edge

28. Which of the following are generally characteristics of carbon/graphite fiber composites? *(ASA 8089)*
    1. Flexibility
    2. Stiffness
    3. High compressive strength
    4. Corrosive effect in contact with aluminum
    5. Ability to conduct electricity
        a. 1 and 3
        b. 2, 3, and 4
        c. 1, 3, and 5

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Analysis of the Differences in Perceptions of Safety Reporting Systems between Collegiate Aviation Students and Airline Pilots

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Collegiate education and training prepare students to enter the workforce, and the collegiate experience should reflect practices in use within an industry. Collegiate aviation combines academic and practical experience with the integration of an industry-standard safety emphasis from the beginning of training. One facet of this safety emphasis, safety reporting, is an integral part of safety management systems (SMS) used in professional aviation. This study examined the differences in the perceptions of safety reporting systems between the pilots of a U.S. major air carrier and the collegiate students enrolled in the aviation program at a U.S. university. A cross-sectional survey was used to collect data from these two groups. Statistical analysis found that collegiate aviation students and airline pilots witnessed a similar number of safety-related issues during the study period. Airline pilots submitted safety reports with greater frequency than did students. Collegiate aviation students in this study indicated that report confidentiality concerns were a factor in this lower reporting rate. The study also found that the perceived effectiveness of organizational safety policies and procedures is influenced by, and inversely proportional to, the number of safety-related issues witnessed by study participants.

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Collegiate education and training prepare students to enter the workforce, and collegiate training for the aviation industry requires a balance of both knowledge and practical experience. Too much knowledge coupled with too little experience renders a student deficient in basic practical skills foundational to success in the industry. Conversely, too little knowledge and a disproportionate level of practical experience may insufficiently prepare a student for the academic rigors of professional aviation and its increasingly complex systems (Carney, 2014). To produce a well-equipped student ready for a career in the aviation industry, collegiate aviation training strives to mirror real-world applications and procedures. However, the ability to fully replicate the industry requires resources beyond the scope of most collegiate aviation programs. Earning any one of numerous aviation certifications constitutes a "license to learn" in industry vernacular, thus making collegiate aviation an environment that provides students the foundational knowledge and practical skills on which to build as they enter the industry (Carney, 2014).

While imparting knowledge and skills is a central part of collegiate aviation education, safety and safety awareness must be imbued in every aspect of the student's educational experience beginning with his/her first course. Safety practice and safety awareness permeate every facet of professional aviation, and a student will not be prepared to enter the industry if they cannot perform progressively complex tasks safely. The collegiate aviation students of today will be the aviation professionals of tomorrow, responsible for ensuring the safety of the flying public. In this study, we surveyed collegiate aviation students from a single U.S. collegiate aviation program and airline pilots from a U.S. FAR 121 major carrier to examine the perceptions of safety reporting systems of both groups and determine if differences exist.

Safety training should be presented and reinforced through practical application in an aviation context to adequately prepare the collegiate aviation graduate to enter the professional aviation workforce. This includes the use of safety reporting systems in place in a student's collegiate aviation program. Reporting safety issues, concerns, or operational safety-related events provides an input to an organization's Safety Management System (SMS) safety assurance function. The data provided by these reports allows the investigation, monitoring, data analysis, system assessment, and corrective action that give an SMS value as a proactive safety tool (FAA, 2020b). These steps within safety assurance allow an SMS and a collegiate aviation program specifically to evaluate its safety climate, identify safety-related trends in its operation, and proactively establish or modify policy and procedure to mitigate risk. Safety reporting by operational users is an essential input to this process as they provide direct observations of the system and how it is used (Lyle, 2020).

Problem Statement

The purpose of this research is to determine the differences, if any, in perception between airline pilots and collegiate aviation students regarding aviation safety reporting systems. The results of this research will contribute to a better understanding of any differences between industry practice and the collegiate aviation environment and provide input for their further alignment.

Research Question

RQ1: Is there a difference between airline pilots and collegiate aviation students regarding their perceptions of aviation safety reporting systems?

Hypotheses

$H1_o$: There is no difference between airline pilots and collegiate aviation students regarding their perceptions of aviation safety reporting systems.

$H1_a$: There are differences between airline pilots and collegiate aviation students regarding their perceptions of aviation safety reporting systems, and these differences influence the reporting habits of the two groups.

Literature Review

The concept of safety has become as labyrinthine as the governmental entities that conceived it and is somewhat contextual and unable to be defined in simplistic terms. From the perspective of the flying public, safety is defined as traveling from point A to point B without injury or death (Stolzer et al., 2013), but for the safety practitioner, that definition is too minimalist. The Federal Aviation Administration (FAA) definition of safety is "…the state in which the risk of harm to persons or property damage is acceptable" (FAA, 2020b, p. A-1). In the current aviation context, safety is often synonymous with SMS, which the FAA describes as "…the formal, top-down, organization-wide approach to managing safety risk and assuring the effectiveness of safety risk controls. It includes systemic procedures, practices, and policies for the management of safety risk" (FAA, 2020b, p. A-2). An SMS is comprised of "…a safety policy, safety risk management, safety assurance, and safety promotion" (FAA, 2020b, p. 8).

Prior to the advent of SMS, safety was a collection of uncoordinated initiatives implemented to prevent catastrophe (Pollock, 1995). As safety education and training have evolved to a more structured, standardized, and integrated format, this has added a new dimension to the collegiate aviation experience. Given this improved safety paradigm, collegiate aviation students must be trained holistically by learning and implementing safety practices within an intentional safety culture. In the collegiate aviation setting, one way to prepare students for the safety challenges they may encounter in the industry is to expose students to SMS early in their training (Velazquez & Beier, 2015). In addition, a student should gain familiarity with SMS when immersed in an environment where a robust SMS is in use. Not only do students learn about SMS, but a higher-risk collegiate flight training setting will also benefit. Safety challenges in a flight training environment are unique; high volumes of inexperienced students are often trained by flight instructors who are their only slightly more experienced peers (Adjekum, 2013). In the flight training environment, students and instructors are subject to simulated malfunctions, maneuvers, and non-normal situations not commonly encountered in professional flying (Adjekum, 2014). For example, professional pilots usually only practice non-normal maneuvers in a flight simulator under controlled conditions and only in the aircraft in an actual emergency or as prescribed as a specific check as part of a post-maintenance check flight.

The value contained in an aviation safety report is the first-hand account of an event by the individual who experienced it, and the documentation of relevant factors contributing to the event (Cohen & Crabtree, 2006). An aviation safety report follows the narrative analytical structure of Rogan and de Kock (2005) by "…asking directly for information…" and "…solicitation of specific narrator experiences…" (p. 632), examined for additional contextual information, and "…evidence for interpretation in the (report) was also sought by examining…the narrator's connecting logic of the sequence of events" (p. 641-642). Aviation safety reporting is an essential input to an organization's SMS safety assurance process, providing data for trend analysis and a proactive safety approach (FAA, 2020b).

An airline safety reporting system known as ASAP (Aviation Safety Action Program) is built on the general concept of candid safety reporting in exchange for no certificate action against the reporting entity (FAA, 2020a). The signatory parties to a Memorandum of Understanding (MOU) which establish and continue an ASAP program are the airline company, the FAA, and an employee representative such as a pilot union. There are strict rules established by FAA orders and regulations that govern the handling of an ASAP report, how they are de-identified, and how the data may be used (FAA, 2003, 2020a). When an ASAP report has completed the review process at the airline level, the de-identified data are submitted to the NASA Aviation Safety Reporting System (ASRS) to be included in the aggregate ASRS public database.

As part of its accreditation process for collegiate aviation programs, the Aviation Accreditation Board International (AABI) works with industry partners to define the "competencies and attributes desired of graduates" of collegiate aviation programs (Carney, 2014). AABI uses these industry inputs in the accreditation process to ensure that aviation program graduates have "an ability to use techniques, skills, and modern technology necessary for professional practice" (Carney, 2014). The collegiate aviation program included in this study is an AABI accredited institution. As the sole recognized accreditor for aviation programs worldwide, AABI recognizes the need for synergy between collegiate aviation and the aviation industry (Carney, 2014). If AABI seeks to prepare collegiate aviation students for "professional practice", aviation safety reporting is part of that preparation.

The collegiate aviation student group surveyed for this study was made up of both professional pilot students and aviation maintenance students. These were the two largest concentrations of students in the aviation department of the study university (University Aviation Association [UAA], 2016), and are also the two student groups most likely to be covered by a formal aviation safety reporting system in professional practice (FAA, 2020a). The student group at the study university is also somewhat unique in that the subject university offers both areas of study, not the case at all collegiate aviation programs (UAA, 2016). Flight education and aviation maintenance are also specifically listed as concentrations subject to the AABI accrediting process, a process designed with industry inputs to prepare students for careers in professional aviation. (Carney, 2014).

Methods

The data collection instrument used in this study was developed from the Collegiate Aviation Perception of Safety Culture Assessment Survey (CAPSCAS), and the survey questions were tailored to fit the sampling requirements of the airline pilot group. As a survey instrument, questions in the CAPSCAS were modified from the Commercial Aviation Safety Survey (CASS) developed by researchers at the University of Illinois Champagne-Urbana (Adjekum, 2013). The CASS is a validated survey instrument that "…identifies the respondents' perception of the current state, as well as the strengths and weaknesses, of the safety culture in an organization" (Adjekum, 2013, p. 18). In addition, supplementary survey questions were also adapted from another unrelated pilot-tested survey instrument (Siao, 2015). The survey instrument used for data collection for this study is included in Appendix A.

Four sub-areas were identified for the study: demographics, safety value, safety reporting, and overall level of safety. When tailoring the survey instrument for the airline pilot group, every effort was made to keep the phrasing of survey questions as identical as possible to the survey questions presented to the collegiate aviation student group. This was done to standardize the survey instrument across both groups and minimize potential bias in survey responses. The researchers felt that the homogenization of the questions between the two groups was important in this case to accurately measure any differences or similarities between groups regarding perceptions of aviation safety reporting systems.

Airline Pilot Group and Sampling Procedures

The airline pilot group sampled was comprised of active pilots listed on the Master Seniority List of a U.S. major commercial air carrier as of March 1, 2016. Approval to survey the pilot group was obtained from the pilot's union Safety Committee Chairman and union Executive Officers. A link to the survey was disseminated to pilots via a weekly union communication vehicle that was sent to all pilots electing to receive it. Due to the proprietary nature of this information, it is not specifically known how many of the 8000 airline pilots elected not to receive this union communication vehicle.

Sampling of the airline pilot group was done electronically through a survey link hosted on www.surveymonkey.com. Other than the modification of demographic questions unique to the airline pilot population, substitution of the word "airline" for "university" in questions 9 and 15, and "airline" for "department" in question 20, the questions were identical to the questions administered to the collegiate aviation student population. Participation was completely voluntary, with participant consent obtained by proceeding past the first page of the survey to begin the demographic section. Anonymity was guaranteed to participants through filters placed on the survey by the researchers that prevented the collection of any personally identifiable information – e.g., the "track IP" function was disabled to provide an additional layer of anonymity.

Collegiate Aviation Student Group and Sampling Procedures

The collegiate aviation student group sampled consisted of university students enrolled in the professional pilot and aviation maintenance programs of a single U.S. university. While the selection of a single collegiate aviation program does limit the ability to generalize findings to collegiate aviation in general, it does provide a consistent baseline of procedures, policies, and safety reporting systems for comparison and analysis. The collegiate aviation program chosen for this study offers six undergraduate concentrations within the Department of Aerospace: administration, technology, dispatch, maintenance, professional pilot, and unmanned aerial systems (UAS). For this study, the researchers chose students from the maintenance and professional pilot concentrations, which represent the two largest concentrations in terms of enrollment, 100 and 348, respectively. (University Aviation Association, 2016).

Participants in the collegiate aviation group were intentionally recruited to ensure a balanced representation between the maintenance and professional pilot concentrations. Students were surveyed in various classes and informed of the voluntary nature of survey participation. Students indicated their consent to participate by signing an informed consent document which was collected separately from the survey itself to ensure anonymity. There were no positive incentives or negative consequences offered for survey participation.

Research Design

The data collection instrument for the airline pilot group was a 21-question survey utilizing a five-response Likert scale for most responses. Of the 21 questions that made up the survey, five were related to demographics, two related to safety value, ten related to safety reporting, and four related to the perception of the overall level of organizational safety (see Appendix A). The survey was open for responses on www.surveymonkey.com from March 26, 2016, to April 19, 2016, with the survey link published in two union communications during that period. Similarly, collegiate aviation students at the subject university were surveyed beginning March 26, 2016, with the last survey administered on April 20, 2016. The design of the airline pilot survey was such that once a respondent began participating in the survey, responses to the questions could be changed while that session was open. Once the respondent exited the survey, there was no ability to change response or participate in the survey more than once. Printed surveys were distributed to the collegiate aviation students in class, and students declining to participate were given the option to turn in a blank survey along with the rest of the class. There was no requirement for a student to complete the survey.

Demographic data were collected during the survey for two primary purposes. The first was to identify the modal groups in each sample. The second was to identify the presence in the student group of respondents outside the modal group that may indicate a non-traditional student that has had previous exposure to a formal safety reporting system such as those used in the military. This would also be the case with airline pilots responding to prior employment with another major airline or the military where a formal safety reporting system was in use.

The survey instrument contained 21 questions and indicated the use of exploratory factor analysis using varimax rotation. A scree plot was used to retain factors with the condition that

Eigenvalues must be above 1. An initial examination of the correlation matrix revealed no correlations above 0.9, indicating no multicollinearity in the data. The determinant was 0.099, which is greater than 0.00001 (Field, 2014). The Kaiser-Meyer-Olin value was .702, well above the minimum criterion of 0.5, suggesting that the sample size was adequate for factor analysis (Field, 2014). Bartlett's test was significant (p = .000), which showed that this was not an identity matrix. As mentioned earlier in this paragraph, only factors with Eigenvalues greater than 1 were extracted which included two factors in this case: safety as a core value and safety report submission rate.

Reliability analyses were conducted on both factors. The initial Cronbach alpha for factor 1 was a = .717, with a value of .70 and above indicating high internal consistency (Adjekum et al., 2015; Field, 2014). While this was satisfactory, deletion of question 6 would increase the Cronbach alpha to a = .738; however, reliability of a = .717 and a = .738 were close, and question 6 was not deleted. For factor 2, the initial Cronbach alpha was a = .680, below the threshold of a = .70 for social science research. The inter-item correlation matrix revealed a low correlation for question 21. Deleting question 21 would increase the Cronbach alpha for factor 2 to a = .717. To increase reliability, question 21 was deleted, the reliability analysis was re-run, and yielded an improved Cronbach alpha value of a = .717 as expected.

The airline pilot survey produced 128 responses during the survey period (n = 128) for a response rate of 1.6% of the pilots at the study airline. The collegiate aviation student survey produced 59 responses (n = 59) for a response rate of 13.2%, for a total of 187 responses (N = 187). Permission to conduct this study was approved by the Institutional Review Board at Middle Tennessee State University (IRB Protocol ID: 16-1226).

Results

Demographic Analysis

Professional pilot sample.

Pilot participants from the U.S. major airline (n = 128) were asked to indicate their current seat position: First Officer, Captain, or Check Airman. No participant selected Check Airman. Participants were also asked to specify their age group from five broad categories: 20-30, 31-40, 41-50, 51-60, and 60-65. It should be noted here that the minimum age to obtain an Airline Transport Pilot certificate required for hire at a U.S. major airline is 23 (21 in certain circumstances), and mandatory retirement as set by the FAA is age 65. From these age groups, 41-50 and 51-60 were the modal groups comprising 75.8% of the professional pilot sample, with the mean of 3.5 lying evenly between these age categories. The background of the airline pilot group, as indicated by previous employment, is varied, with Military (38.3%) being the modal group followed by Other Major Airline (27.3%; Table 1). There was one female respondent in the professional pilot group.

Table 1
Professional pilot demographic variables of Seat Position, Age, and Prior Employment

Variable	Value	Percentages	Variable	Value	Percentages
Seat Position			Prior Employment		
First Officer	51	39.8%	Corporate	17	13.3%
Captain	77	60.2%	Military	49	38.3%
Check Airman	0	0%	Freight	6	4.7%
			Regional	21	16.4%
Age Group			Other Major Airline	35	27.3%
20-30	1	0.8%			
31-40	11	8.6%			
41-50	52	40.6%			
51-60	45	35.2%			
61-65	19	14.8%			

Collegiate aviation student sample.

Similar to the question of seat position for airline pilots that is driven by seniority, students were asked to select their year group: Freshman, Sophomore, Junior, Senior, and Other. The Other category was included to accommodate graduate students but was not selected by any student respondent. The age groups were modified for the collegiate survey using smaller category ranges at five-year intervals. The modal group is the 20-25 age range, which comprises 78% of the collegiate respondents (Table 2). Students in age categories above the modal group were 13.6% of the collegiate aviation student group. In place of prior employment in the airline survey, students indicated their international or domestic status. Female student participation was low as was the case with airline pilots, with only four female respondents in the collegiate group.

Table 2
Collegiate demographic variables of International Status, Age, Year Group, and Concentration

Variable	Value	Percentages	Variable	Value	Percentages
International/Domestic			Age Group		
International	12	20.3%	Below 20	5	8.5%
Domestic	47	79.7%	20-25	46	78.0%
			26-30	5	8.5%
Year Group			31-35	2	3.4%
Freshman	3	5.1%	36-40	0	0%
Sophomore	23	39.0%	41-45	0	0%
Junior	19	32.2%	46-50	0	0%
Senior	14	23.7%	Above 50	1	1.7%
Other	0	0%			
			Concentration		
			Pro-Pilot	24	40.7%
			Maintenance	31	52.5%
			Other (see note)	4	6.8%

Note. The “Other” category under concentration includes Administration and Flight Dispatch.

Safety as a Core Value

There was no significant difference between collegiate aviation students and airline pilots on how they perceived safety as a core value of their department or workgroup. Aviation students (M = 4.27, SE = .14) viewed safety as a slightly higher priority within their department than did airline pilots (M = 4.19, SE = .11), possibly representing a negligible difference. The difference, -0.08, BCa 95% CI [-.262, .427], is not significant t(184) = .448, *p* = .654, and represents a small effect, *r* = .07.

There was no significant difference between collegiate aviation students and airline pilots in how they viewed the concern for safety demonstrated by the leadership of their department or workgroup. Aviation students (M = 4.17, SE = .11) said that their leadership showed a slightly higher concern for safety than did airline pilots (M = 4.07, SE = .09), a small difference. The difference, -0.10, BCa 95% CI [-.215, .395], is not significant t(184) = .639, *p* = .524, and represents a small effect, *r* = .05.

Awareness of a Safety Reporting System

Regarding a difference between airline pilots and collegiate aviation students in their awareness of aviation safety reporting systems, this study found no significant difference between the two groups. When asked whether participants were aware of a safety reporting system in their department/workgroup, all collegiate aviation students (n = 59; 100%) responded "Yes", 125 airline pilots (n = 128, 98%) responded "Yes", with two responding "No" (1.6%). Although there was a small difference between the two groups, the difference was not significant t(184) = -.966, *p* = .335, and represented a small effect, *r* = .07. There were some significant differences found in the sub-areas of safety value, safety reporting, and overall level of safety between the two groups that are reported in the following paragraphs.

Safety Reporting

The data indicated a significant difference between collegiate aviation students and airline pilots when asked if they had submitted an aviation safety report. 93.2% of collegiate aviation students surveyed (M = 1.93, SE = .03) responded that they had not submitted a report, while 84.3% of airline pilots surveyed (M = 1.16, SE =.03) indicated that they had (Table 3). The difference, 0.77, BCa 95% CI [.661, .871], is significant t(156.84) = 16.737, *p* = .001, and represents a large effect, *r* = .80. More airline pilots had submitted an aviation safety report than had collegiate aviation students in this study.

Table 3
Number of study participants that had submitted an aviation safety report

	Students		Airline Pilots	
Safety Report Submission	Value	Percentage	Value	Percentage
Yes	4	6.8%	107	83.6%
No	55	93.2%	20	15.6%
Total	59	100%	127	99.2%

Note. One participant from the pilot group did not respond to this question.

Respondents indicated a significant difference in their perception of the confidentiality of an aviation safety report once it is submitted. Collegiate aviation students (M = 3.44, SE = .13) had significantly lower confidence in a report's ability to remain confidential than do airline pilots (M = 3.90, SE = .11). This difference, -0.46, BCa 95% CI [-.795, -.117], is significant t(142) = -2.493, p = .014, resulting in a small effect, r = .20. In this study, airline pilots had slightly higher confidence in the ability of an aviation safety report to remain anonymous.

Closer examination of two possible sub-factors which influenced the perception of reporting confidentiality may provide insight into collegiate aviation students' lower reporting rate when compared to airline pilots in this study. When surveyed regarding the ability to report safety discrepancies without fear of negative consequences, there is no significant difference between collegiate aviation students (M = 3.78, SE = .11) and airline pilots (M = 4.01, SE = .10), a difference of 0.23, BCa 95% CI [-.531, .088], t(142) = -1.401, p = .163, r = .19. Willingness of the two groups to file an aviation safety report if the event was caused by their own actions showed a significant difference. Collegiate aviation students (M = 3.29, SE = .12) were less likely to file a report under these circumstances than airline pilots (M = 3.74, SE = .09), a difference of -0.45, BCa 95% CI [-.776, -.131], t(142) = -2.779, p = .006, r = .23. These sub-factors may provide some insight into the lower reporting rate of collegiate aviation students.

Frequency of Safety Report Submission

The previously mentioned findings may also impact the frequency of aviation safety report submission, measured here by the number of times a respondent had filed a report. Collegiate aviation students filed fewer safety reports (M = .09, SE = .04) than airline pilots (M = 3.44, SE = .20), a significant difference of -3.35, BCa 95% CI [-3.73, -2.92], t(132) = -16.530, p = .000, and represents a large effect, r = .80 for the two groups included in this study. The lower incidence of collegiate aviation student safety report submission is further confounded by the number of perceived safety-related issues witnessed. Respondents were asked to indicate the number of perceived safety-related issues witnessed in a four-month period for airline pilots or semester for students (Figure 1). Perceived safety-related issues witnessed by collegiate aviation students (M = 3.85, SE = .14) was slightly higher than airline pilots (M = 3.79, SE = .08) during this time period, an insignificant difference of .067, BCa 95% CI [-.282, .391], t(178) = .444, p = .657, representing a small effect, r = .03. While the mean for both groups lay between 11-15 and 16-20 perceived safety-related issues witnessed during the study period, the results indicated that the number of safety reports filed by collegiate aviation students was not commensurate with the number of perceived safety-related issues witnessed (Figure 2).

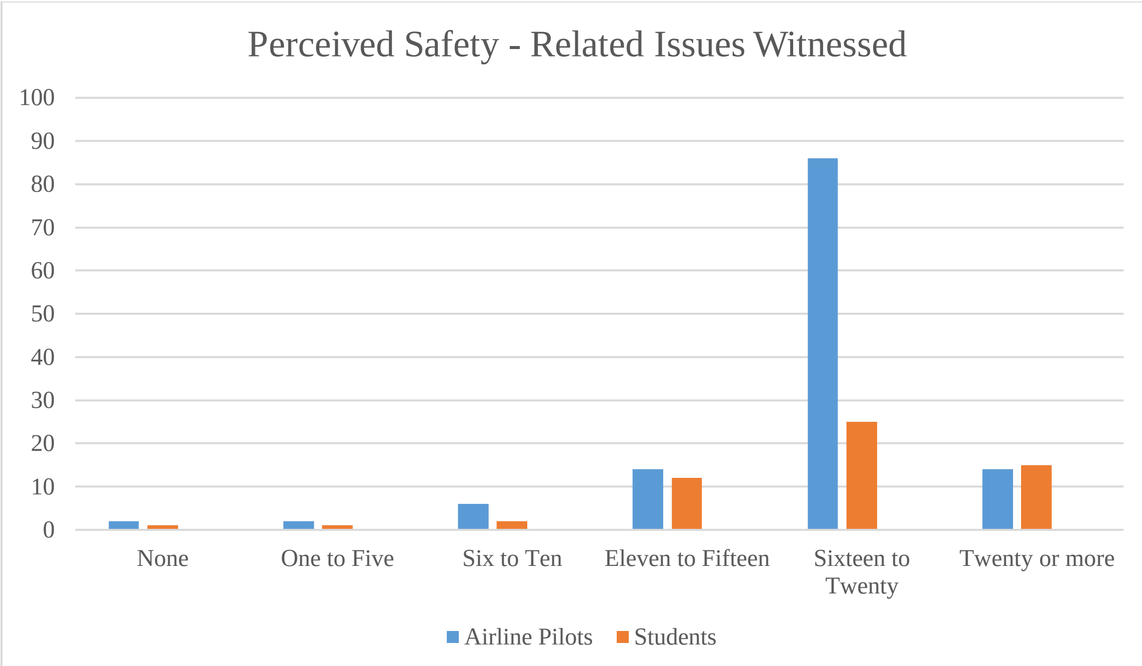

Figure 1. Perceived safety-related issues witnessed

Note. For safety-related issues witnessed, participants were selected from a scale of six items. Selection "0" corresponds with "None," "1" corresponds with "1-5," etc. See Appendix A.

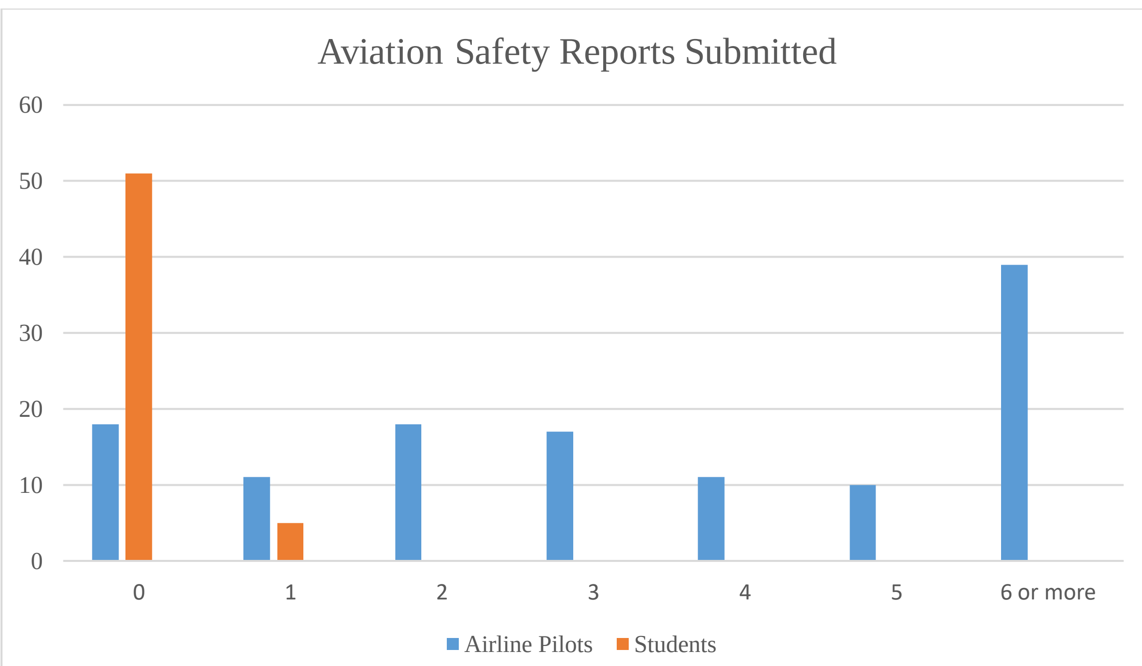

Figure 2. Aviation safety reports submitted

Effectiveness of Safety Policies and Procedures

Study participants were asked their perceptions of the effectiveness of safety policies and procedures in effect at their organization. Collegiate aviation students ($M = 3.93$, $SE = .09$) indicated a higher level of effectiveness of safety policies and procedures than airline pilots ($M = 3.70$, $SE = .08$), an insignificant difference of .227, BCa 95% CI [.002, .443], $t(140) = 1.86$, $p = .064$, $r = .20$.

Conclusions

Study findings showed that there is a difference in perceptions of aviation safety reporting systems between collegiate aviation students and airline pilots included in this research. The results indicate that there was no significant difference between collegiate aviation students and airline pilots regarding the perception that safety is a core value of their respective organizations. There was also no significant difference between the two groups regarding their awareness of a safety reporting system at their respective organization. The number of perceived safety-related issues witnessed over the study period was not significantly different between the two groups, but there was a significant difference in the number of safety reports submitted by each group. Airline pilots reported at a higher rate than collegiate aviation students. While we conclude from the results that the frequency of safety report submission did not solely depend on the number of perceived safety-related issues witnessed, the number of issues witnessed contributed to a respondent's perception of the effectiveness of safety policies and procedures at their respective organization. For the collegiate aviation program included in this study, we also conclude from the results that student safety reporting is influenced by a perceived lack of report confidentiality by students in this program

Discussions

Two important findings stand out from the research results regarding the differences in perception of aviation safety reporting systems between collegiate aviation students and airline pilots included in this study. First, there were no significant differences between collegiate aviation students and airline pilots regarding awareness of an aviation safety reporting system within their organization. It was expected that airline pilots would have a heightened awareness of such a system due to their additional exposure to and training as to its use. This may be the result of a robust aviation safety reporting system being present within the single collegiate aviation program surveyed in this study or an isolated event. This is an important positive finding that collegiate aviation students were aware of an aviation safety reporting system. The second was the finding that collegiate aviation students participating in this study, while having an awareness of an available aviation safety reporting system roughly equal to that of airline pilots, reported at a significantly lower rate. Three sub-areas were identified and analyzed to gain a deeper insight into this finding, two of which were significant: student impression that their reports would not remain confidential and a reluctance to file a report about an unsafe condition that was caused by their own actions.

One reason cited by the collegiate aviation student respondents in this study for the lower reporting rate was the difference in perception of confidentiality safeguards present within their aviation safety reporting system. This finding is reported in the Safety Reporting subsection of the Results section of this paper. It is possible that the ASRS reporting system that collegiate aviation students are most familiar with is relied upon to de-identify the data in an incoming report and does not have the confidentiality benefit of airline ASAP report data that is de-identified before it gets to ASRS. This is one possible explanation for the lower reporting rate of collegiate aviation students.

The collegiate aviation respondents were comprised of students from both the maintenance management and professional pilot concentrations. Regardless of concentration or curriculum requirements, receptacles exist in both the maintenance and flight schools for the anonymous submission of safety reports in the study collegiate aviation program. Students in the collegiate aviation program may have classes together, and the details of a reported safety event may quickly become common knowledge throughout the department. This may provide another explanation for the lower reporting rate of collegiate aviation students: a smaller, geographically concentrated population making anonymity difficult as compared to a larger, geographically dispersed population for airline pilots.

Further examination of safety report frequency showed that students and airline pilots witnessed similar numbers of perceived safety-related issues during the study period. This finding suggests that the frequency of safety report submission is not solely dependent on the number of perceived safety-related issues witnessed. Collegiate aviation students and airline pilots both indicated similar perceptions of the effectiveness of safety policies and procedures in their respective organizations. The general trend in each group showed that the perception of the effectiveness of safety policies and procedures tend to decrease with an increase in the number of perceived safety-related issues witnessed. These findings suggest that students may not view safety reporting as an integral component of safety management and the safety culture of their organization and may not have internalized their status as a member of that safety culture. Behavior such as this could provide an indicator as to the robustness of the organizational safety culture and the view that "…the safety department does not own safety, rather it is owned by every employee" (Stolzer et al., 2013, p. 29).

Limitations

The selection of a single collegiate aviation program, single U.S. FAR 121 air carrier, and limited period for data collection were all limitations of this study. Thus, the ability to generalize findings beyond these two entities is limited. However, the analytical process described in the following paragraphs would be applicable to different airline and collegiate aviation groups. The authors do not assume, stated or implied, that there was a safety reporting deficiency on the part of either group included in this study, but that there is a difference in experience level and operating environment between the two groups that explained any difference. As a self-reporting tool, an aviation safety report is subject to the bias of the reporter, primarily self-reporting bias and recall bias (Lyle, 2020).

The authors assumed that one of the primary objectives of collegiate aviation education and training is to prepare students for careers in professional aviation. This assumption was validated by Carney (2014) and the input of industry partnerships that influence AABI accreditation criteria. Professional pilot and maintenance management collegiate aviation students were intentionally selected for two reasons: they were the two largest concentrations in the program studied and were most likely to be covered by an aviation safety reporting system in professional practice.

Recommendations

One purpose of collegiate aviation training and education is to prepare a student to enter the professional aviation workforce. To achieve this goal, a student should be trained to industry standards of which safety is a large component. Aviation program accreditation seeks to promote this educational process. This study found several areas where the collegiate aviation department studied was congruent with the industry, and areas where it differed from industry practice. One such finding is the lower safety report submission rate for collegiate aviation students, the concern for report confidentiality cited as a reason by respondents. Perhaps the structure and confidentiality procedures of an airline ASAP program are scalable to the collegiate aviation environment (FAA, 2003, 2020a). A safety report could be submitted online to an entity not directly involved with the operation of the collegiate aviation program, such as the Aviation Accrediting Board International (AABI) or University Aviation Association (UAA). The AABI Safety Committee defines its mission to "…provide guidance…about safety matters related to AABI criteria…and safety matters related to a safety management approach to fostering an effective safety culture in aviation programs" (AABI, 2018). The report would undergo a review similar to an ASAP report but tailored to the collegiate aviation environment, and feedback provided to the affected aviation program for review and mitigation. Access to this data could be limited to departmental faculty or safety officers responsible for safety areas for confidentiality. An additional benefit would be the establishment of a database by the collecting entity to analyze and identify overall collegiate aviation safety trends of member departments. This trend analysis allows for a proactive approach to safety, identifying and mitigating risk before it rises to the level of a hazard, and reflects industry-standard practice in professional aviation.

Directions for Future Research

Administrators, instructors, and students must actively work toward industry-standard safety practices, evoking all sentiments of laboriousness associated with change management (Simon & Cistaro, 2009). To implement the changes necessary to address the safety-related issues found in this study, future data collection could include multiple collegiate aviation programs. Through the study of multiple programs, researchers should be able to validate trends related to safety perceptions found in this study or determine that the results of this study are germane to the single collegiate aviation program included here. In addition to the quantitative method used here, a qualitative component could be added to enable a richer understanding of survey responses. It would also be beneficial to survey students regarding the benefits of an aviation safety course and how it would affect a student's perception of safety reporting and safety culture. The survey instrument used here could also be replicated at other major and regional airlines to collect and analyze data from a more operationally diverse population employed in professional aviation.

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UNIVERSITY AVIATION ASSOCIATION

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Pilot Surveys on Identification of a Failed Engine in Twin-Engine Propeller Aircraft

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Twin-engine propeller aircraft accidents occur for many reasons including human factors, such as misidentifying a failed engine. Engine misidentification has led to several fatal accidents. Babin, Dattel, & Klemm (2020) found that, in a simulated engine failure scenario, using a visual indicator for engine identification resulted in significantly lower response time than the "dead leg-dead engine" procedure. To better understand the pilot perspective regarding the issue of engine failure and the method used for the identification of a failed engine, opinions and feedback were collected via surveys. Method: Two surveys were created and distributed among pilots to gather their opinions regarding the issue. Survey One was completed by airline pilots operating twin-engine turboprop aircraft; Survey Two was completed by instructor pilots operating light single- and twin-engine piston aircraft. Results: Forty-nine airline pilots and twenty-three instructor pilots responded to the survey. The average flight experience was 6,000+ flight hours/nine years for airline pilots and 420 flight hours/four years for instructor pilots. Approximately nineteen percent of airline pilots and half of the instructor pilots had had to utilize the engine-out procedure in their prior experience. Most respondents felt comfortable with the current method of identification of a failed engine. Twenty-nine percent of airline pilots and fourteen percent of instructor pilots agreed with the statement that there could be a better method of identification of a failed engine. Forty percent of all pilots who provided suggestions for improvement to the current method (both surveys combined) recommended adding a visual indicator to help with the identification. The results of the surveys provide greater insight into the problem of engine misidentification and suggest that many pilots favor visual cues, supporting findings described in Babin et al. (2020).

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Engine failure is not a rare occurrence in aviation. A review of the National Transportation Safety Board (NTSB) database showed that in visual conditions, engine failure and incorrect handling caused one-third of all accidents in twin-engine piston aircraft (Boyd, 2015). Although a second engine provides additional power and reliability, twin-engine propeller aircraft require special handling in case of an engine failure to ensure the safe outcome of the situation. Not only does a failed engine stop providing power, but it also can add significant drag in flight as its propeller starts windmilling, which is followed by a notable yaw toward the failed engine due to thrust asymmetry. An engine failure on takeoff, combined with the propeller drag, may result in a 80% to 90% loss in climb performance (Federal Aviation Administration [FAA], 2021). On initial climbout, when the aircraft is at full engine power and a high angle of attack, such reduction in performance is detrimental and can lead to an accident if not resolved properly. Hence, a significant portion of multi-engine pilot training is devoted to single-engine operation of twin-engine aircraft and a successful recovery, especially if the failure occurs on takeoff.

Since at least the 1970s (Bramson & Birch, 1973), multi-engine pilots operating propeller aircraft have been trained to utilize the Identify-Verify-Feather (I-V-F) procedure in response to an engine failure in flight, particularly on takeoff. Per the procedure, while depressing one rudder pedal to compensate for the yaw from the thrust asymmetry in an effort to stabilize the aircraft, the pilot should determine which leg is not pushing the rudder pedal (dead leg). The dead leg will be on the side of the dead engine; hence this method is called “dead leg – dead engine.” Correct identification is verified by pulling back the throttle of the presumably dead engine and expecting no change in engine sound or power. Finally, the pilot feathers the propeller, turning its blades parallel to the airflow to minimize drag.

Some findings point to issues with the identification of a failed engine in propeller aircraft. Data collected for a period of 12 years showed that almost half of all inflight shutdowns in turboprop multi-engine aircraft involved the good (i.e., working) engine (Sallee & Gibbons, 1999). Investigations from several past fatal accidents involving an engine failure on takeoff in a twin-engine propeller aircraft suggested that a working engine was shut down in error (Aviation Safety Council, 2016; National Transportation Safety Board, n.d.; South African Civil Aviation Authority, n.d.). Wildzunas, Levine, Garner, and Braman (1999; as cited in Aviation Safety Council, 2016) found that 40% of surveyed twin-engine helicopter pilots admitted having confused an engine lever in an emergency at least once either in real life or in a simulator.

It is possible that the method currently used for identifying a failed engine is not effective in all circumstances and can lead to confusion. On takeoff, the mental capacity of a pilot and the time available to make a decision are limited, while the workload is at elevated levels. The high workload is recognized to be correlated with higher error rates and reduced productivity (Harris, 2011). Hence, identification of the failed engine and the action to feather it need to be quick and accurate to avoid a catastrophic outcome. The “dead leg – dead engine” method adds complexity to the process of identification as it relies on one’s sensation of leg movement (mechanoreception) and requires additional mental resources to process that information. Furthermore, startle and stress, both of which may accompany an unexpected event such as an engine failure, have been found to delay decision-making, negatively affect operator information processing, and reduce working memory capacity (Martin et al., 2016).

Therefore, pilots operating twin-engine aircraft may benefit from a simpler and more straightforward method for the identification of a failed engine, possibly involving other sensory channels. Many pilots seem to favor warning systems that can help reduce workload through clear indications of the failure and the status of aircraft condition (Ulfvengren, 2001). Typically, aircraft are equipped with visual and audio alerts, and there are advantages and disadvantages to using each. Audio alerts can assist in achieving a shorter response time, immediately bringing a failure to the pilot's attention. Response to a visual alert, on the other hand, has shown better performance of the task at hand (Niu et al., 2019). Niu et al. (2019) suggested that a combination of audio and visual alerts provide the best outcome for short response time and good performance; ultimately however, the selection of the alert type depends largely on its purpose.

The purpose of the "dead leg – dead engine" method, as well as any alert that can potentially replace it, is to relay the critical information to the pilot to ensure that a correct decision is made. Upon reaching the identification phase of handling an engine failure, the pilot would be aware of the failure through other salient stimuli (such as the yaw toward the failed engine or difference in engine sounds). Babin, Dattel, and Klemm (2020) introduced and tested a visual indicator of a failed engine and compared it to the "dead leg – dead engine" method. The visual indicator was designed to provide accurate information at a glance and consisted of a panel with two circles imitating aircraft annunciator lights (one for each engine), colored either in green (engine working) or red (engine not working). The color changed based on the corresponding engine parameters. Babin et al. (2020) showed that, in a simulated scenario involving an engine failure on takeoff, pilots who used the visual indicator were able to identify a failed engine significantly faster than those who used the traditional method.

Findings by Niu et al. (2019) suggest that the visual channel may be suitable for handling an engine failure, and Babin et al. (2020) showed the benefits of using a specific visual indicator. However, it is also important to determine the perspective of operators who have had to deal with real-life engine failures and who are the primary users of any methodology for handling engine failures. Even with past accident data and research findings as supporting evidence, reluctance to change exists among the general population, especially when it comes to an FAA-endorsed procedure ("dead leg-dead engine") commonly taught, practiced, and used. Eliciting pilots' experiences and opinions would be beneficial to understand the general attitude and receptiveness to potential changes to the current procedures of how pilots identify a failed engine. For that purpose, surveys were conducted on pilot opinions regarding the procedure for identification and verification of a failed engine in twin-engine propeller aircraft. These surveys were also an attempt to build on the information found by Wildzunas et al. (1999).

Method

Two surveys were created and distributed to two different pilot groups. Survey 1 was distributed to pilots of a US regional airline operating twin-engine turboprop aircraft. Survey 2 was distributed to instructor pilots at a US aeronautical university.

Participants

Survey 1. Forty-nine airline pilots participated in Survey 1. All participants were employed as pilots (either captain or first officer) at the time of participation and had prior or current experience in operating twin-engine piston and turboprop aircraft.

Survey 2. Twenty-three flight school instructor pilots participated in Survey 2. All pilots had at least a Certified Flight Instructor (CFI) rating and were actively engaged in flight instruction in piston-powered propeller aircraft at the time of participating in the survey.

Materials and Apparatus

Survey 1 contained 10 questions, with four open-ended questions, four categorized questions (Yes/No), and one scaled item. Survey 2 contained 11 questions, with six open-ended questions, three categorized questions, and one scaled item. The questions in both surveys asked pilots about their experience flying twin-engine aircraft in general as well as twin-engine turboprop aircraft for airline pilots, difficulties handling an engine failure during simulator training, and past experience with engine problems encountered when operating all types of twin-engine propeller aircraft in real life. The questions asked pilots to also provide their opinions on the current method of identification of a failed engine, including how comfortable they were with the I-V-F procedure (scaled from 1 to 5), any positive and negative aspects of the method, and if they had any suggestions for improvement to the current method of identifying a failed engine. Some categorized questions had comment fields for participants to provide additional information. Several questions had to be modified between surveys to account for the difference in experience between the two participant groups. Both surveys were created through the https://www.surveymonkey.com website (SurveyMonkey). The surveys had unique links that could be used by participants to access the survey and answer questions. Microsoft Excel and IBM Statistical Package for Social Sciences (SPSS) software were used for data analysis.

Procedure

Each Survey was distributed to pilot groups via an internal email (sent from the Safety Department for Survey 1 and Training Department for Survey 2) asking for their participation and providing a direct link to the survey. Upon following the link, each participant was provided a consent form. Individuals who volunteered to participate were redirected to the next page containing the survey. Individuals who did not agree to participate were redirected to the last page of the survey and prompted to close the browser window. All data were automatically collected and scored by SurveyMonkey and later exported into a spreadsheet for analysis.

Results

Survey 1

The average experience in flying twin-engine turboprop aircraft was 8.97 years (*SD* = 11.21) and 6,230 flight hours (*SD* = 8,695.11). The average experience flying all types of multi-engine aircraft was 13.91 years (*SD* = 12.53) and 7,229 flight hours (*SD* = 8,924.87). The most experienced participant in the sample had 40 years as a pilot and over 30,000 flight hours.

Almost one-fifth (18.75%) of all respondents reported utilizing the Engine-Out procedure when operating the twin-engine turboprop aircraft in their capacity as a pilot with the airline. For past simulator training, 23% of respondents admitted having problems with identifying a failed engine at least once, 5.71% of respondents had problems with feathering an engine, and the rest did not report having any problems. Fifty-three percent of respondents reported encountering engine problems at least once in their real-life experience flying all types of aircraft. Examples of engine problems are low oil pressure, high oil temperature, low power output, and failures of engine accessories. Although not every pilot mentioned the type of aircraft in which they experienced troubles, the aircraft types that were mentioned ranged from light twin-engine general aviation aircraft to military transport aircraft and civil airlines powered by propeller engines. Although most pilots (71%) indicated that they were very comfortable with the I-V-F procedure, 24% were somewhat comfortable, one (2%) felt neutral, and another one (2%) felt somewhat uncomfortable. The most commonly reported benefits of the I-V-F procedure were categorized as “redundant,” “accurate,” and “simple,” and the most mentioned negative aspects of the I-V-F procedure included an opportunity for an error, potential high workload, and long time required to complete it. Of the nearly one quarter of participants who provided their suggestions for improvement of the current method, four (34%) suggested adding visual indication (e.g., a light), three (25%) proposed improving aircraft automation to better handle a failure, two (22%) proposed audio indication, and the other two (22%) proposed other improvements to the indications. (see Figures 1, 2, and 3)

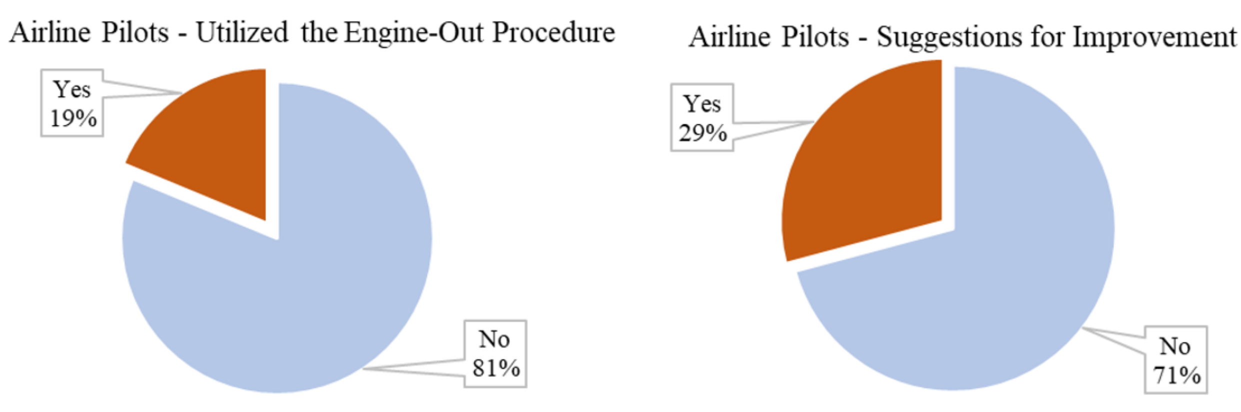

Figure 1. Airline Pilots – Engine-Out Experience and Suggestions for Improvement
Note. The figure shows *the* percentage of airline pilots who have utilized the Engine-Out procedure (left) and airline pilots who have provided suggestions for improvement of the current method (right).

Survey 2

The average flying experience in operating twin-engine aircraft was 4.0 years (*SD* = 7.2) and 419.64 flight hours (*SD* = 631.31). The most experienced participant had 25 years as a pilot and 2,500 flight hours.

Half of the participants reported previously using the Engine-Out procedure in their experience operating twin-engine aircraft. Regarding simulator training experience, two respondents (9%) reported difficulties identifying a failed engine, the other two reported difficulties verifying a failed engine, and four pilots (18%) reported problems feathering the failed engine. Forty-one percent of participants reported having had engine problems in their real-life experience. Most of the reported problems included malfunction of the Engine Control Unit (ECU) or the inability of the engine to maintain stable power output. Considering that surveyed pilots were instructor pilots at a flight school with fewer hours than participants in Survey 1, it seems likely that the engine problems they reported were experienced in GA twin-engine aircraft.

Regarding the current I-V-F procedure, 10 respondents (57%) reported that they were very comfortable with the current method, seven (33%) were somewhat comfortable, and two (10%) were neutral. The most commonly reported benefits of the I-V-F procedure were described as simplicity, reliability, and ease of remembering. The most-reported negative aspect was the opportunity for an error if the method is rushed or pilot stress levels are high in an emergency, which could potentially cause loss of aircraft control due to a pilot fixating on the procedure. Three pilots (14%) provided suggestions for improvement to the current method. The suggestions included a visual indicator of a failed engine, both an aural or a visual indicator, and an aural indicator that plays a signal on the side of the failed engine (see Figures 2, 3, and 4).

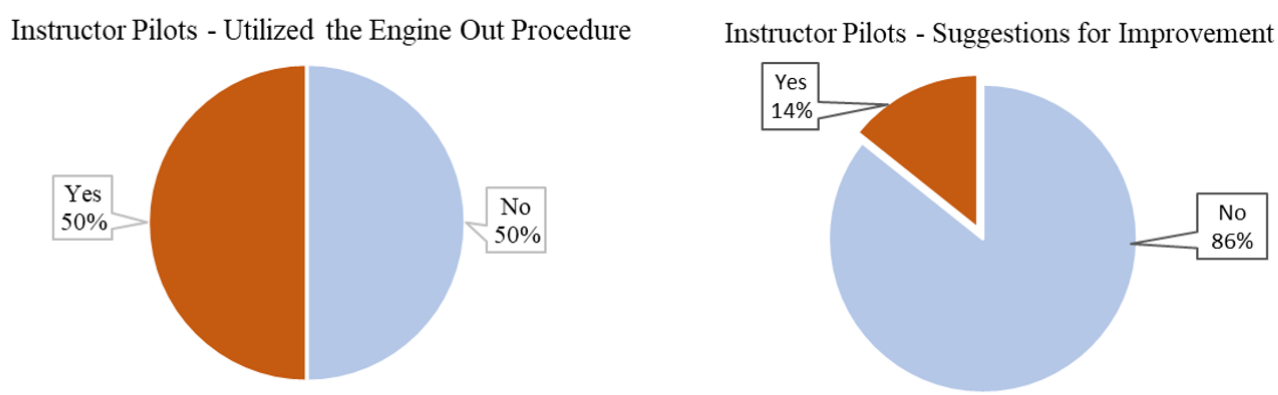

Figure 2. Flight School Instructor Pilots – Engine-Out Experience and Suggestions for Improvement

Note. The figure shows *the* percentage of instructor pilots who have utilized the Engine-Out procedure (left) and instructor pilots who have provided suggestions for improvement of the current method (right).

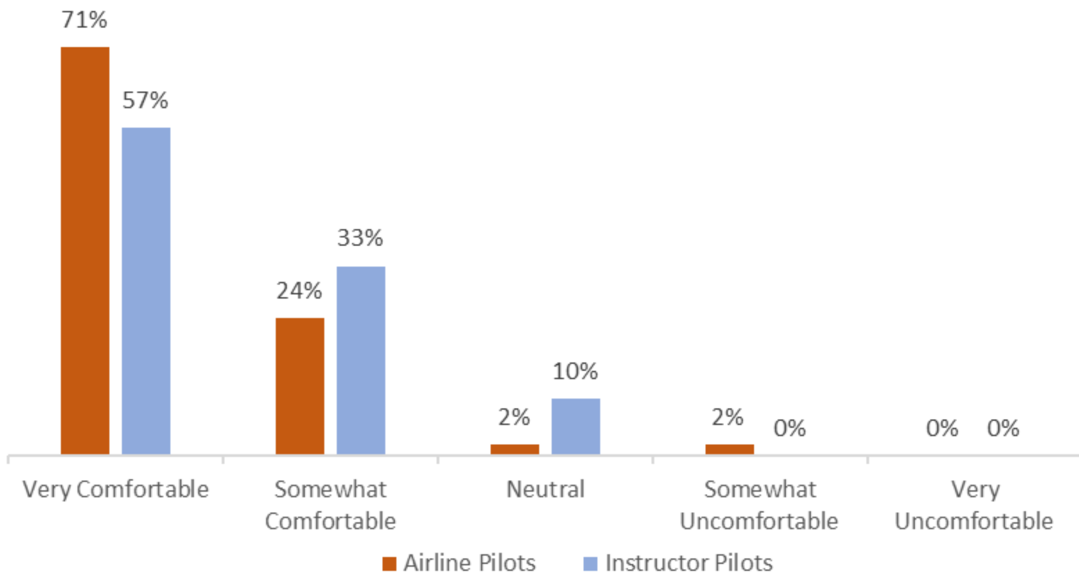

Figure 3. Comfort Levels with the Current Method, Both Groups Combined.

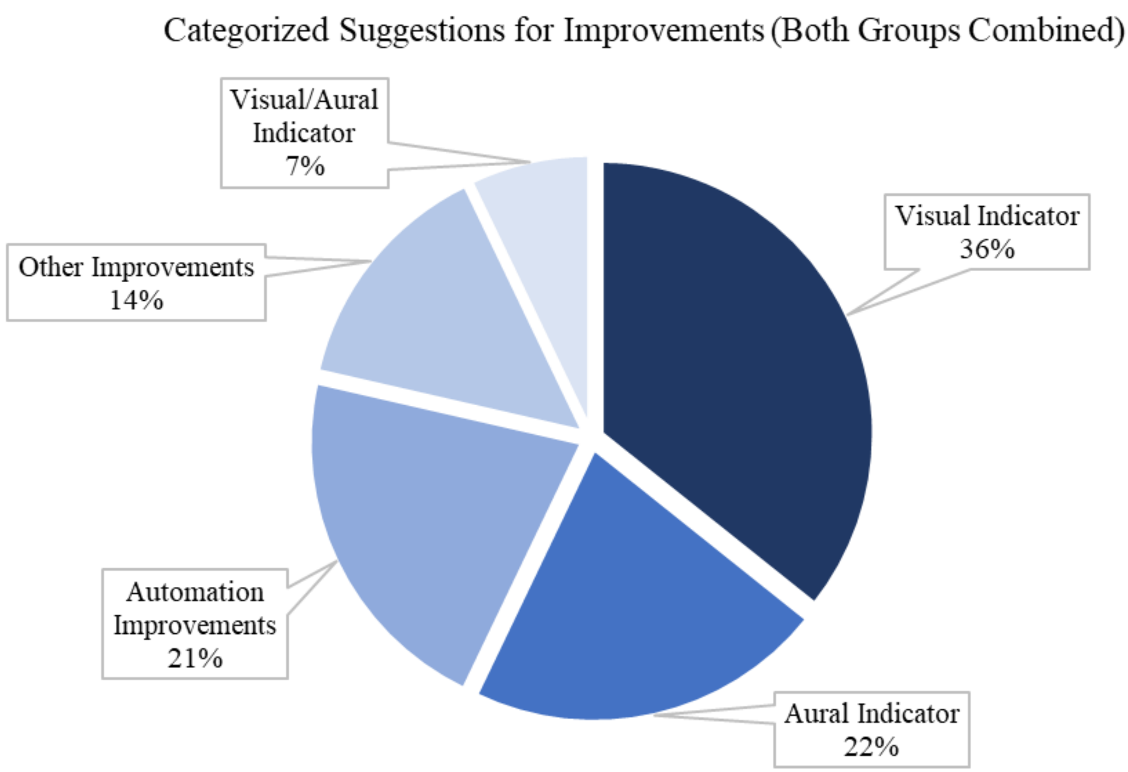

Figure 4. Suggestions for Improvement of the Current Method, Both Groups Combined.

Discussion and Conclusion

The surveys sought feedback from two pilot groups of different experience levels; airline pilots had notably more years and hours of flying and aircraft type ratings than flight school instructor pilots. This difference provides insight into perspectives and opinions from various representatives of the pilot population, from aspiring pilots at the beginning of their airline careers to seasoned captains.

A greater number of flight school instructor pilots from Survey 2 reported using the Engine-Out procedure in past flying compared to the airline pilots from Survey 1. Several factors may explain these results. First, targeting different demographics, the two surveys varied slightly – Survey 1 was designed for airline pilots operating a specific aircraft type; thus the Engine-Out question queried particular experience in the type of aircraft operated. Participants in Survey 2, on the other hand, were not trained or rated on a specific aircraft model. Hence the survey inquired about the engine-out experience in multi-engine aircraft in general. Second, because of how the question was structured, it could also be related to how it was interpreted by the respondents. In-flight simulation of an engine failure (completed by reducing its power to idle but not shutting it down) is part of twin-engine pilot training; thus an Engine-Out procedure must be utilized before one becomes a CFI. Additionally, for someone who teaches other pilots to fly twin-engine aircraft, it would be a common practice to utilize the Engine-Out procedure as part of the training curriculum. We recognize that a side-by-side comparison of the responses to this question from both groups may not be a one-to-one match and acknowledge that this is a limitation of the survey study. A more determinable finding may be the fact that in both pilot groups, a similar number of respondents reported having had engine troubles at least once while operating multi-engine aircraft. This similarity shows consistency in experience despite a notable difference in aircraft types operated.

Another interesting similarity between the two groups was how comfortable pilots felt with the I-V-F procedure that includes the “dead leg – dead engine” method. Of all respondents (both surveys combined), only one pilot reported being somewhat uncomfortable with the current method while the majority felt either neutral or comfortable, with most saying they were very comfortable; no pilot stated that they were very uncomfortable with the method. The “dead leg – dead engine” method is widely common and can be used in the operation of many twin-engine propeller aircraft. Considering pilots’ familiarity with the method, it is not unusual that the respondents would feel comfortable using it. The “dead leg – dead engine” is also recommended by the FAA and is part of multi-engine aircraft pilot training - anecdotal evidence from personal conversations suggests that even some pilots only rated for single-engine aircraft are familiar with the I-V-F method. Moreover, considering that commercial pilots undergo periodic proficiency checks to maintain their license, admitting that the pilot is not comfortable with a method that is an essential part of aircraft operation could have a negative effect on confidence. It is not unlikely that social desirability has contributed to survey responses. Therefore, such a finding is not unexpected. However, pilots in both groups listed multiple negative issues to the method, including opportunities for error and increased workload. Many of these respondents also provided suggestions for improvement. Despite the self-reported comfort levels of using the “dead leg-dead engine” procedure, these findings further highlight the potential for an alternative method of identification of a failed engine.

Perhaps the most important findings were in the suggestions provided by the pilot groups. Among all suggested improvements, the overall majority of participants proposed a visual indicator to help in the identification of a failed engine, a trend seen across the more experienced pilots and the less experienced pilots. This recommendation can be explained by the fact that 80% of information received by humans comes visually (Geruschat & Smith, 2010). People are also more likely to notice visual cues (Hecht & Reiner, 2008) and tend to prioritize and trust visual information over audio and haptic when it is received at the same time (Xu, O'Keefe, Suzuki, & Franconeri 2012). Hence, it may feel more natural to receive timely and critical information through the visual channel, especially if it is placed in a fashion that is not intrusive yet remains within the operator's field of view. These suggestions further corroborate findings by Babin et al. (2020) and show that not only a method that relies on the visual channel is more effective in a simulated environment, but its implementation would most likely be accepted and acknowledged by trained and experienced pilots who operate twin-engine propeller aircraft and who would directly benefit from it. Furthermore, the benefits of the visual channel are recognized in the industry – some displays produced by Garmin offer an indication of a failed engine when a power differential is sensed by the system (Garmin, 2020).

The surveys of this study were intended to provide more insight on pilots' experience in handling a critical system failure while operating a specific class of aircraft as well as solicit their input regarding potential opportunities for improvement. Despite the subjective nature of survey responses, the results found in this study show certain similarities in pilot encounters with the issue of engine failure and engine troubles in general. Although most pilots feel comfortable with the current method, many also agree that it can be improved. We would like to emphasize that the majority of the suggestions for improvement included a visual indicator as means of delivering critical information to the pilot. These findings are important because they indicate the preferences of the end-user and align with evidence from past research.

Considering the benefits of using the visual channel and the preference voiced by the respondents, we recommend continuing to investigate the potential for implementing an alternative method of identification of a failed engine. This study primarily sought to understand whether there is a general interest in such an alternative method. To further explore this alternative method, Babin et al. (2020) recommended performing research studies with pilots who are certified and experienced in operating twin-engine aircraft. A more effective method for identification of a failed engine may not only make improvements to the safe operation of twin-engine propeller aircraft but consequently lead to changes in pilot opinions and preferences.

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Usability of the Virtual Reality Aviation Trainer for Runway-Width Illusions

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The Virtual Reality Aviation Illusion Trainer (VRAIT) is a simulator that targets the topic of in-flight visual and vestibular illusions affecting pilots, specifically focusing on the runway width illusion. Effective training using state-of-the-art Virtual Reality (VR) technology is a new instructional method that can be leveraged to train pilots in recognition and awareness of aviation illusions, thus fostering a safer environment in the aviation industry. The VRAIT is designed to demonstrate simulated situations that can lead to illusions by providing examples of what the illusions look and/or feel like. A runway illusion scenario was designed, and pilots were recruited to provide feedback on their experience in the VRAIT. During the experience, pilots were reminded of what to do if illusions were experienced in flight through an active learning experience that aimed to better prepare the pilot to identify and take corrective action when and if future in-flight illusions occur. Data was collected on pilot experience during the scenarios, pilot enjoyment, realism, simulator sickness, the effect of the illusion, and knowledge gained in the scenario. Although knowledge on VR as a training tool is widely available, the research aimed to address the gap in whether VR is a useful and effective tool for training pilots for in-flight illusions.

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Introduction

One of the leading causes of worldwide fatal aircraft crashes is loss of control in flight (IATA, n.d.). In-flight illusions can be a major causal factor to loss of control in flight (Patterson, 2013). The human body receives orientation and movement information from three main physiological sources when flying: vestibular, somatosensory, and visual systems (FAA, 2011). Although most accidents happen during the maneuvering phases of takeoff and landing, in-flight illusions severely degrade the pilot's situational awareness, which is a major factor in the chain of events that lead to a crash (Meeks et al., 2021). Pilots generally have a clear idea of body and aircraft movement based on information received from these three systems; however, under certain flying conditions, pilots can become disoriented when one or more of these systems provide conflicting information to the brain. The vestibular system, for example, becomes unreliable when the pilot loses visual contact with the horizon (FAA, 2016). Disorientation can then lead the pilot to misinterpret airplane attitude and unintentionally put the aircraft in an unfavorable/dangerous flight profile. One example is the crash of Flash Airlines Flight 604. The first major contributing factor to this accident was Spatial Disorientation experienced by the flight crew, as cited on the Egyptian Ministry of Civil Aviation's (EMCA) Final Report of the accident (EMCA, 2005).

Two remedies for overcoming spatial disorientation are prevention and awareness (FAA, 2011). Virtual Reality (VR) training can be a great resource to help develop an awareness and possibly prevent pilots from getting into a disoriented scenario by allowing them to experience the illusion from a safe training setting. By simulating the flight scenario using VR, pilots can visualize what the illusion looks like so they can be better prepared to take corrective action should they encounter such a situation in flight. The training aims to expose pilots to a runway width illusion scenario through VR and analyze various aspects of the usability and perceived fidelity of the system. The goal of the experiment is to analyze the effectiveness of VR as a learning/training tool, and to examine the reaction of student and instructor pilots to a VR software that simulates a changing runway width in-flight illusion.

Review of Relevant Literature

Vision is one of the most important senses for the safety of flight (FAA, 2016). The use of visual cues through hours of training gives the pilot an idea of the aircraft's orientation relative to the ground. Though heavily relied upon, there are key pitfalls to the visual system of which pilots need to be cognizant to prevent falling into unfavorable flight attitudes. A visual illusion occurs when a pilot becomes disoriented due to conflicting visual cues (FAA, 2016).

Runway Width Illusion

One type of visual illusion is the runway width illusion, which occurs when a pilot is approaching a runway that is narrower or wider than they are accustomed to. When the runway is narrower than what they are used to, the pilot's visual system gives them the feeling that they are higher on their approach path than normal (FAA, 2016). The pilot's response would then be to pitch down to increase the descent rate, to achieve what the pilot feels to be a normal approach path. In doing so, the pilot will then fly a lower-than-normal approach, causing the pilot to touch down before the start of the runway (FAA, 2011).

On the other hand, if the pilot was to approach a runway that is wider than normal, visual cues would give the pilot the impression that they are on a lower approach path than normal (FAA, 2011). To correct the illusion of being low, the pilot's response would be to increase the pitch attitude to arrest the descent rate and establish an approach path that the pilot feels to be normal. In doing so, the aircraft would actually be flying a higher approach path than normal, which may result in a low-altitude stall or a missed approach (FAA, 2011).

Although there is no single direct remedy to overcome spatial disorientation or counteract the perception of being high/low during an approach to a wide or narrow runway, there are measures that can be taken to lessen the risk associated with entering an undesired flightpath. Hazard awareness and assessment are two key strategies that can help pilots avoid the effects of a visual illusion (Airbus, 2005). Knowing the airport environment and assessing the terrain information relevant to the operation are ways of mitigating the risk of a visual illusion. Furthermore, if flying in a multi-crew environment, Crew Resource Management is a key resource to be used, as task sharing and effective cross-check of items inside and outside the cockpit are fundamental for ensuring the safety of the flight and checking to ensure the crew is not susceptible to illusions (Flight Safety, 2009).

Illusion training and education are two methods that can also prepare pilots ahead of time on what to expect, should they find themselves flying into a wider/narrower runway than they are accustomed to. Topics such as depth, perception of height, and assessment of glide path are important for pilots to understand for them to know beforehand what to expect when flying an unfamiliar approach (Airbus, 2005). Furthermore, making use of all available resources, such as approach lights, runway lights, and instrument approaches, can help the pilot accurately judge the airplane's height over the terrain and thus reduce the chance of being deceived by a visual illusion (Flight Safety, 2009). Following the indications of the instruments is the safest action a pilot can take if found in an undesirable situation. A pilot should seek to avoid following body sensations and reference the flight instruments whenever possible before changing the aircraft's flight path (Wynbrandt, 2004).

Another method pilots use to help develop an awareness of disorientation in flight is by undergoing a simulation training scenario. The Barany Chair and Vertigon are two devices that induce a spatial disorientation sensation by various rotating parts and gimbals. The GAT Trainer is also a simulator that is placed on a rotating base that allows the pilot to fly a scenario while the base of the simulator spins, thus allowing the pilot to experience various vestibular illusions (Wynbrandt, 2004). With the continual development of new technologies, VR has also become a major innovative solution for the prevention of in-flight illusions.

To adequately adapt aviators to flight illusions, training programs can effectively utilize VR, which has progressively proven to produce better performance in memory tasks than traditional book methods of learning and video conditions (Allcoat, D., & von Muhlenen, A., 2010). VR adapts all three learning styles of visual, auditory, and kinesthetic to aid the user in the proficiency of learning a new concept. Learning through multiple modalities ensures the effectiveness of retaining information and allows the user to test concepts that enable active learning. When a user is placed in an immersive system, their learning complexity is simplified to Mayes and Fowler's three fundamental stages of "conceptualization, construction and dialogue" (Fowler, 2015). The user conceptualizes information by gathering facts, then constructs these facts through presenting and explaining what was learned through a final dialogue, whether that be through an application or some form of discussion.

Counteracting disorientation through flight is best attempted using adaptation. To effectively adapt an individual to any new circumstance, adaptation should be consistent, incremental in exposure and introduced over a distributed period to counteract aversive effects. Options considered as stimuli have been medication, adaptation programs, behavioral strategies and sensory cueing. Medication treats the symptoms but does not prevent the symptoms from occurring (Lawson, Rupert, & McGrath, 2016). Behavioral strategies are not always readily available in up-tempo situations in which individuals experience task overload or emergency situations. What is left becomes adaptation training programs and sensory cueing where somatosensory inputs are enhanced.

To effectively target participants to respond realistically in VR, realistic simulations are imperative. For a user to become engaged in realistic responses with the immersive system, there are two necessary components called place illusion and plausibility illusion (Slater, 2009). Place illusion contributes to the user having a sensation that they are present within the simulation even though they are not there. The sense of immersion within the illusion is codified through sensorimotor contingencies, which are the actions carried out to perceive the environment such as moving the head up and down, or bending down and seeing something from a different point of view (Slater, 2009). The further the user probes the system, the more likely the place illusion is to break once the virtual boundaries are surpassed. Each user comes out of the experience with a different opinion that will dictate the place illusion's effectiveness.

The plausibility illusion keeps the user engaged in the scenario that is occurring. To maintain the user's attention, events that are not in direct user control in the virtual environment must always refer to the user. The user's realistic response to items in the virtual world is thereby referred to as "response-as-if-real" (Slater, 2009). Overall, the place illusion can be treated as binary because the illusion is either there or not, in different modalities. Individuals are capable of maneuvering through a cockpit tutorial while still asking their instructor questions that are not within the tutorial. In contrast, the plausibility illusion does not reform again if broken (Slater, 2009). The ability to maintain both place and plausibility illusions is dependent upon an event lining up with the expectations of what the user deems is likely to occur in each scenario. Perhaps the point of presence in the illusion is to target the user on a perceptual level, not as in a cognitive illusion. The user's perceptual system recognizes a threat and rapidly responds much before the cognitive system can catch up and remind the user that the illusion is not real; however, the reaction has already occurred. Although users are aware that the VR scenario is a fictitious environment, that does not change their attitude or perception of the training (Slater, 2018).

Simulator Sickness in VR

Disorientation is a major symptom of cyber-sickness, also called VR sickness. Causes of cyber-sickness can be separated into three main categories: hardware, content, and human factors, all of which contribute to overall user discomfort. Hardware factors include features of the device itself, such as display, where content factors reference the function and use within the program/experience itself, thus referring to differences related to individual personal characteristics that affect discomfort during VR use. A literature review by Chang, Kim, and Yoo (2020) found that existing research on hardware factors have focused primarily on display, with sub-factors including latency, flicker, field of view (FOV), and display type and mode. Most of these studies have collected data via subjective measures, namely, the simulator sickness questionnaire (SSQ) as opposed to objective features. With advances in hardware, however, updates to the software must also occur. Chang, Kim, and Yoo (2020) identified five categories of VR content factors: optical flow, graphic realism, reference frame, content FOV, and task. Again, measurements were primarily subjective. The use of objective measurements has been limited. The field of VR research should diversify the forms of measurement used, particularly by collecting more physiological data or otherwise objective measurements (Chang, Kim, and Yoo, 2020.).

The Motion Sickness Questionnaire (original version by Kennedy, R.S., Lane, N.E., Berbaum, K.S., Lilienthal, M.G., 1993) was used to quantify any motion sickness participants might have felt during the scenario. The benefit of the Simulator Sickness Questionnaire (SSQ) over a general Motion Sickness survey is that the SSQ focuses more on symptoms that can be experienced under exposure to a simulator, which is a reliable method of measuring various symptoms that can be felt by participants specifically in a simulator environment. The questions addressed in the SSQ asked the user to rate symptom intensity ranging from none, slight, moderate, or severe in the following:

- General Discomfort
- Fatigue
- Headache
- Eye Strain
- Difficulty Focusing
- Salivation
- Sweating
- Nausea
- Difficulty Concentrating
- Fullness of the Head
- Blurred Vision
- Dizziness with Eyes Open
- Dizziness with Eyes Closed
- Vertigo
- Stomach Awareness
- Burping

Results from the survey questions and how different groups of participants' answers differed from each other will be further analyzed in the Results section of the report.

Usability of VR in Training

Virtual illusions are utilized in VR to keep the user engaged and counteract the user's rigid perception of reality. The human brain quickly adapts to unchanging stimuli in a process called adaptation (Huckins, 2020). Manipulation of environments within the virtual world exceeds that of the physical world in false visual feedback, which can be utilized as a direct benefit in training (Cuperus, 2019). To create human-machine interfaces to support such models of training, eye-hand controls and head motion tracking devices have been under continuous revision. Visual mechanisms focus on the lower, middle, and higher levels of vision. The lower level concentrates on where the user's attention is focused at the time on the high visual acuity of the fovea. The middle level of vision focuses on the peripheral sense of motion perception. The higher level of vision is the eye movements that generate the "representation" or "cognitive model" of a scene (Stark, 1995).

With these separate processes occurring in the eye, there is a top-down model created where vision completes the perceived visual information of the visual world where humans foveate approximately 30 times in 10 seconds throughout varied scan paths (Stark, 1995), which can at times lead to the illusion of seeing without looking when there are dual displays on augmented reality. Particularly in simulated airplane landings onto runways, there are documented cases where individuals are looking at dual controls and the runway simultaneously and overlook a vehicle at the end of the runway (Stark, 1995). Training to counteract these occurrences has proved beneficial when presented with these situations in VR.

Engaging users through VR beyond the perceptual level to the cognitive level requires effective processes to be applied. Bottom-up multisensory processing, sensor motor self–awareness frameworks, and top-down prediction manipulations can be utilized in combination to generate brain mechanisms of a user to "believe" that a computer-generated world can be real (Gonzalez, 2017). In bottom-up processing the brain combines bodily signals to adapt feedback that will enable the user to respond effectively to the environment, which serves as a key component of self-body consciousness (Gonzalez, 2017).

Problems with simulators tend to divulge themselves when the visual and vestibular systems do not match. The brain then is made to believe that the body is both static and moving (Gonzalez, 2017). To overcome the differences in information the brain is receiving, systems can be manipulated to outweigh the information that is being relayed to the brain. Sensory information can then be changed by keeping moving individuals stationary or seated. When seated, an individual has more proprioceptive sensors relaying to the brain that the body is static, which can overcome the visual information being relayed to the brain. To overcome visual information relayed to the brain, headset hardware must be specially designed to maximize peripheral vision to the user. Enhancing cognitive level effects in VR illusions can benefit the "conversion moment" described by users since the 1980s; the conversion from stepping out of the real world into one of VR is now cognitively possible (Gonzalez, 2017), thanks to the advances in hardware and software technology currently available.

Summary

VR makes it possible for users to feel that they are part of an altered situation and identity. Participants have responded to these situations as if they were their reality. To be able to create these illusions, there is basic equipment and stimulations of the sensory inputs that are necessary. VR instrumentation includes sensors to track and measure a set of the participants' body motions, physiological states, and displays (Gonzalez-Franco et al., 2017).

When the sensor-coupled stimuli match what participants' brains expect of what will come next, the brain tends to treat that simulated reality as real, then engages more neural mechanisms to continue the perceived truth of the illusion. Research shows that VR can stimulate coordinated perceptual modalities so that the brain mechanisms which collect and process afferent sensory input will interpret the information coherently (Kilteni et al., 2015). For participants to be able to interact with their environment without breaking the illusion, there must be minimum VR instrumentation with a continuously updated (head-tracked) display. (Gonzalez-Franco et al., 2017).

Therefore, VR training for in-flight illusions can be an effective training solution for illusion prevention and awareness. By engaging in active learning through the VR environment, participants can experience the illusion from a safe setting (simulation), which aims to better prepare them for maintaining constant awareness in-flight. Specifically tailored to the runway-width illusion, the experiment aims to better prepare pilots to detect and take corrective action during the final approach to a runway that might seem wider or narrower than what the pilot is accustomed to.

Methodology

The runway width illusion experiment aimed to investigate the usability of VR training software and supporting devices to determine whether VR is an appropriate system that can accurately simulate real-world aviation illusion scenarios. Embry-Riddle Aeronautical University's (ERAU) Institutional Review Board approved the research project.

Recruitment

Participants were recruited through the use of flyers, emails, and word-of-mouth. The participants were required to be ERAU students, possess or currently be undergoing training for a Federal Aviation Administration (FAA) pilot certificate, and be at least 18 years of age. A total of 30 participants were recruited, each with varying levels of flying experience.

Process and Procedures

All participants met one-on-one with the researcher for the entire duration of the study and were scheduled for a one-hour time block. The illusion scenario was conducted in the Extended Reality (XR) Lab in the ERAU College of Aviation in Daytona Beach, FL. The procedure began with the participant filling out the Informed Consent Form, followed by the completion of the Demographic Survey. The participant was briefed on how the equipment worked and how to operate the controllers for the VR scenario. The participants then completed the illusion training scenario under the supervision of the researcher and simulator technician. Following the scenario, the participants completed the SSQ and the Post-Training Survey.

Equipment

The VR equipment used was the Valve Index Headset. Participants were instructed to sit in a normal rotating office chair located in the center of the XR Lab. Two hand controllers were available for participants to navigate through menus, but the illusion scenario required no physical input from the participants during the flight scenarios.

Results

The experiment recruited a total of 30 participants (n=30). Of the 30 participants, 13 held or were undergoing training for their Private Pilot certificate, six were Commercial Pilots, and 11 were CFIs. Furthermore, out of the 30 participants, 18 of them were aged 19-21, and 12 were 22 years old and over. For statistical analysis purposes, participants were divided into two groups: Those with a CFI certificate and those without. Age was considered as a factor to separate participants into two groups, but flight experience was chosen as a better method of making groups more unique. In this case, those holding a CFI certificate were deemed the group that has more flight experience due to the training time required to possess the additional certificate. Between participants who held a CFI certificate and those who did not, there was significant difference ($p < .001$) in the average amount of flight time; for CFIs (M = 392.455, SD = 124.1542) and Non-CFIs (M = 184.789, SD = 110.9537). Therefore, based on flight experience, "CFI vs. Non-CFI" was used as a category to separate participants into two groups. There were a total of 11 CFIs and 19 Non-CFIs in the study.

Pilots with less flight experience (and less exposure to aeronautical knowledge) may benefit more from a VR training experience. For this reason, multiple usability and reaction questions were compared between more experienced and less experienced pilots, to examine if there were any changes in pilot perception of the training software due to flight experience. Results collected and analyzed comprised the usability of the VR equipment (aspects such as how participants enjoyed the illusion, how confident they felt in their abilities to identify a runway illusion, how likely they were to recommend the illusion scenario to a fellow pilot, as well as data regarding the SSQ (which simulator symptoms participants felt, and the strength of each symptom felt).

Post-Training Survey

The Post-Training Survey aimed to investigate the usability of the VRAIT as an appropriate and accurate aviation illusion simulator. The following questions were addressed in the survey:

1. The scenario made me feel as if I was on a real approach to landing.
2. The controls in the scenario were easy to understand and use.
3. The scenario made me feel as if my altitude was changing when the aircraft was paused.
4. The scenario gave me a greater awareness of runway width illusions.

5. I feel more confident in my ability to perceive runway width illusions.
6. The narration during the scenario helped me understand this runway illusion lesson.

The Likert Scale was used as a means to quantify user opinion with scores ranging from 1-5, where 1 was Strongly Disagree, and 5 corresponded to Strongly Agree. Results were recorded along with some basic demographic data from each participant, so answers could be analyzed as a whole, as well as compared between different groups of participants. For the Post-Training Survey, a mean closest to five would indicate better/more favorable simulator usability.

Table 1
Usability of the VRAIT among CFIs and Non-CFIs: Means & SD

	CFI or Non-CFI	N	Mean	Std. Deviation
The scenario made me feel as if I was on a real approach to landing.	Non-CFI	19	4.37	0.60
	CFI	11	4.36	0.92
The controls in the scenario were easy to understand and use.	Non-CFI	19	4.63	0.50
	CFI	11	4.73	0.47
The scenario made me feel as if my altitude was changing when the aircraft was paused.	Non-CFI	19	4.05	1.03
	CFI	11	4.00	1.18
The scenario gave me a greater awareness of runway width illusions.	Non-CFI	19	4.68	0.48
	CFI	11	4.64	0.92
I feel more confident in my ability to perceive runway width illusions.	Non-CFI	19	4.42	0.61
	CFI	11	4.36	1.03
The narration during the scenario helped me understand this runway illusion lesson.	Non-CFI	19	4.63	0.50
	CFI	11	4.73	0.47
I would recommend this training scenario to fellow pilots.	Non-CFI	19	4.74	0.45
	CFI	11	4.73	0.65

The objective of the experiment was to analyze how well VR software can reliably represent the runway width illusion scenario in a training environment, and if there were any differences in response among two different groups of pilots. The null hypothesis that there was no difference in how well participants reacted to the VR training scenario between CFIs and Non-CFIs was tested. The assumption of the equality of variance was tested. Levene's test of equality of variance was not significant for any case ($p > .05$).

All of the questions received a mean score of 4 or above on the Likert Scale. Most of the questions were close to a value of 5, which indicates the participants Strongly Agree. These high scores indicate a positive reaction by both low and highly-experienced pilots towards the VRAIT as a learning and training tool.

One of the questions, "The scenario made me feel as if my altitude was changing when the aircraft was paused," had a slightly higher SD of 1.18 among the CFI group's mean of 4.0. Reasons for this could include that some CFIs have already been exposed to other illusion training aids, are already knowledgeable about the illusion, or possibly have experienced the runway width illusion in real life, which would lead to a wider distribution of scores. Pilots with less experience, including those still undergoing training, were believed to benefit more from a training device such as the VRAIT. This idea is supported by means of questions 2, 3, and 4. Pilots with lower experience ranked these questions slightly higher and with a smaller SD compared to CFIs. Nonetheless, the overall scores of all questions, for both groups support good usability, high fidelity and effectiveness of the VRAIT as a training and learning tool for pilots, as shown in Figure 1.

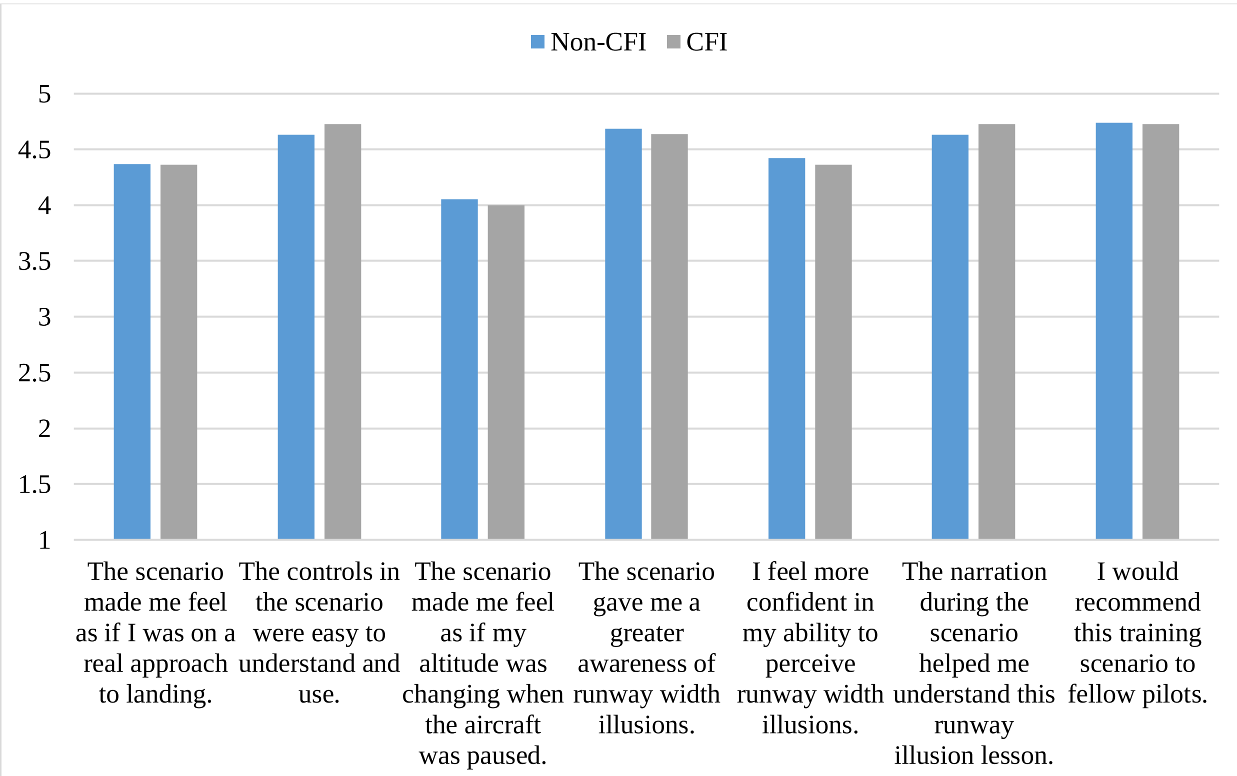

Figure 1. Usability of the VRAIT among CFIs and Non-CFIs: Means (Illustrated)

None of the *t*-tests presented a statistically significant difference in how CFIs and Non-CFIs ranked their answers related to the Usability of the VRAIT. “The controls in the scenario were easy to understand and use,” for CFIs (M = 4.727, SD = .4671) scored a slightly larger mean than for Non-CFIs (M = 4.632, SD = .4956). Nonetheless, an independent samples *t*-test was not significant at the alpha level of .05, $t(28) = -.520$, $p = .607$. The null hypothesis was retained for all cases.

Simulator Sickness Questionnaire

A *t*-test was conducted to identify any differences in simulator sickness symptoms:

Table 2
Motion Sickness Symptoms among CFIs and Non-CFIs: Means & SD

	CFI or Non-CFI	N	Mean	Std. Deviation
General Discomfort	Non-CFI	19	1.16	0.37
	CFI	11	1.36	0.67
Fatigue	Non-CFI	19	1.00	0.00
	CFI	11	1.27	0.47
Headache	Non-CFI	19	1.00	0.00
	CFI	11	1.27	0.65
Eye Strain	Non-CFI	19	1.21	0.42
	CFI	11	1.36	0.67
Difficulty Focusing	Non-CFI	19	1.21	0.42
	CFI	11	2.09	1.14
Salivation Increase	Non-CFI	19	1.11	0.32
	CFI	11	1.36	0.81
Sweating	Non-CFI	19	1.37	0.68
	CFI	11	1.18	0.40
Nausea	Non-CFI	19	1.00	0.00
	CFI	11	1.18	0.40
Difficulty Concentrating	Non-CFI	19	1.00	0.00
	CFI	11	1.55	1.04
Fullness of the Head	Non-CFI	19	1.26	0.56
	CFI	11	1.46	0.69
Blurred Vision	Non-CFI	19	1.37	0.60
	CFI	11	1.82	0.87
Dizziness (Eyes Open)	Non-CFI	19	1.00	0.00
	CFI	11	1.27	0.65
Dizziness (Eyes Closed)	Non-CFI	19	1.00	0.00
	CFI	11	1.18	0.60
Vertigo	Non-CFI	19	1.05	0.23
	CFI	11	1.09	0.30
Stomach Awareness	Non-CFI	19	1.05	0.23
	CFI	11	1.00	0.00
Burping	Non-CFI	19	1.00	0.00
	CFI	11	1.00	0.00

The null hypothesis that there was no difference in motion sickness symptoms felt among CFIs and Non-CFIs was tested. None of the *t*-tests presented a statistically significant difference in how CFIs and Non-CFIs felt the symptoms of motion sickness, except “Difficulty Focusing.” “Difficulty Focusing” was the only symptom that demonstrated a statistical difference among participants. Levene’s test of equality of variance was significant (p = .005).

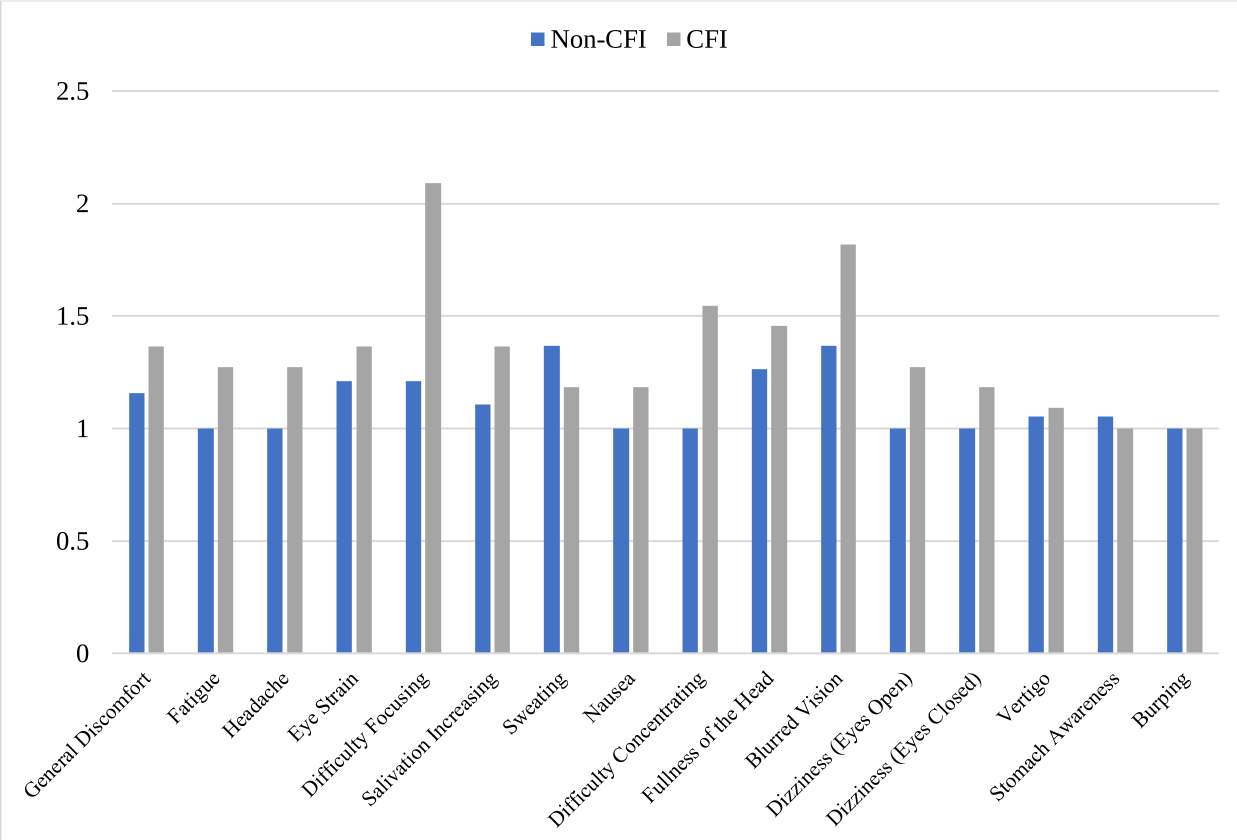

Figure 2. Motion Sickness Symptoms among CFIs and Non-CFIs: Means (Illustrated)

CFIs ranked difficulty focusing (*M* = 2.091, *SD* = 1.1362), higher than Non-CFIs (*M* = 1.211, *SD* = .4189). A one-independent sample *t*-test was significant at the alpha level of .05, *t*(11.596) = -2.474, *p* = .030, therefore, the null hypothesis was rejected. Cohen's *d* = 1.03, which is a large effect. Apart from Difficulty Focusing, all other motion sickness symptoms were not significantly different among the two groups of participants. Most means were considerably low, which on the Likert Scale, closest to one would indicate none/very low motion sickness symptoms.

Table 3
Motion Sickness Symptoms among CFIs and Non-CFIs: t-tests

	t	df	Sig. (2-tail)
General Discomfort	-.932	13.652	.367
Fatigue	-1.936	10.000	.082
Headache	-1.399	10.000	.192
Eye Strain	-.770	28	.447
Difficulty Focusing**	-2.474	11.596	.030
Salivation Increasing	-1.015	11.785	.330
Sweating	.822	28	.418
Nausea	-1.491	10.000	.167
Difficulty Concentrating	-1.747	10.000	.111
Fullness of the Head	-.828	28	.414
Blurred Vision	-1.675	28	.105
Dizziness (Eyes Open)	-1.399	10.000	.192
Dizziness (Eyes Closed)	-1.000	10.000	.341
Vertigo	-.392	28	.698
Stomach Awareness	.755	28	.456

*** indicates p < .05*

Scenario Description

Participants were seated in a Cessna 172 on final approach to a runway on a clear day. As the aircraft approached the runway, the simulation froze at 100 feet above the ground (AGL), and the runway width increased/decreased at certain intervals. A verbal narration provided participants context and knowledge on the illusion during the course of the simulation. The approach then continued until the aircraft was about to flare, and the simulation froze one more time. The runway width again transitioned multiple times from narrow, to normal, to wide, while the narration described ways to identify and mitigate the illusion.

Figure 3. Demonstration of changes in runway width: Wide, Normal, Narrow

Limitations

There were three limitations encountered throughout the study. First, the sample size was somewhat small (*n*=30), as the study was designed as a proof of concept for further training material development. Conclusions and statistical comparisons could be more robust if the sample size was larger and included pilots with various experience levels. Second, the participants were only recruited from students enrolled at ERAU's Daytona Beach campus. Therefore, the results obtained may not be generalizable to the entire general aviation population but instead focused more on the collegiate aviation training program population. Lastly, some of the questions posed were opinion-type inquiries and were reliant on truthful answers and subjective opinions of participants.

Discussion, Conclusions, and Recommendations

There are various factors that contribute to the safety of the aviation industry in the United States. Mechanical equipment, infrastructure, facilities, and personnel training in aviation are structured and maintained at very high standards to lessen the chances of an unexpected event and mitigate risks. Pilots are trained and evaluated by rigorous FAA standards constantly, ensuring the safety of individuals as well as of the general flying public. Human factors, however, play a large role in the safety of the aviation system. (Patterson, 2013).

Disorientation can lead a pilot to put the aircraft in an undesired state, compromising the safety of flight if not properly corrected. Therefore, pilots must understand possible in-flight illusions and their effects, as well as ways to overcome them when encountered. There is no single solution to overcoming in-flight illusions, but two main remedies for detecting and overcoming in-flight illusions are awareness and prevention (FAA, 2011). Awareness could be accomplished by a pilot effectively planning for unexpected pitfalls before the flight and knowing what to expect for that specific operation. Prevention, on the other hand, could be accomplished by practice and simulation training.

The Virtual Reality Aviation Illusion Trainer was a resource used to simulate the Runway Width in-flight illusion. Participants from different age groups and different flight backgrounds ran through the scenario and were asked to evaluate their experiences and opinions about usability, faithfulness, general reactions, and physiological symptoms they might have felt in the scenario. Participants were separated into two groups based on flight experience (split between CFIs and Non-CFIs), and results to multiple post-session questions were analyzed and compared among the two groups.

Both groups had a generally positive reaction to the simulation scenario. Seven questions were asked regarding the usability of the VRAIT, based on a scale of 1-5 (where 5 would be very good). The means of all the questions were 4 or above for all questions among both groups of participants, indicating the participants enjoyed the scenario and viewed the VRAIT as a useful training tool. When comparing the symptoms of motion sickness, 16 different symptoms were analyzed per participant. Fifteen of those did not present a statistically significant difference between groups. Most means were considerably low (on a scale of 1-4, where 1 would indicate no symptom felt). When analyzing these results, flight experience had no significant effect on participant perception/reaction towards the VR training, as well as among symptoms of motion sickness. Based on these results, the VRAIT could be an effective tool for training pilots of different age groups and different flight experience backgrounds.

Some recommendations for future studies include gathering a larger sample size for better accuracy of data collected. Although the study counted with a total of 30 subjects, if more participants were available, subjects could be placed into more diverse categories for comparison purposes. Another recommendation for further research could include different questions aimed at addressing other factors of equipment usability, such as biometrics or ergonomic factors. More questions could be tailored toward objective parts of the illusion, such as testing if subjects were able to identify a purposefully integrated flaw or detail into the illusion scenario. Furthermore, the development of different illusions appears to be the most relevant recommendation following the completion of the study, according to the overall positive feedback received from participants.

Technology is in constant growth and development across all sectors of the aviation industry. In the field of training, since the first aircraft simulator was created, new training solutions have been developed and adapted by flight schools, airlines, and governmental agencies for better and more accurate personnel training. The VRAIT aims to use the best of existing VR technology to help pilots become more aware of in-flight illusions and further their knowledge on prevention techniques. Modern, effective training using VRAIT aims to help bring forth a safer environment for pilots and all users of the national airspace system.

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School Choice Factors Influencing Flight School Selection: Among Student Pilots Who Enrolled as Teenagers

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This study examined school choice factors influencing decisions to enroll in vocational flight schools among student pilots enrolled as teenagers. The purpose of identifying these factors is to inform flight school recruiters about possible insights for effectively recruiting teenage students. The study data was based on a 2019 survey. This study included 45 participants who met the following inclusion criteria: intended to become airline pilots, were aged 15–18 at enrollment, and were enrolled in vocational, non-collegiate flight schools for private pilot training in California in 2016-2019. The data were analyzed using descriptive statistics. The key findings regarding training program factors that influenced decisions were: training quality, safety records of the programs, the reputation of certificated flight instructors, availability of flying opportunities, length of time to complete the program, scheduling flexibility. In terms of institutional factors, the participants highlighted training costs, overall school reputation, training capacity, career placement, administration integrity, friendliness of the campus, financial aid availability, and administration effectiveness. Moreover, the participants considered family members, school flight instructors, and school staff as the most important individuals influencing their school selection. With respect to school marketing promotion approaches, the teenage group identified contact with school flight instructors, contact with school staff, campus visits, word of mouth, and school's website as relatively more influential approaches. This study contributes to the current literature on vocational school choice decision-making, specifically for teenage students choosing flight schools. In addition, collegiate aviation programs recruiting young adult students could also benefit from this study's findings since very few studies have been conducted examining students' choice patterns for collegiate aviation institutions.

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Introduction

Air transportation is a major contributor to the U.S. economy, specifically with it supporting 6.5 million jobs across the U.S. as well as 4.2% of the country's gross domestic product (International Air Transport Association, 2019). However, due to the impact of the COVID-19 pandemic, domestic passenger demand may take about four years to return to where it was in 2019; yet at that time, the industry may experience some degree of shortage of pilots (Federal Aviation Administration [FAA], 2021). Boeing's (2020) pilot outlook of 2020 to 2039 also stressed that maintaining a sufficient and competent pilot workforce will remain an issue when aviation activities resume to 2019 levels since a large number of senior pilots are approaching their retirement age in the coming decade. For example, between 2017 and 2026, approximately 42% of active airline pilots from the five largest airlines in the U.S. have retired or are retiring (Becker & Cunningham, 2017). These forecasts suggested that there is a crucial need for developing a sustainable pilot workforce.

Nevertheless, the U.S. Government Accountability Office (GAO, 2014) reported that fewer people had attended flight schools for the pilot programs. Recently, the former Secretary of Transportation, Elaine L. Chao, presented in the 2020's Youth Access to American Jobs in Aviation Task Force meeting that fewer high school students were interested in becoming aviation professionals including professional pilots (FAA, 2020). Given that the majority of aviation activities rely on the availability of pilots, a deficiency in the number of new pilots along with a large percentage of senior pilots approaching their retirement age could be unfavorable to the industry's full recovery and long-term sustainability. Therefore, it is essential to encourage the next generation to enroll in professional pilot training programs.

Mann, Harmoni, and Power (1989) stated that during adolescence, individuals are typically beginning the decision-making process for the initial career, which ultimately can impact their future vocational experience. To effectively attract and recruit the next generation of prospective professional pilots and expand the workforce, understanding the adolescent group of students' school choice patterns for flight schools can be one starting point. As Hemsley-Brown and Oplatka (2016), Paulsen (1990) proposed that, by understanding student's choice patterns of how institutional factors affect students' decisions in enrolling in their schools, the recruiters can obtain the fundamental information and develop or tailor strategies accordingly to enhance marketing and recruiting effectiveness.

Literature Review

Chapman's (1981) school choice theory for higher education proposed that, to effectively market and recruit, it is essential to understand students' needs and wants of their prospective schools. These needs and wants in making their ultimate school choice decisions are affected by both student personal characteristics (e.g., socioeconomic status, high school performance) and influential external factors (e.g., significant persons, institutional characteristics) (Chapman, 1981). More recently, Hoyt and Brown's (2003) marketing framework for higher education referred to these influential external factors as school choice factors.

There have been four themes of school choice factors recognized in the literature: program characteristics (e.g., teaching quality, the reputation of instructors) (Melvin, 2003; Sheppard, 2013), institutional characteristics (e.g., tuition, location) (Melvin, 2003; Sheppard, 2013), relevant people (e.g., family members, school staff) (Hoyt & Brown, 2003; Meyer, 2019; Rocca, 2013; Walton, 2014), and marketing promotion approaches (e.g., school's website, campus visits) (Melvin, 2003; Meyer, 2019; Rocca, 2013). Hemsley-Brown and Oplatka (2016) proposed a school choice theory that similar to Chapman's (1981) and introduced student characteristics (e.g., age, gender, and socioeconomic status) as the focus in market segmentation. Market segmentation was viewed as a key component in higher education marketing strategies; this tactic makes it easier for school recruiters to tailor strategies in accordance with student market segments' different preferences toward various choice factors (Hemsley-Brown & Oplatka, 2016).

According to Hemsley-Brown and Oplatka (2016), age was demonstrated as a strong distinguishing variable between various factors influencing students' attitudes in selecting their school and their ultimate school choice decisions. Kotler and Fox (1995) also stressed the importance of assessing age to successfully market educational institutions, especially because they proposed that consumers' "wants and capacities" are affected by one's age (p. 217). More specifically, previous research has demonstrated how individuals of different age groups valued different choice factors in influencing their school selection. For instance, nontraditional students typically are older than 24 years of age, are employed, and have family obligations (Employment and Training Administration [ETA], 2007); they rated the availability of a specific major (Hutchens, 2016; Padwal, 2011; Sheppard, 2013) and value of degree (Padwal, 2011; Sheppard, 2013) as the most influential factors. Whereas traditional students are typically between 18 and 21 years of age, are recent high school graduates, and are enrolled as full-time students in their higher education (ETA, 2007); this group rated school academic reputation, graduates get good jobs, and the cost as the key influential factors (Stolzenberg et al., 2019). For high school seniors who intended to continue their education, the National Center for Education Statistics (2012) reported that in 2004, seniors generally considered courses being offered, school academic reputation, and financial aid as important factors in selecting their higher education institutions.

Gaps in the Research

It is important to note that the available literature on factors that influence students' school selection primarily focused on academic colleges and universities. There has been a limited number of studies focusing on vocational, non-collegiate flight schools specifically based upon teenagers' choice experiences and perspectives. In the U.S., this type of flight school accounted for 95% of civilian flight schools providing training (GAO, 2011) and has been playing a crucial role in the pilot training industry. Yet, factors that influence the selection of flight schools, which are the vocational education sector in higher education, have been proposed to differ from the academic education sector in terms of recruitment techniques (Belcher, Frisbee, & Sandford, 2003). To fill the gap in the literature, this study investigated school choice factors influencing decisions to enroll in vocational, non-collegiate flight schools among student pilots who enrolled as teenagers.

Statement of Purpose and Research Questions

The purpose of this study was to determine which school choice factors most influenced teenage student pilots when enrolling in California non-collegiate flight schools for the private pilot programs (initial training programs). This study was guided by the following research questions:

1. How important are training program characteristics (e.g., the reputation of flight instructors, training quality) for teenage student pilots in their school choice decision-making?
2. How important are institutional characteristics (e.g., training cost, location) for teenage student pilots in their school choice decision-making?
3. How much influence do relevant people (e.g., family members, school staff) have on teenage student pilots' school choice decision-making?
4. How much influence do marketing promotion approaches (e.g., social media, campus visits) have on teenage student pilots' school choice decision-making?

Methodology

Data Source and Study Sample

The data in this study was based on Jin's (2019) online survey, which was approved by Alliant International University's Institutional Review Board. Jin's (2019) survey data collection was conducted between July and October 2019, examining student pilots' choice patterns for non-collegiate flight schools. A total of 201 valid responses from adults aged 18 years and older were included in Jin's (2019) study. At the time of the survey, all participants completed the informed consent form. These participants were diverse in age profiles when they enrolled in their flight schools for the initial training during 2016-2019.

The current study's sample included 45 valid responses, a sub-sample from Jin's (2019) survey dataset, who endorsed that they were aged *18 or younger* at enrollment for their initial training. These participants in the current study are referred to as teenage student pilots. It is important to take into account that there is no minimum age to start training as long as one receives training from a certificated flight instructor (CFI) (FAA, 2013). Based on Jin's (2019) survey research design, the participants in the current study met the following inclusion criteria: intended to become airline pilots, were aged 15–18 at enrollment, and were enrolled in non-collegiate flight schools for (airplane) private pilot training in California between 2016 and 2019.

Regarding participants' demographics, there were more male teenage student pilots (91.1%) than female counterparts (8.9%). Domestic student pilots accounted for 93.3% of the sample, and the remaining 6.7% were international student pilots. Of the participants, 46.7% of them enrolled in non-collegiate Part 61 flight schools, and 53.3% of them enrolled in non-collegiate Part 141 flight schools. With respect to annual household income, 35.6% of the participants responded to making under $25,000, 17.8% of them responded to making between $25,001-$50,000, both the between $50,001-$75,000 and the between $75,001-$100,000 had responses of 13.3%, and 20% of the participants had the household income higher than $100,000.

Basic Research Design

Some high schools provide private pilot programs (initial pilot training programs) as elective courses, but they mainly focus on the ground knowledge portion of the pilot certification. Non-collegiate flight schools, as of the GAO's 2011 report, accounted for 95% of civilian flight schools offering full-fledged pilot training programs and flexible classes. Hence, high-school-aged students could have the opportunity to engage in requisite flight maneuvers and obtain the private pilot certificate while they are still completing their high school diploma. To best recruit high-school-aged students to non-collegiate flight schools, it is important to identify the determinative choice factors that influenced them to enroll in school pilot training programs at this age. By including a subset of the original sample (age range 15–18) (Jin, 2019), recruiters can strategize the marketing and recruitment approaches by keeping these factors in mind.

Data Collection

The data was collected via an online survey software. As introduced previously, the data collection took place between July and October 2019. The survey was distributed to various pilot community websites. 110 non-collegiate flight schools in the U.S. were contacted to help distribute the survey to prospective participants. The random sampling method was utilized to ensure that each potential participant had an equal chance to be included in the study (Panacek & Thompson, 2007).

Instrumentation and Analysis

To increase the content validity of the survey instrument, following Burns and Grove's (1993) recommendation, it was constructed by adapting previous researchers' studies on school choice factors. In addition, by inviting a panel of experts from related fields (i.e., education major professors, flight school managers, and pilots) to review and revise this study's survey instrument, the reliability was enhanced (Burns & Grove, 1993). The survey included 43 flight school choice items, and these items were divided into four themes. The four themes were (1) training program characteristics, (2) institutional characteristics, (3) relevant people, and (4) marketing promotion approaches. The survey instrument adopted the five-point Likert scale model as it allows the middle (third) point to be represented and interpreted as neutrality (Chyung, Roberts, Swanson, & Hankinson, 2017; Colman, Norris, & Preston, 1997). The participants were invited to rate the level of the importance or influence of each factor on their school selection (1 = not important/no influence/not influential at all, 5 = extremely important/influence/influential). To address each aim of the study, descriptive statistics were utilized.

Findings

Research Question One

How important are training program characteristics for teenage student pilots in their school choice decision-making?

Table 1 displays the results of teenage student pilots' perceived importance of twelve training program characteristics on their school choice decision-making. The average ranking across the twelve program characteristics was 3.74. The ones that were rated above this average included: training quality (*M* = 4.80; *SD* = 0.46), safety records of the programs (*M* = 4.31; *SD* = 0.90), reputation of CFIs (*M* = 4.27; *SD* = 0.69), availability of flying opportunities (*M* = 4.22; *SD* = 0.93), length of time to complete program (*M* = 4.02; *SD* = 1.01), and scheduling flexibility (*M* = 4.00; *SD* = 1.04). This study interpreted these rated above-average-ranking program characteristics as relatively more important than the other six. The six program characteristics that were rated less important included: mechanics on staff (*M* = 3.73; *SD* = 1.18), the types of training aircraft (*M* = 3.67; *SD* = 1.28), availability of various training programs (*M* = 3.44; *SD* = 1.16), flight simulators (*M* = 3.07; *SD* = 1.25), availability of extra tutoring (*M* = 3.02; *SD* = 1.31), and the distance of training aircraft to the runway (*M* = 2.33; *SD* = 1.33).

Table 1
Importance of Training Program Characteristics

	M	SD
(1) Training quality*	4.80	0.46
(2) Safety records of the programs*	4.31	0.90
(3) Reputation of certificated flight instructors*	4.27	0.69
(4) Availability of flying opportunities*	4.22	0.93
(5) Length of time to complete program*	4.02	1.01
(6) Scheduling flexibility (e.g., classes, planes)*	4.00	1.04
(7) Mechanics on staff	3.73	1.18
(8) The types of training aircraft	3.67	1.28
(9) Availability of various training programs	3.44	1.16
(10) Flight simulators	3.07	1.25
(11) Availability of extra tutoring	3.02	1.31
(12) The distance of training aircraft to the runway	2.33	1.33

Note:

- *n* = 45
- Likert scale: 1 = not important at all, 5 = extremely important.
- Mean response to all characteristic = 3.74.
- * indicates that this specific characteristic was ranked above the mean (3.74)

Research Question Two

How important are institutional characteristics for teenage student pilots in their school choice decision-making?

The results of teenage student pilots' perceived importance of fourteen institutional characteristics on their school choice decision-making are provided in Table 2. The institutional characteristics that rated above the average ranking of 3.66 were: training cost (*M* = 4.44; *SD* = 0.87), the overall reputation (*M* = 4.29; *SD* = 0.76), training capacity (*M* = 4.00; *SD* = 1.04), career placement (*M* = 3.96; *SD* = 1.21), administration integrity (*M* = 3.87; *SD* = 1.04), friendliness of the campus (*M* = 3.82; *SD* = 1.01), financial aid availability (*M* = 3.69; *SD* = 1.28), and administration effectiveness (*M* = 3.67; *SD* = 1.04). Since this study interpreted these rated above-average-ranking characteristics as relatively more important, the following six institutional characteristics were found to be rated as less important: location (*M* = 3.64; *SD* = 1.11), campus technology and facilities (*M* = 3.58; *SD* = 0.97), distance from your home (*M* = 3.31; *SD* = 1.26), appeal of the campus (*M* = 3.27; *SD* = 1.27), school social life (*M* = 3.11; *SD* = 1.32), and insurance policy for training (*M* = 2.62; *SD* = 1.32).

Table 2
Importance of Institutional Characteristics

	M	SD
(1) Training cost*	4.44	0.87
(2) The overall reputation*	4.29	0.76
(3) Training capacity (student to training aircraft and flight instructor ratio)*	4.00	1.04
(4) Career placement*	3.96	1.21
(5) Administration integrity*	3.87	1.04
(6) Friendliness of the campus*	3.82	1.01
(7) Financial aid availability*	3.69	1.28
(8) Administration effectiveness*	3.67	1.04
(9) Location	3.64	1.11
(10) Campus technology and facilities	3.58	0.97
(11) Distance from your home	3.31	1.26
(12) Appeal of the campus	3.27	1.27
(13) School social life	3.11	1.32
(14) Insurance policy for training	2.62	1.32

Note:
- Mean response to all characteristic = 3.66
- * indicates that this specific characteristic was ranked above the mean (3.66)

Research Question Three

How much influence do relevant people have on teenage student pilots' school choice decision-making?

The results of teenage student pilots' perceptions of the influence that relevant people had on their school choice decision-making are shown in Table 3. Out of the nine provided options, the participants ranked self (*M* = 4.58; *SD* = 0.78), as having a major influence. Other key influencing people that rated above the average ranking (relatively more influence) of 2.89 were: family members (*M* = 3.69; *SD* = 1.40), school flight instructors (*M* = 3.02; *SD* = 1.44), and school staff (*M* = 3.00; *SD* = 1.45). The participants rated the following five relevant people's influence below the average ranking: current pilot trainees (*M* = 2.71; *SD* = 1.34), graduates (*M*

= 2.53; *SD* = 1.38), friends (*M* = 2.42; *SD* = 1.42), school executive committee (*M* = 2.11; *SD* = 1.25), and school sales personnel (*M* =1.96; *SD* = 1.15). This study interpretated that these five relevant people relatively had less influence on teenage student pilots' school choice process.

Table 3
Influence of Relevant People

	M	SD
(1) Self*	4.58	0.78
(2) Family members*	3.69	1.40
(3) School flight instructors*	3.02	1.44
(4) School staff*	3.00	1.45
(5) Current pilot trainees	2.71	1.34
(6) Graduates/program graduates	2.53	1.38
(7) Friends	2.42	1.42
(8) School executive committee	2.11	1.25
(9) School sales personnel	1.96	1.15

Note
- Mean response to all characteristic = 2.89
- * indicates that this specific characteristic was ranked above the mean (2.89)

Research Question Four

How much influence do marketing promotion approaches have on teenage student pilots' school choice decision-making?

Table 4 presents the results of teenage student pilots' perceived influence of eight marketing promotion approaches on their school choice decision-making. The approaches that rated above the average ranking (relatively more influential) of 2.95 were: contact with school flight instructors (*M* = 3.49; *SD* = 1.10), contact with school staff (*M* = 3.40; *SD* = 1.16) and campus visits (*M* = 3.40; *SD* =1.36) (rated equally influential), word of mouth (*M* = 3.31; *SD* = 1.33), and school's website (*M* = 3.11; *SD* = 1.45). The following three approaches were rated below the average ranking: internet sources (*M* = 2.64; *SD* = 1.35), social media (*M* = 2.60; *SD* = 1.27), and conventional media (*M* = 1.64; *SD* = 1.03). This study interpretated that these three approaches were relatively less influential on teenage student pilots' school choice decisions.

Table 4
Influence of Marketing Promotion Approaches

	M	SD
(1) Contact with school flight instructors*	3.49	1.10
(2) Contact with school staff*	3.40	1.16
(2) Campus visits*	3.40	1.36
(3) Word of mouth*	3.31	1.33
(4) School's website*	3.11	1.45
(5) Internet sources other than school's website and social media	2.64	1.35
(6) Social media	2.60	1.27
(7) Conventional media (e.g., radio, television, and print)	1.64	1.03

Note

- Mean response to all characteristics = 2.95
- * indicates that this specific characteristic was ranked above the mean (2.95)

Discussion and Conclusions

The purpose of this study was to examine which school choice factors influenced teenage student pilots when enrolling in California non-collegiate flight schools for private pilot programs. The discussion is presented based on the four themes: training program characteristics, institutional characteristics, relevant people, and marketing promotion approaches. Following the discussion of the four themes, the generalizability of the findings and limitations are presented.

Training Program Characteristics

It was found that training quality and reputation of CFIs (excluding safety records of the programs as it is not a common factor in other education fields) were rated as the two most important program characteristics. These findings appeared to be general in higher education since the findings were also observed by Hoyt and Brown's (2003) research in which they analyzed 22 studies on higher education school choice. In addition, the finding that both length of time to complete the program and scheduling flexibility rated above the average ranking was aligned with Sheppard's (2013) study. Sheppard (2013) investigated graduate students' choice patterns for their universities; all the study participants (graduate students) had at least one dependent, and a majority were employed. It is possible that with these responsibilities that the graduate students valued length of time to complete the program and scheduling flexibility to balance their education, work, and family responsibilities. Although the current study examined student pilots' choice patterns for flight schools when they enrolled at ages 15–18 years, further research should consider whether both graduate students and this study's sample share similar motives for emphasizing such two program characteristics, due to balancing school, work, and other responsibilities.

Nevertheless, it should be noted that this study focused on the participants who enrolled in flight schools at ages 15–18 years. Typically, individuals at that age in the U.S. are enrolled in secondary schools. It may be due to the balance between their secondary education and their desire to enroll in a flight school. These individuals deemed scheduling flexibility as one of the relatively more important program characteristics in their school selection. In addition to their highlighting of scheduling flexibility, as can be seen, availability of flying opportunities and length of time to complete the program were also emphasized in the ranking. The emphasis on these three program characteristics may imply that there was a preference for flight schools that provide efficient training and assist students in obtaining pilot certificates within their desired timeline. This may be because some degree programs in aviation or aeronautics allow certain academic credits to students who have a particular level of a pilot certificate (e.g., Embry-Riddle Aeronautical University, n.d.; Utah Valley University, n.d.). Teenage student pilots who intend to obtain a higher education degree in aviation may prefer to obtain a pilot certificate in advance, thus reducing their workload within the college or university.

Moreover, the implication that these teenagers expected flight schools to provide efficient training may suggest schools notice the importance of intensive or time-shortened training courses in assisting students to complete the training and obtain pilot certificates within the estimated timeframe. This implication was supported by Scott and Conrad's (1992) study finding that students who appreciate intensive courses, especially because of such course format's "convenience and efficiency" (p. 443). Particularly, the intensive or time-shortened course structure is suitable for practice-based learning (Lasker et al., 1975 as cited in Daniel, 2000) and computational techniques learning (Daniel, 2000), and fostering a continuous learning atmosphere that motivates students to efficiently comprehend course material (Scott, 1993). Kucsera and Zimmaro (2010) stated that students who choose intensive courses tend to exhibit high levels of motivation. With high motivation, students are more apt to succeed in accomplishing their educational goals (Daniel, 2000). Indeed, this present sub-study (based upon Jin's [2019] survey data) revealed that a high percent (71.1%) of the teenage student pilots rated *passion for flying* as their motivational factor in pursuing an airline pilot career. Overall, Daniel (2000) concluded that successful intensive or time-shortened courses typically include a focus on goal-driven learning, a variety of training strategies, well-planned class activities, and regular assessments.

Institutional Characteristics

As seen in the findings, training cost was rated as the most important institutional characteristic. The importance of cost over students' decisions in selecting a school has been identified in previous research (Andrea, 2010; Dickinson, 2003; Meyer, 2019) and theory (Hemsley-Brown & Oplatka, 2016) and seemed general in higher education. Additionally, the GAO (2014) also emphasized training cost that cost may be one of the main factors causing fewer people to enroll in flight schools. Yet, Dunnett, Moorhouse, Walsh, and Barry (2012) found that regardless of the increasing cost of education, overall school reputation was the most important factor in influencing individuals' selection of an (academic) higher education institution.

Although this present study focused on vocational education, the finding also revealed that teenage student pilots considered overall school reputation (ranked 2nd in Table 2) crucially important. Therefore, flight schools need to stress the overall reputation in their marketing and recruitment procedures. The Aircraft Owners and Pilots Association (AOPA, n.d.a) introduced "flight regulations and safety policies" relevant to a school's reputation and suggested prospective flight students assess these attributes before application (para.13). Nguyen and LeBlanc (2001) stated that a school's overall reputation could be a difficult construct to define since there are differences in how people perceive a school's reputation. Further research would benefit from understanding students' perceptions of this factor, specifically with flight schools, in addressing the influence it has on students' school choice decision-making.

In addition to the overall school reputation being a factor that was considered to compensate for concerns regarding cost (Dunnett et al., 2012), additional studies recognized that career placement (Haskins 2018) and financial aid availability (Chapman,1981; Eagan, Lozano, Hurtado & Case, 2013; Walton, 2014) were also of similar magnitude. The latter two factors were highlighted in the current study findings as well. According to Jackson (1978), an individual's pursuit of higher education can be viewed as an investment, and the investor (student) is expecting returns; the returns are typically reflected on the enhanced socioeconomic attainments. In alignment with the current study findings and Haskins' (2018), it is logical that a student would consider the education costs and career placement in making their choice of investment. Specifically, the journey to becoming an airline pilot involves different levels of pilot training and different types of pilot jobs. This journey may be complicated for those who are not familiar with the pilot industry. Hence, flight schools may consider providing career counseling services in their recruitment procedures as it may not be clear to some prospective students how the industry is organized.

With respect to financial aid availability (e.g., scholarships, grants, and loans [Eagan et al., 2013]), Chapman (1981) claimed that: "if costs pose an obstacle to college-going, financial aid is supposed to reduce or eliminate the problem" (p. 496). Chapman (1981), Eagan et al. (2013), Walton's (2014) further research affirmed financial aid availability being crucial important affecting students' selection of their colleges or universities. Although the current study focused on vocational, non-collegiate flight schools, it should be noted that there are scholarship opportunities for teenage students from this type of flight school (e.g., AOPA Primary Training Scholarship Program, AOPA High School Flight Training Scholarship Program [AOPA, n.d.b]). Flight school recruiters should notify (potential) students of financial aid information since some students may not be aware of such financial aid sources for vocational, non-collegiate schools.

Training capacity was included in the relatively more important institutional characteristics. The AOPA (n.d.a) also stressed this factor when guiding potential students to choose a flight school. Similar to most other vocational education fields, flight schools provide hands-on, practice-based training that prepares students for their desired careers. Reasonably, teenage student pilots would expect a school with a proper ratio among students, instructors, and training aircraft for obtaining efficient training. Moreover, this study found that the teenage group rated both administration integrity and administration effectiveness above the average ranking. The AOPA (2012) asserted that "flight training is a customer service experience" (p. 31). When inviting customers to provide service experience feedback, they emphasize the service providers' "expertise, honesty, and integrity" as the basis of the evaluation standards (Kretovics, 2011, p. 169). To meet flight students' expectations and satisfaction on these matters, the AOPA (2012) suggested flight schools provide authentic estimated training timelines and budget for obtaining a pilot certificate and accommodate well-structured classes for efficient training.

Relevant People

The participants rated themselves as having a major influence on their school choice decision-making, followed by the key influencing people of family members, school flight instructors, and school staff. These findings differ from a research brief derived from a longitudinal study in which the top selected individual(s) who influenced high school students' post-secondary education decision-making were their family members; the second most common influential source was the students themselves (Oymak, 2018). Oymak (2018) also found that high school students rarely selected teachers and counselors (school staff) as important sources of influence. The current study investigated a cohort of high-school-aged students' vocational education decisions —flight school choice decisions. This study's key findings revealed that self had a major influence and that family members, instructors, and staff were substantially more influential. These findings revealed that teenage students were the primary decision-makers in their flight school selection and also implied that the study data reliably reflected these teenagers' perceptions and decision-making rather than other sources (e.g., family members).

Nevertheless, the current study identified that family members (ranked 2nd in Table 3) had a strong influence over teenage student pilots' school choice process. This finding was consistent with previous research (Bohman, 2009) and theories (Cabrera & LaNasa, 2000; Chapman, 1981; Hossler, Schmit, & Vesper, 1999; Paulsen, 1990) and may be general in higher education. Family members' opinions usually would form students' expectations toward their prospective schools and thus affect students' decisions in choosing a particular school (Chapman, 1981). Of the family members, the parental influence was repeatedly stressed by many researchers. For instance, according to Cabrera and LaNasa (2000), Hossler et al. (1999), parental influence specifically includes encouraging their children's aspirations in continuing education, motivating their children toward higher educational goals, and providing practical supports (e.g., accompanying their children at campus tours, financially supporting children). To give comprehensive support for their children's post-secondary education, Rowan-Kenyon, Bell, & Perna (2008) found that parents generally depend upon schools for guidance and support, and some parents even hire private counselors for extensive resources. Accordingly, flight school recruiters should make efforts in offering contact and communication with prospective teenage students' parents and other family members.

School flight instructors were ranked the third most influencing people. When taking private pilot training, students have to spend most of their class time one-on-one with the instructor and sit very close in the training aircraft. Understandably, students will expect the flight school to assign an instructor that best reflects their attributes and learning style (AOPA, 2012). Taking these factors into account, these teenage student pilots stressed flight instructors' influence during their school choice process.

Marketing Promotion Approaches

Contact with school flight instructors was found to be the most influential approach. Paulsen (1990) stated that faculty/instructors who can offer professional information regarding the program to inquiring potential students could positively affect students' final school choice decisions. Furthermore, Herren, Cartmell, and Robertson (2011) and Rocca's (2013) research on student college choice (for agriculture programs) affirmed the effectiveness of contact with faculty/instructors marketing promotion approach. It is well-known that airline pilots are high-stakes professions that involve individualized and hands-on training. Therefore, this specialized training may have influenced the teenage student pilots to rate flight instructors as a key factor in their school choice decision-making (see Table 3 and Table 4). These findings may suggest prospective students' need for mentorship assistance from flight instructors since their school search phase. Flight schools may be necessary to designate certain instructors to be part of school sales personnel, recruiters, and counselors to interact with prospective students.

In addition to the highlighting of contact with school flight instructors, contact with staff was also included in the key influential approaches by the study participants. Martirano's (2017) study revealed that students from small colleges and universities generally recognized the contacts-with-school-personnel (i.e., instructors, staff) marketing promotion approach as an influencer on their school selection. Such a preference is possible because small institutions are relatively more flexible to provide personalized, one-on-one responsiveness to inquiring potential students that focus their interests and needs (Martirano, 2017; Vander Schee, 2010).

Moreover, this study's findings on the campus visits approach being a strong influence aligned with Meyer (2019), Pampaloni (2010), Rocca's (2013) studies which focused on students' choice patterns for colleges and universities. Pampaloni (2010) stated that campus visits are important to students as an opportunity to compare their prospective schools' features and narrow down their school options. Considering the high levels of complexity and responsibility of the pilot career, when choosing a flight school, it is understandable that potential students often desire to communicate with school instructors and staff, visit the campus, and depend upon word of mouth to collect information.

As can be seen, this study participants indeed included the word of mouth approach as an influencer in their school choice process. This finding was supported by previous research on marketing higher education (Martirano, 2017; Sung & Yang, 2008). Additionally, Alves and Raposo's (2007) study finding suggested students' "word of mouth actions as a direct consequence of satisfaction" (p. 6). Annamdevula and Bellamkonda (2016) asserted that maintaining students' satisfactory schooling experience is essential for a school to accumulate its brand image since students are an important source of word-of-mouth referrals. One way for flight schools to indirectly improve or enhance their word-of-mouth promotion, according to Douglas, Douglas, and Barnes' (2006) proposal, schools can conduct surveys regularly to understand how satisfied students are with school services, facilities, and training quality; based on the feedback, school management strategies and policies can be adjusted.

School's website in this study was ranked as the fourth influential approach. Yet, some other recent studies, such as Mahajan and Golahit's (2017) study of students' choices for a technical university and Meyer's (2019) study of students' choices for two-year colleges, showed that the school's website was rated as the most influential approach. Since this present study aimed to identify effective marketing promotion approaches for teenagers when selecting a flight school, it is relevant for recruiters to be aware of the great amount of time this age group spends utilizing the internet. For instance, out of a sample of 13–17 year olds in the U.S., 95% of them endorsed owning a smartphone or accessing one, 97% of them claimed using one or more popular social media platforms (e.g., YouTube, Instagram), and 45% of them stated that they spend a vast majority of their daily time online (Anderson & Jiang, 2018). Although the current study participants ranked social media as a less influential approach, Kisiołek, et al. (2021) found that social media and school websites were the two most effective online marketing promotion approaches for higher education. Therefore, to keep up with the trend, it is recommended that flight schools also utilize the social media approach to maximize recruitment efforts.

Generalizability of the findings

It is crucial to examine the school choice factors influencing prospective teenage students' enrollment in pilot programs for not only collegiate aviation institutions, but also for non-collegiate institutions since there is an expected shortage of regional airline pilots (FAA, 2021) and fewer adolescents are interested in becoming aviation professionals (FAA, 2020). Understanding this market segment's school choice patterns can provide insight for effective marketing and recruitment strategies (Hemsley-Brown & Oplatka 2016; Paulsen, 1990). The current study provided school choice information based upon the perceptions of a group of student pilots who enrolled in their vocational, non-collegiate flight schools at ages 15–18 years. The findings of this study may be valuable for vocational flight school administrators, recruiters, and prospective teenage student pilots. In addition, this study's findings and implications may be applicable to collegiate pilot programs recruiting young adult students since very few studies have been conducted examining students' school choice decisions for collegiate aviation institutions.

Limitations and Future Research

Although this study's findings may apply to collegiate aviation institutions, more studies are recommended to confirm this generalization. In addition, the survey was constructed with a limited number of choice factors, so future studies would benefit from incorporating more factors, such as flight training via virtual reality. According to Fussell (2020), this type of training may become a popular training modality in flight schools. Finally, this study only focused on flight schools in California. Therefore, it is suggested future studies include other states or regions for a comprehensive understanding of teenage student pilots' school choice patterns.

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Assessing Motivation as Predictors of Academic Success in Collegiate Aviation Classrooms

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The aviation industry changes rapidly. As such, it is important to continually re-assess our understanding of future aviation professionals and how their motivation translates into career-related performance. The present study applies Social Cognitive Theory (Bandura, 1986) to understand 229 students' motivation in a fourth-year technical aircraft systems course. To further our understanding of motivation and performance, the Science Motivation Questionnaire II (SMQ-II; Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011), which measures intrinsic motivation, career motivation, grade motivation, self-determination, and self-efficacy, was adapted to the collegiate aviation domain. Using structural equation modeling techniques (Arbuckle, 2017), the study found strong predictive relationships between self-efficacy and academic performance, as well as a moderate relationship between self-determination and academic performance. The study found weak or unanticipated results as to the regression relationship between academic performance and grade motivation, intrinsic motivation, and career motivation. This study reinforces concepts on motivation and academic performance within the environment of collegiate aviation.

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During the time of this study (2018-2019), a significant pilot shortage existed and was forecasted to worsen (Klapper & Ruff-Stahl, 2019; Meredith, 2019). Pilot candidates were offered generous incentives such as hiring bonuses, guaranteed interviews at major carriers, and other lucrative perquisites (Lutte & Lovelace, 2016; Regional Airline Association, 2019; Samost, 2018). The external rewards and the incentive to enter the industry were arguably strong for future aviation professionals, each interested in securing a coveted seniority number at a select airline or commercial aviation operator. These conditions provided a unique context in which to study motivation within the pre-career collegiate aviation student. What remains to be seen is the influence of the various motivational subtypes on pre-career collegiate aviation students' academic success. How much does career motivation matter? Are the students intrinsically motivated to perform? Are there other motivational theories that appear to influence the academic performance of pre-career aviation students?

In the present study, we examined the relationships of a set of motivation constructs adapted from the Science Motivation Questionnaire-II (SMQ-II; Glynn et al., 2011), including Intrinsic Motivation, Career Motivation, Self-Determination, Self-Efficacy, and Grade Motivation. The adapted SMQ-II survey was provided to senior-level aviation students and combined with their academic outcome represented as an average exam score in a technical systems course. The academic course in which this study was conducted was meaningful for several reasons, primarily the temporal proximity to career entry as well as the subject matter and method of delivery of the course content. To explain further, participants were pre-career aviators studying aircraft types that they would likely fly in their future career path. Additionally, as a matter of enrollment in the course, the students were using aircraft systems courseware employed by many regional and mainline air carriers in the United States. The timing and content associated with the course in which this study was undertaken are critical as the participants are seeing a small window into their potential career paths; thus, the study is undertaken during a transitional point in their lives to evaluate students' motivations and academic achievement. To begin, we will provide a brief overview of changes in the airline industry, discuss relevant motivational theory, and finish with relevant research into motivation.

Changes in the Aviation Industry

Industry conditions present during the decade prior to this study allow us to understand issues relevant to the pre-career aviation professionals' decision to enter the field. As has been well documented by research and media reports, a pilot shortage was quickly developing and was forecasted to increase (Higgins et al., 2013; Lutte & Lovelace, 2016, Meredith, 2019). At the time of the data collection, the Boeing Pilot & Technician Outlook (2019) indicated 804,000 new civil aviation pilots would be needed globally over the next 20 years. As such, significant market demand for new pilots and growth in demand in air travel has placed significant pressure on the supply of commercial pilots. Sources of qualified pilots, such as currently certified flight instructors (CFIs) at collegiate aviation institutions, are prime candidates for recruiters from regional airlines, major airlines, cargo, corporate, and military recruiters. This favorable recruitment environment may have impacted pre-career aviators' expectations and motivations towards their chosen careers. Offering theoretical perspective into this research, relevant motivational theories and concepts are described below.

Motivational Theory

Many motivational theories offer diverse perspectives on how to interpret individual motivation within a particular environment. Glynn et al. (2011) utilized motivational theories from multiple sources to inform and interpret the SMQ-II. One such motivation theory is Bandura's (1986) Social Cognitive Theory (SCT). Additionally, other prominent theories, such as Self-Determination Theory (SDT) (Ryan & Deci, 2000a; Black & Deci, 2000), inform the interpretation of other latent constructs within the SMQ-II. Individual motivational constructs included in the SMQ-II are explained here.

Self-Efficacy

In this study, Bandura's tripartite model was represented through the personal factor as *self*-efficacy or the belief in one's ability to perform or achieve. In the research by Glynn et al. (2009), low self-efficacy was shown to be related to assessment anxiety. The results suggest that high self-efficacy would lead to low-grade anxiety and an expectation of success as a result of one's confidence in their abilities. Within the aviation career path, an individual's confidence in their abilities may continue to rise as they progress through repeated tests and performance validations. Students who do not pass high-pressure exams or flight checks may self-select out of such programs and may not be reflected in this dataset.

Intrinsic Motivation

Intrinsic motivation, or the enjoyment or interest in a particular subject, arises from the work of Ryan and Deci (2000) within SDT. Intrinsic motivation has been found to be a predictor of airline career choice (Daku & Stupnisky, 2017), as well as the number of hours spent to complete flight lessons (Forsman, 2012). In the current study, students may demonstrate an intrinsic interest in the study of aircraft systems due to their complexity, innovation, or design. Alternatively, students in the sample may find the subject matter boring or dry and may not be intrinsically motivated to study the material.

Self-Determination

Self-determination is referenced by Black and Deci (2000) as motivated behaviors, "which vary in the degree to which they are as autonomous versus controlled" (p.741). Ryan and Deci (2000b) describe self-determination as being used interchangeably with autonomy. In the context of learning science, self-determination was also cited as *responsibility* for an outcome by Glynn et al. (2009). In the present study, self-determination is characterized by the individual choices and actions (autonomy) an aviation student exerts towards the study of aircraft systems.

Career Motivation

Career motivation is referenced as a form of long-term *extrinsic motivation* as cited by Glynn et al. (2011). Extrinsic motivation is defined as “the performance of an activity in order to attain some separable outcome” (Ryan & Deci, 2000a, p. 71). A collegiate aviation student’s career motivation could include an opportunity for competitive salary or prestige associated with the commercial aviation career path. Individual items within the career motivation latent variable are most closely aligned with what Ryan and Deci (2000a) label *identified* motivation, or “a conscious valuing of a behavioral goal or regulation” (p.72). As such, the career motivation variable could be informed by both SDT as an extrinsic *identified* motivator as well as by SCT (Bandura, 1986) as an environmental factor.

Grade Motivation

Grade motivation is another form of extrinsic motivation, but with a short-term view of external rewards (Glynn et al., 2011). A collegiate aviation student in the study may consider a high exam or course grade a positive outcome or reward for their efforts in class. Grade motivation does not specifically have a formal theoretical underpinning yet may be informed both by SDT (Ryan & Deci, 2000a) or by SCT (Bandura, 1986).

For aviation students included in this study, it is important to consider multiple variations of motivation and how the temporal and contextual environment may influence such motivation. A review of motivation and the airline career path follows.

Research on Motivation and the Airline Career Path

Research on the motivation of pre-career aviation professionals is in the early phases of development, and limited research exists among this unique population. One example of such motivation relates to motivation and career path interest (Daku & Stupnisky, 2017). In that study, the authors invoked Self-Determination Theory (SDT) (Deci & Ryan, 1985; Ryan & Deci, 2000) to understand intrinsic, extrinsic, and amotivation as they relate to the pilot graduate’s choice of regional career post-graduation. The results indicated that students who exhibit higher *identified* motivation may be more likely to choose an airline by hourly pay and crew base. Additionally, the research revealed collegiate aviation students who report higher *intrinsic motivation* may choose an airline based on the referral of a friend or peer already working at the airline. Finally, important differences were observed in how students with different motivational attributes (such as *identified*, *intrinsic*, or *amotivated*) select their regional carriers for employment consideration. The current study sought to expand this developing area of research into the relationship of sub-types of motivation and how pre-career aviation students perform academically.

The purpose of the study is to evaluate the reliability and validity of the SMQ-II (Glynn et al., 2011) within the collegiate aviation environment using exploratory and confirmatory factor analysis. The second purpose of this research is to employ structural equation modeling (SEM) to determine which latent construct of the SMQ-II best predicts academic success in a senior-level advanced aircraft systems course. The motivational subscales include intrinsic motivation, career motivation, self-determination, self-efficacy, and grade motivation. The analysis of the research will be evaluated through the lens of SCT (Bandura, 1986).

Method

Participants and Procedure

This study was conducted within a senior-level advanced aircraft systems course offered at a university in the midwestern United States. The course was selected as it was in the fourth year of the academic curriculum and studied subject matter directly applicable and in a similar delivery method to students' intended career path. Of the 272 students enrolled in the advanced aircraft systems course, 84.2% (N = 229) participated in the study and completed the course (students who withdrew from the course before the end of the session were not included in the data analysis). The mean age of the participants was 22.1 (SD = 3.0), female students represented 12.7% (n=29) of the respondents in the dataset. The students reported their racial identity as White (83.8%), Asian (7.9%), more than one race (2.6%), Black or African American (0.4%), Native Hawaiian or Pacific Islander (0.4%), or not reported (4.8%). As the course was for senior-level students, most participants reported senior status (82.1%), and the remaining were junior (17.0%) or sophomore (0.9%). The mean self-reported GPA was 3.45 on a 4.0 scale. Participants reported the expected grade to receive in the course as an "A" (52.1%), "B" (39.7%), or "C" (7.0%). At the time of the study, 70.8% of the students reported they were enrolled in a defined airline career pathway program or intended to be enrolled, whereas 29.3% reported not enrolled.

The survey instrument adapted to the "aircraft systems" subject matter was disseminated via the Qualtrics online survey tool. The survey research was conducted in Fall 2018, Spring 2019, Summer 2019, and Fall 2019 academic semesters. The research was approved through the institutional IRB, and participants provided consent through the survey response.

Measures

The survey instrument was adapted from the Science Motivation Questionnaire II (SMQ-II), previously validated by Glynn et al. (2011). The survey instrument was selected as it included a diverse set of motivational subscales, which were thought to allow for the observation of differences in the studied population. The original five subscales from the SMQ-II were included in the survey instrument, including *Intrinsic Motivation, Career Motivation, Self-Determination, Self-Efficacy,* and *Grade Motivation.* Individual survey items that included the word "science" were replaced with "aviation" to provide the participants with a specific context. There were five items for each subscale, and each response was provided on a five-point Likert scale (1 = *Strongly Disagree*, …, 5 = *Strongly Agree*). Example items for the subscales were as follows: *Intrinsic Motivation,* "Learning aircraft systems is interesting; *Career Motivation,* "Learning aircraft systems will help me get a good job"; *Self-Determination*, "I study hard to learn aircraft systems"; *Self-Efficacy*, "I am confident I will do well on aircraft systems tests"; *Grade Motivation*, "It is important that I get an A in aircraft systems" (full survey item wording is listed in Appendix, Table A1).

Student academic outcome (achievement) was measured through an individual variable compiled from four individual block exam scores and a final exam score during the academic term. The students' exam scores were summed and divided by the total exam points available through block exams and the final exam to generate a composite exam score variable.

Rationale for Analysis

The survey data was compiled with a composite average exam score for each student. Missing data was limited to nine individual unique items within the SMQ-II scale and was addressed by using similar response pattern matching (SRPM) technique outlined in Byrne (2016). SRPM was selected as it allows for bootstrapping and computation of additional model fit statistics, compared to other methods of handling missing data. Structural equation modeling (SEM) was accomplished using AMOS version 27 (Arbuckle, 2017). During the confirmatory factor analysis (CFA) process, measures of model fit were compared to recommended metrics. Recommendations from for model fit include RMSEA <.06 = great, <.08 good, <.10 marginal; CFI > 0.90, >0.95 advised; TLI > 0.90 ok, >=0.95 good fit (Hu & Bentler, 1995; Byrne 2016). Hu and Bentler (1995) suggest a good fitting model with SRMR <= 0.08, whereas Byrne (2016) suggests a stricter definition at SRMR <0.05.

Results

Although this study employed an established scale, the questionnaire was adapted to a new discipline and new demographic. An exploratory factor analysis (EFA) was performed on the dataset using the dimension reduction feature of SPSS. Initially, the EFA was performed using principal-axis factoring, direct oblimin rotation and solutions with eigenvalues >1.0. This analysis method suggested a five-factor solution. Subsequently, the EFA was re-analyzed with a five-factor solution identified and suppressing factor loadings <0.30. The results of the EFA are shown in Table 3. Each of the five motivational constructs from the established questionnaire was evaluated for reliability using SPSS (IBM, 2017). Each scale showed good internal reliability. Results of reliability analysis are shown in Table 1.

The EFA yielded reasonably expected factor loadings with limited cross-loading of selected items. For consistency with Glynn et al. (2011), two individual survey items were retained on their original construct despite evidence to support movement to a stronger loading construct. Next, we performed a confirmatory factor analysis (CFA).

Goodness of fit indices suggested inadequate fit of the initial CFA model. To improve model fit, individual factor loadings suggested one observed item on each of the Intrinsic Motivation (IN4) and Grade Motivation (GM5) subscales be removed. Evaluation of modification indices (MIs >10) suggested the inclusion of covariance paths between a selection of error terms within the same two latent constructs. On the intrinsic motivation latent construct, covariance paths were added between the error terms of IN1 and IN5 and between IN3 and IN5. On the self-efficacy latent construct, covariance paths were also added between two pairs of error terms, those being SE2 and SE5 as well as SE3 and SE4. Allowing error terms within the same construct to covary suggests variation in the individual error terms follows a similar pattern and may be related; subsequently, the addition of covariance paths between related error terms improves model fit. After these model respecifications, the revised CFA model improved and was deemed sufficient for further analysis (see Figure 1).

Table 1
Factor Loadings, Mean, SD and Reliability (SMQ-II Adapted to Aviation)

	Factor				
Item	Career Motivation	Grade Motivation	Self-Efficacy	Intrinsic	Self-Determination
IN1				0.49	
IN2				0.51	
IN3	0.44			0.35	
IN4				0.58	
IN5				0.74	
CM1	0.59				
CM2	0.94				
CM3	0.70				
CM4	0.65				
CM5	0.70				
SD1					0.41
SD2					0.68
SD3					0.59
SD4					0.64
SD5					0.48
SE1			0.67		
SE2			0.83		
SE3			0.34	0.34	
SE4	0.41		0.37		
SE5			0.70		
GM1		0.55			
GM2		0.80			
GM3		0.82			
GM4		0.88			
GM5		0.41			
Mean	4.71	4.42	4.06	4.17	4.08
SD	0.51	0.63	0.69	0.63	0.59
α	0.88	0.86	0.84	0.82	0.81

Note: N=229

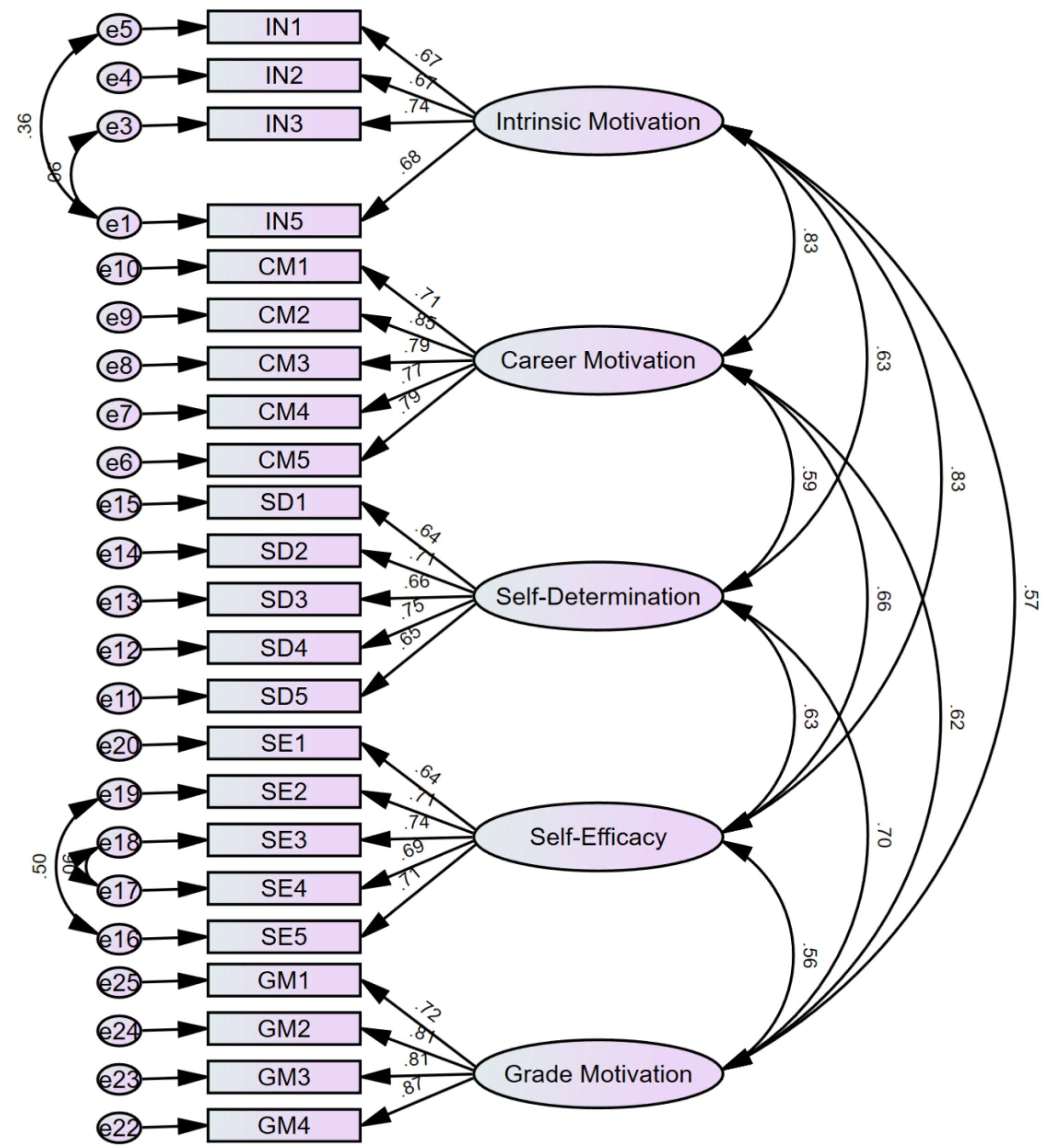

Figure 1. Confirmatory Factor Analysis using SEM, Revised Model

Note: N=229. Chi-square = 482.7, RMSEA = 0.074, CFI = 0.909, TLI = 0.893, SRMR = .061

Using the revised CFA model, analyses of convergent and discriminant validity were performed. Evidence of convergent validity was first evaluated by a review of individual standardized factor loadings for strength and statistical significance. In the revised model, all individual standardized factor loadings were above 0.50, and most approached or exceeded 0.70, which is cited as preferable by Hair et al. (2014). Additional assessment of convergent validity is accomplished through review of average variance extracted (AVE) to examine which exceeded the 0.50 threshold (i.e., more than 50% of the scale variance explained by individual items). Average variance extracted were as follows: Intrinsic (0.48), Career Motivation (0.61), Self-

Determination (0.47), Self-Efficacy (0.49), and Grade Motivation (0.65). This information suggests evidence of convergent validity for two of the five latent constructs and weak to moderate convergent validity for the remaining three.

To assess discriminant validity, which is if the latent variables are significantly unique or different from each other, the researchers compared the ‘average AVE’ between two constructs with the square of the bivariate correlation between the two constructs (Hair et al., 2014). If the average AVE between the two latent constructs is greater than the square of the bivariate correlation, it suggests evidence for discriminant validity. Evidence of discriminant validity existed for all combinations of latent constructs except between intrinsic and career motivation as well as intrinsic and self-efficacy. The high degree of correlation between these two combinations of latent constructs suggests the possibility for multicollinearity between the intrinsic motivation latent construct and two other latent constructs. Stated simply, students intrinsic motivation towards learning aircraft systems appeared to be highly correlated to their career motivation as well as their self-efficacy or their belief in the ability to succeed.

After completing the CFA, a structural model was constructed in which the five motivation constructs predicted the endogenous variable cumulative exam score ((i.e., a fully saturated model, Figure 2). Goodness of fit indices remained consistent with the CFA previously performed, with little noted change. The student cumulative exam scores appeared to be strongly predicted by their self-efficacy. Somewhat paradoxically, intrinsic motivation was negatively predictive of their averaged exam score, although both statistical and contextual explanations for this result may exist. Weak predictive relationships are noted between self-determination, career motivation, and grade motivation and the students’ academic outcome (cumulative exam score).

Bolded paths are significant to the $p < .05$ level. Manifest variables, covariance paths between selected error terms from the CFA model, and correlation path calculations between latent variables are included and calculated in the above model. However, they have been visually suppressed to aid model analysis and interpretation.

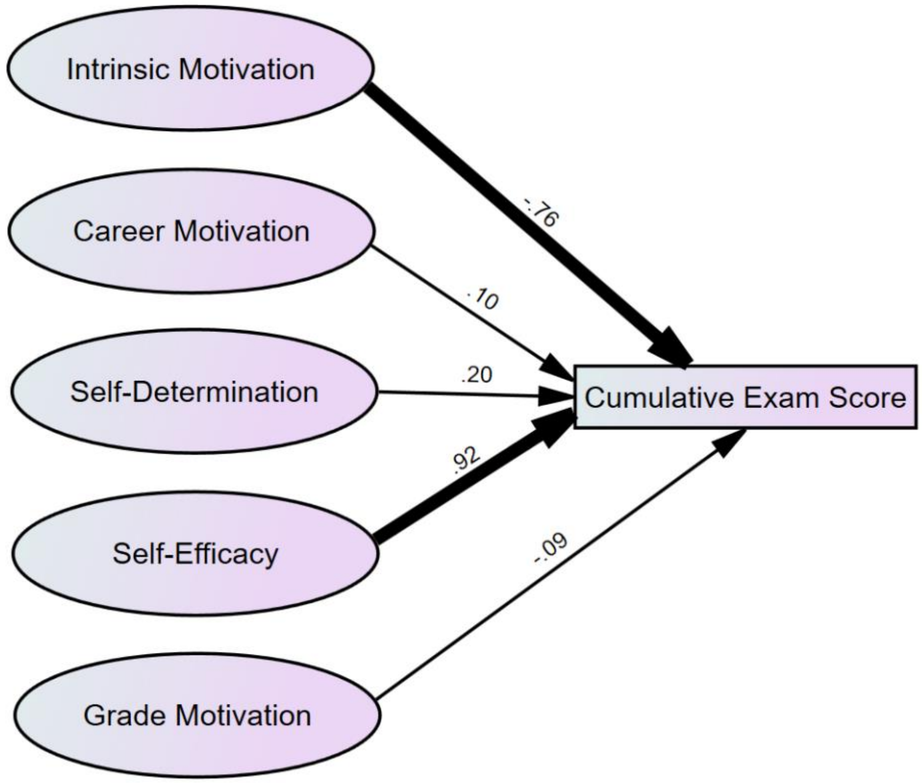

Figure 2. Motivation Construct SEM and Relationship to Cumulative Exam Score

Note: N=229. Chi-square = 529.7, RMSEA = 0.074, CFI = 0.901, TLI = 0.884, SRMR = .067.

To compare the fully saturated model with the existing theory, a competing structural model was created. Based on self-determination theory, the model was generated using two latent constructs as exogenous variables (self-determination, self-efficacy which are similar to the basic psychological needs of autonomy and competence) with paths to endogenous latent variables of intrinsic motivation, career motivation, and grade motivation, which in turn predicted academic outcome (cumulative exam score). Additionally, evaluation of modification indices (MIs) suggested the inclusion of covariance paths between selected error terms from three latent constructs. The results of the alternate structural model appear in Figure 3. Goodness of fit indices suggest this path model does not fit the data adequately; however, strong relationships were observed from self-efficacy to intrinsic motivation and, in turn, academic outcome. In the alternative structural model, the regression path from self-efficacy to intrinsic motivation and from intrinsic motivation to academic outcome are both statistically significant, p <.05. The total and indirect effect of self-efficacy on academic outcome was 2.33, whereas the total and direct effect of intrinsic motivation on academic outcome was 4.22.

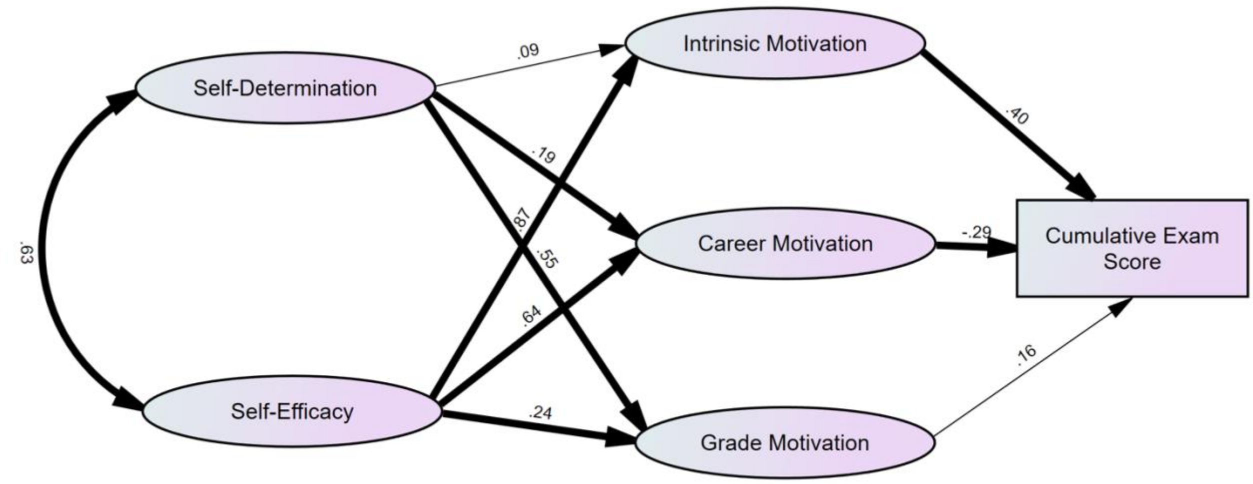

Figure 3. Alternate Structural Model – Self-Efficacy and Self-Determination as Predictors of Intrinsic, Career, and Grade Motivation

Note: *N* = 229. Chi-square = 591.11, RMSEA = 0.081, CFI = 0.882, TLI = 0.862, SRMR = .071
All bolded regression paths were statistically significant to the p<.05 level.
Removal of non-significant paths did not meaningfully improve model fit.

Discussion

Evaluation of the SMQ-II within Collegiate Aviation

The results of the EFA and correlation analysis of the modified SQM-II (Glynn et al. 2011) suggest a reliable survey instrument within the collegiate aviation environment. The CFA suggests an opportunity for improvement of construct validity through revision or removal of individual survey items on selected latent variables (e.g., intrinsic motivation and grade motivation). Analysis of discriminant validity suggests possible multicollinearity between intrinsic motivation and career motivation as well as intrinsic motivation and self-efficacy. Multicollinearity may obscure results between affected latent constructs, and within a SEM path diagram, the endogenous variable. As such, researchers who choose to use the adapted SMQ-II within collegiate aviation should do so with appropriate caution placed on the interpretation of results. Larger sample size or within a more diverse sample frame of collegiate aviation students may yield different results.

The nature of the studied population may also partially explain the cross-loading of certain manifest variables onto other factors. In the case of the cross-loading variables, these may be partially explained by the subject population's proximity to career entry and its impact on item response versus the items appropriateness or inappropriateness for inclusion within the scale. In the case of the variable IN3, "The aircraft systems I learn are relevant to my life*",* the item loads onto the Intrinsic construct, however, also loads more strongly onto the Career Motivation construct. In this specific example, one could imagine how this question has direct relevance to the pre-career aviator's career motivation and *literally* may impact their life.

SMQ-II as a Predictor of Academic Outcome

Consistent with Bandura's (1986) SCT and prior research by Glynn et al. (2011), self-efficacy showed a strong positive relationship to academic outcomes. This relationship of self-efficacy to academic outcome held true in the fully saturated model (Figure 2) as well as the alternate model through intrinsic motivation to academic outcome (Figure 3). The results of this study appear to align with expectations regarding one's belief in their own abilities and how that translates into performing on a given task. Airline recruiters and pilot training personnel may find the relationship between a pilot's self-efficacy and his or her performance important to the hiring and qualification processes. Although not statistically significant, the data showed a positive, although weaker, predictive relationship between self-determination and their cumulative exam scores (Figure 2), which aligns with results from prior research by Glynn et al.

Contrary to Glynn et al. (2011) and the theoretical work of Ryan and Deci (2000a), in the fully saturated structural model, intrinsic motivation showed a strong negative relationship to the students' cumulative exam scores. Two likely circumstances led to this unexpected result: one statistical and one contextual. As noted by Ryan and Deci, intrinsic motivation reflects the inherent tendency to pursue challenges, explore, and learn (2000a). Students enrolled in this course may not hold intrinsic interest in the study of highly technical aircraft systems and may, in fact, find it boring, overwhelming, or not relevant to their status as collegiate aviation students. A reality of the course is that the students are not currently flying the aircraft they are studying in the course, such as the Airbus A320, Boeing 737, or Bombardier CRJ700. As such, the intrinsic motivation survey items "The aircraft systems I learn is relevant to my life" or "Learning aircraft systems is interesting" may not resonate with most students enrolled in the course in a way that translates meaningfully into academic performance. As noted above, it is also possible that multicollinearity with other latent constructs may affect the results of the intrinsic motivation and predictive relationship to a student's cumulative exam score, as observed within Figure 2. If we combine concepts from SCT and SDT into Figure 3, the role of intrinsic motivation on academic outcome appears more in line with prior research.

If we apply Bandura's (1986) approach to SCT and include environmental factors (airline demand for qualified pilots), other alternative explanations for the results may become meaningful. At the time of this study, most participants (70.8%) in this study were enrolled in or intended to be enrolled in an airline pathway program. This environmental factor cannot be ignored as it relates to students' expectations and motivation for entry into the aviation career path. Enrollment or acceptance within a pathway program may indicate that students have preferential hiring arrangements and/or may have been given a conditional job offer by an airline or aviation company of choice. Given this reality, we would expect career motivation to be high and result in a strong relationship to the student's performance on course exams. However, only a weak relationship existed between career motivation and the average exam score. Given the study results showing a weak predictive relationship of career motivation on academic performance, there exists a possibility that some form of career path entitlement or presumed job placement may be reflected in the data. Students may assume a job is waiting for them, which may serve to nullify any career-related motivations.

There are also demographic differences between the populations studied by Glynn et al. (2011) and those included in the present study. First, the students in this study are predominantly in their fourth year of education and, as such, are financially and academically committed to a career path in aviation. This point differs somewhat from Glynn et al. (2011) regarding the year of academic performance of the average student participant. These differences may help to explain certain variations in predictive relationships. For example, a fourth-year senior aviation student may have accepted their path as a professional aviator (both cognitively and contractually) and may not value the course grade as much as someone trying to establish an academic pedigree as a freshman in a competitive science field. Additionally, if the student has committed both cognitively and contractually to a particular regional career, military or similar option, the pressure to perform may be partially reduced and not be as strongly witnessed as a science major working to compete towards entry into an elite medical school.

Limitations

Due to the specific recruitment process of the participants, the results of this study may limit generalizability to students within collegiate aviation environments and/or academic programs with a clear linkage to professional career pathways. The sample population also was mainly white (83.8%) and male (87.3%), which may further limit the generalizability of results to other contexts. The study occurred prior to the COVID-19 pandemic, and new data may yield different results as economic and vocational prospects have likely changed. The outcome variable used in this study (average exam score) was somewhat different compared to prior research using the SMQ-II, which used college science GPAs. The outcome variable of average exam score from one course may influence analysis when compared to the inclusion of an outcome variable reflecting performance in multiple courses. This research did not consider other backgrounds (personal factors) such as family members in airlines or aviation, or if participants had industry mentors. Certain secondary factors may influence motivational responses in one direction or another or otherwise influence the predictive relationship to academic outcome. The study also includes a small amount of missing data that was addressed using similar response pattern matching (SRPM; Byrne, 2016). SRPM was employed to address the missing data, which allows for the computation of certain fit indices and modification indices (MIs) within the AMOS program.

Conclusion and Future Directions

The airline and aviation industries are continuously evolving to meet economic demands (Boeing, 2019). The employees of these dynamic organizations play a key role in the organization’s performance and efficiency. This study, using the adapted SMQ-II (Glynn et al., 2011) presents a window into this dynamic environment, motivation factors of the next generation of aviation professionals. The results of this study suggest that prior research within Social Cognitive Theory (SCT; Bandura, 1986) remain relevant many years later as we understand *self-efficacy* to continue as an important factor within motivation and performance. Airline and industry personnel involved in recruitment, hiring, and training of the next generation of aviation professionals may find this information useful as they develop techniques for recruiting, developing, and retaining highly qualified aviation professionals. Personnel training and development designed to support an individual’s self-efficacy may improve the individual’s contribution towards organizational objectives. Opportunities for future research could include the inclusion of recruitment instruments that evaluate an individual’s self-efficacy prior to hiring. Additionally, colleges and universities could develop curricula intended to focus on supporting self-efficacy for students. Finally, future research in this domain could benefit from longitudinal studies involving the role of self-efficacy in the career performance of active professional pilots.

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Appendix

Table A1
Science Motivation Questionnaire II (SMQ-II) (Glynn et al., 2011) Adapted to Collegiate Aviation Students.

Item ID	Adapted Survey Statement
IN1	Learning aircraft systems is interesting (4)
IN2	I am curious about discoveries in aircraft systems (9)
IN3	The aircraft systems I learn is relevant to my life (14)
IN4	Learning aircraft systems makes my life more meaningful (19)
IN5	I enjoy learning aircraft systems (24)
CM1	Learning aircraft systems will help me get a good job (5)
CM2	Understanding aircraft systems will benefit me in my career (10)
CM3	Knowing aircraft systems will give me a career advantage (15)
CM4	I will use aircraft systems problem-solving skills in my career (20)
CM5	My career will involve aircraft systems (25)
SD1	I study hard to learn aircraft systems (1)
SD2	I prepare well for aircraft systems tests and quizzes (6)
SD3	I put enough effort into learning aircraft systems (11)
SD4	I spend a lot of time learning aircraft systems (16)
SD5	I use strategies to learn aircraft systems well (21)
SE1	I believe I can earn a grade of ‘‘A’’ in aircraft systems (2)
SE2	I am confident I will do well on aircraft systems tests (7)
SE3	I believe I can master aircraft systems knowledge and skills (12)
SE4	I am sure I can understand aircraft systems (17)
SE5	I am confident I will do well on aircraft systems quizzes and projects (22)
GM1	Scoring high on aircraft systems tests and labs matters to me (3)
GM2	It is important that I get an ‘‘A’’ in aircraft systems (8)
GM3	I think about the grade I will get in aircraft systems (13)
GM4	Getting a good aircraft systems grade is important to me (18)
GM5	I like to do better than other students on aircraft systems tests (23)

Note. Survey adapted from Glynn et al. (2011) substituting the word “science” for “aircraft systems”. Survey items were arranged in a semi-random order. Numbers at the end of each statement indicate the order of the stem question as it was presented within the survey instrument. Responses range from (Strongly Disagree =1 to Strongly Agree =5). IN = Intrinsic Motivation, CM = Career motivation, SD = Self-Determination, SE = Self-Efficacy, and GM = Grade Motivation.

Table A2
Survey Results by Individual Item

Item	N (Valid)	Mean	Std. Dev.	Skewness	Kurtosis	Range
IN1	229	4.4	0.7	-1.7	5.1	4
IN2	229	4.3	0.8	-1.2	1.8	4
IN3	229	4.5	0.8	-1.9	4.8	4
IN4	229	3.5	1.0	-0.3	-0.1	4
IN5	229	4.2	0.8	-1.4	2.7	4
CM1	229	4.6	0.7	-1.8	4.0	4
CM2	229	4.8	0.5	-3.4	16.7	4
CM3	229	4.7	0.7	-2.6	8.9	4
CM4	229	4.7	0.6	-2.9	11.2	4
CM5	229	4.8	0.5	-4.5	26.3	4
SD1	229	4.2	0.7	-1.3	3.2	4
SD2	229	4.1	0.8	-1.0	2.1	4
SD3	229	4.1	0.8	-1.0	1.4	4
SD4	229	4.0	0.8	-0.7	0.6	4
SD5	229	4.0	0.8	-0.7	0.9	4
SE1	229	4.1	1.0	-1.1	0.8	4
SE2	229	3.8	0.9	-0.7	0.5	4
SE3	229	4.2	0.9	-1.4	2.2	4
SE4	229	4.3	0.7	-1.4	4.1	4
SE5	229	3.9	0.8	-1.1	2.2	4
GM1	229	4.6	0.7	-2.2	6.0	4
GM2	229	4.4	0.8	-1.6	2.9	4
GM3	229	4.5	0.8	-1.8	3.5	4
GM4	229	4.5	0.7	-2.0	5.8	4
GM5	229	4.1	1.0	-0.9	0.4	4

Note. Results include both course offerings face-to-face/blended and online/asynchronous.

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SMS Implementation: System Safety Tools for Improving Part 135 Operators' Safety Culture

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On May 15, 2017, N452DA, a Learjet 35A operated by Trans-Pacific Air Charter, LLC, departed from Philadelphia to Teterboro, New Jersey and crashed south of Teterboro Airport (TEB) on a positioning flight under 14 Code of Federal Regulations Part 91 (Part 91) in Visual Meteorological Conditions (VMC). While circling to land Runway 01 after executing the Instrument Landing System (ILS) Runway (RWY) 06 approach, N452DA stalled and crashed one half mile south of the approach end of runway 01. The flight records indicated that the crew committed numerous errors prior to the accident, including deviations from air traffic control (ATC) clearances, company standard operating procedures (SOP), stabilized approach criteria without initiating a go-around, all of which contributed directly to the outcome. While the National Transportation Safety Board (NTSB) investigation issued several recommendations to the Federal Aviation Administration (FAA) and one recommendation for a change to the company's SOP, using a group of practitioners' perspectives, the authors used Fishbone Ishikawa Analysis and Fault Tree Analysis to discover upstream contributing factors followed by SMS implementation to improve the safety culture.

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Introduction

Trans-Pacific is a 14 CFR Part 135 (Part 135) operator, N542DA was flying from Philadelphia International Airport (PHL) to Teterboro (TEB), New Jersey under Part 91 as a positioning flight with no passengers on board. For this specific flight, the crew's third of the day, the PIC filed a flight plan for a 28-minute flight at a cruising altitude of flight level (FL) 270 and a cruise speed of 441 knots true airspeed (KTAS).

The NTSB (2019, pp. 1-7) accident report indicated that the straight-line distance from PHL to TEB is about 80 nautical miles (NM), but the flight plan indicated a less direct route. PHL cleared the aircraft for takeoff shortly after 1500 (all times given in local time). Soon after takeoff, ATC cleared the aircraft on a different, shorter route via the waypoint MAZIE. ATC also limited the aircraft to an altitude of 4,000 feet above Mean Sea Level (MSL). At 1509, ATC issued temporary vectors away from the revised route for traffic sequencing. The aircraft exceeded the Part 91.117 airspeed limitation of 250 knots indicated airspeed (KIAS) below 10,000 feet MSL. Cockpit dialog indicated a complacent attitude from the pilots. The PIC requested a higher altitude a few minutes later, a request that ATC did not grant. About 10 minutes into the flight, the crew checked in with New York approach, and the approach controller provided vectors for the TEB ILS RWY 06 approach, circle to land runway 01. Forty-eight nautical miles from TEB, the PIC commented to the SIC that they were hundreds of miles from TEB. Less than a minute later, the controller instructed the crew to descend to 3,000 feet MSL to intercept the localizer for runway 06. While attempting to join the localizer, the SIC mistakenly identified Newark International Airport (EWR) as TEB and told the PIC that he had the runway in sight. The aircraft flew across the correct localizer course, and a short time later, the controller noted this error. The crew then followed the controller's instructions to correct their course, turning left to intercept the TEB localizer and flying toward the VINGS waypoint.

While N542DA was inbound to VINGS, the SIC tried to transfer the controls to the PIC, but the PIC did not respond, so the SIC continued to fly the approach. The circle to land maneuver would consist of a right turn followed by a left turn onto the extended center line of runway 01. About 08 miles prior to VINGS, the approach controller cleared N452DA for the approach. Contrary to company policy, the pilots did not conduct an approach briefing, and instead, the PIC continued to coach the SIC through the speed and altitude requirements for the approach (NTSB, 2019).

At 1526 the approach controller instructed the crew to do three things – contact TEB tower, cross the next waypoint DANDY at 1500 feet MSL, and initiate the circling maneuver at the final approach fix TORBY located 3.8 miles from runway 06. The flight crew acknowledged these instructions but neglected to do all three. The PIC had become so preoccupied with coaching the SIC through the approach that both pilots lost situational awareness. The crew did not contact TEB tower; they crossed DANDY at 2000 feet MSL, and they did not begin the circling approach at TORBY. About two minutes later, ATC again instructed N542DA crew to contact the tower, and the PIC continued to coach the SIC, instructing him to descend to the circling minimum of 760 feet. When the crew did establish contact with TEB tower, the controller cleared the aircraft to land on runway 01. When N542DA was about one nautical mile from the approach end of runway 06, the tower asked the aircraft if they were going to start the turn. N542DA banked hard to the right. While the airplane was in the right turn, the SIC turned over the controls to the PIC. The PIC took the controls and directed the SIC to watch the airspeed, and began a left turn to runway 01 at a high bank angle. During the turn, the SIC called airspeed four times; the PIC called out stall, and the SIC agreed, repeating airspeed twice more. In less than 30 seconds, the aircraft impacted the ground in an industrial area just south of the airport.

Final NSTB Accident Report

In the final report, the NSTB found the probable cause as the PIC's attempt to salvage an unstabilized visual approach, which resulted in an aerodynamic stall at low altitude. The NTSB concluded that the PIC's focus on the visual maneuver of aligning the airplane with the landing runway distracted him from multiple indications of decreasing stall margin. Despite the SIC call-outs, the PIC did not add power or reduce the aircraft's angle of attack during the left turn. Further, the PIC's decision to allow an unapproved SIC to act as pilot flying, the PIC's inadequate and incomplete preflight planning and the flight crew's lack of an approach briefing, and the PIC's decision to allow the unqualified SIC to fly all contributed to the outcome (NTSB, 2019).

The NTSB's citation of ineffective or non-existent company safety programs among its final contributing causes resulted from an extensive analysis of the company's existing policies and practices. The existing policy did not contain necessary measures to make the company aware of the kind of deviations or issues associated with the accident crew. Beyond the initial identification of these issues and the resulting categorization of each pilot, this policy contained no measures to provide surveillance of or updates on the performance of the lower category pilots. The company also had no check airmen qualified on the Learjet 35 and depended on the FAA for the administration of line check flights. This practice precluded the effective monitoring of regulatory and SOP compliance by company pilots.

Furthermore, the company's crew resource management (CRM) training also did not address SOP compliance or the "influence of planning, briefing, and decision-making on workload and time management" (NTSB, 2019, p.49), issues of particular importance during the accident flight. The CRM program addressed the responsibilities of a PIC as a team leader only in the most general terms. The NTSB also identified that the PIC had never received any form of leadership training prior to his designation as a PIC.

The company's director of operations served as the safety officer and acted on the informal safety information that he received, including performance deficiencies reported by the training provider regarding both the PIC and SIC. This awareness, however, did not prevent the assignment of these two pilots to fly together, as an effective progressive qualification policy might have. The company indicated that it had initiated the implementation of an SMS at the time of the accident, but still had not done so two years later (NTSB, 2019, pp. 44-51).

Risk Management Analysis – A Case Review

Confusing Assignment of Flight Crews

For most of the flight, the PIC did not maintain sufficient oversight of the crew and aircraft operation instead of instructing the SIC in basic flying of the airplane. His resulting inattention to his Pilot Monitoring (PM) duties resulted in multiple regulatory and procedural deviations, as well as numerous missed radio calls. To summarize, the PIC's decision to allow the SIC to act as Pilot Flight (PF) placed both pilots in roles they did not routinely perform and for which neither prepared adequately. Thus, neither performed their assigned duties competently during the flight (NTSB, 2019).

Situational Awareness

Further, the PIC seemed to lack overall awareness of the flight environment in both his preflight planning and his in-flight assessments. By filing for a cruise altitude of FL270 and later stating that the aircraft was "hundreds of miles from [TEB]," he demonstrated that he did not understand that the flight would only cover approximately 80 NM. Given that normal ATC practice would require the aircraft to be at 3,000 feet MSL approximately 10 nautical miles and three minutes before landing, the available distance to climb from takeoff to FL270 and back to 2,000 feet MSL would have been only 70-80 NM, flown in approximately 24 minutes. The climb and descent tables available to the crew indicated that this combined climb and descent would have required 80.7 NM and 13.7 minutes (computed for a typical aircraft takeoff weight of 15,000 pounds at standard pressures and temperatures) (FlightSafety International, 2011, p.23, p.54), as well as integration of the accident aircraft into the traffic arriving and departing from TEB and the other airports in the vicinity.

Latent Factors

While these failures would not have resulted in an accident in many circumstances, the crew operated this flight in some of the most congested airspace in the country, where they should have anticipated rapid changes of frequency, multiple changes of routing, numerous other radio transmissions, both for their aircraft and others, which the crew should have tracked to maintain necessary levels of situational awareness, and the requirement in VMC to maintain a constant visual scan outside the aircraft for other traffic. Such a short flight, approximately 28 minutes from takeoff clearance until anticipated landing, would require the crew to perform its normal checklists and procedures more rapidly than normal, even while dealing with the issues associated with the congested airspace, creating a demanding operating environment for even an experienced professional crew (NTSB, 2019).

These demands placed an even greater premium on both preflight preparation and the assignment of suitable duties to each crew member. During a long flight, the crew would have had time to prepare for the arrival and approach while in the later stages of cruise flight, after collecting weather, arrival, and approach information for the destination. In the absence of adequate preflight planning, time pressure exaggerated the crew's high workload and precluded any such preparation. The resulting disorientation proved fatal (NTSB, 2019).

Internal Supervision vs. Organizational Culture

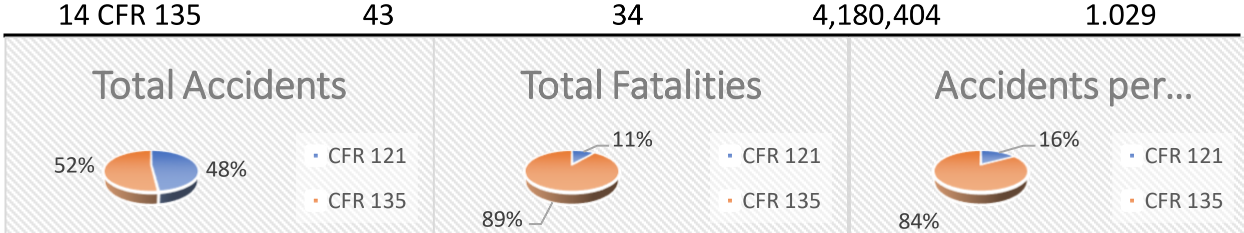
At the most important level, an effective safety program would have established a safety culture that would have identified many of the hazards that the crew encountered and mitigated the associated risks, which include reporting, just, informed, and learning cultures (Lu, 2011). While absent from the NTSB report's solid conclusions, the executives created a major impediment to the company's safety culture. In fact, most directors of operations could not have provided an independent assessment of the safety issues associated with their own operations. Per the "Hawthorne Effect" theory, this director's supervisory responsibilities over the pilot workforce would also have had a chilling effect on independent or anonymous safety reporting by his subordinates (Lu, 2021). This salient conflict of interest is attributable to a failure of the flight crews before and during the flight. Evidently, reporting culture was not shaped as well as most SMS components.

FAA SMS Policy

The FAA's Part 121 Air Service Providers SMS mandate listed a compliance deadline of March 2018 (FAA, 2019 March); therefore, 2019 was the first year to compare Part 121 safety statistics with Part 5 against Part 135 Air Taxi safety statistics without a mandatory requirement. The statistical analysis from the NTSB's 2019 national database (NTSB, 2020) was conducted. According to the number of accidents, it did not differentiate between Part 135 operators utilizing an effective SMS from those operators who did not. However, Part 121 carriers logged roughly four and half times more flight hours than Part 135 operators; thus, the authors focused on the accidents and fatalities rate (one hundred thousand hours and departures data) for a common neutralized data comparison showing Part 135 had encountered a much higher accident rate than that of Part 121 (NTSB, 2020).

Table 1
2019 NTSB Accident Statistics: Accidents per 100,000 Flight Hours

US air carrier operating rules	Accidents	Fatalities	Flight Hours	Accidents per 100,000 Flight Hours
14 CFR 121	40	4	19,786,547	0.202
14 CFR 135	43	34	4,180,404	1.029

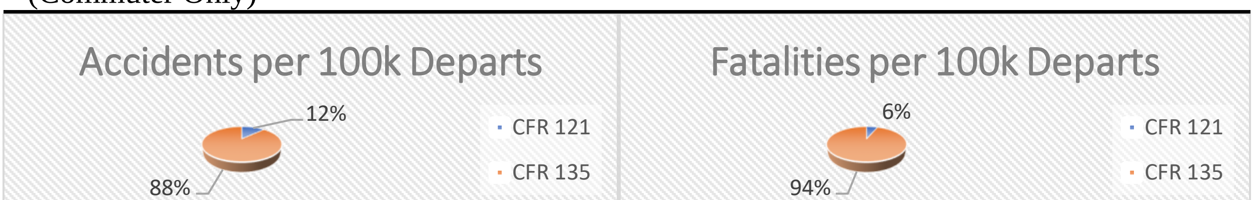


Source: NTSB (2020). Data and statistics.

In addition, as the NTSB's data indicated, the Part 135 operators' accident rate per 100,000 flight hours was approximately five times higher. This statistic created the illusion that Part 135 operators were five times more likely to have an accident, but a deeper review comparing the total number of departures was necessary. Taxi, takeoff, and landing are statistically the most dangerous phases of a flight, not the cruise flight portion that comprised most flight hours (Boeing, 2012). To enhance the meaningfulness of data analysis, the authors also compared the total number of departures between Part 121 and Part 135. Unfortunately, the NTSB only recorded the total number of departures for Part 135 commuter operations and omitted the Part 135 on-demand departures, which might have misled the readers. However, even some Part 135 (on-demand air taxi) operations were not recorded by the NTSB, the table below (Table 2) remained strong, showing accident rates of Part 121 and Part 135 service providers. This data indicated Part 135 commuter operators had approximately seven times more accidents in 2019 than Part 121 carriers (NTSB, 2020). This analysis simultaneously highlighted a safety gap that the NTSB and FAA have been seeking to close.

Table 2
2019 NTSB Accident Statistics: Accidents per 100,000 Departures

US air carrier operating rules	Accidents	Fatalities	Departures	Accidents per 100,000 Departures
14 CFR 121	40	4	19,786,547	0.202
14 CFR 135 (Commuter Only)	9	2	632,793	1.422



Source: NTSB (2020). Data and statistics.

FAA Advisory Circular AC 120-92B

On January 8th, 2015, the FAA published Advisory Circular AC 120-92B, which required air operations under Part 121 to adhere to Part 5 SMS requirements (FAA, 2015 January). The deadline to comply with this regulation was March 2018. The FAA Safety Team broke Part 5 down into six subparts which outlined the FAA's expectations of a compliant airline SMS as shown in Figure 1 below:

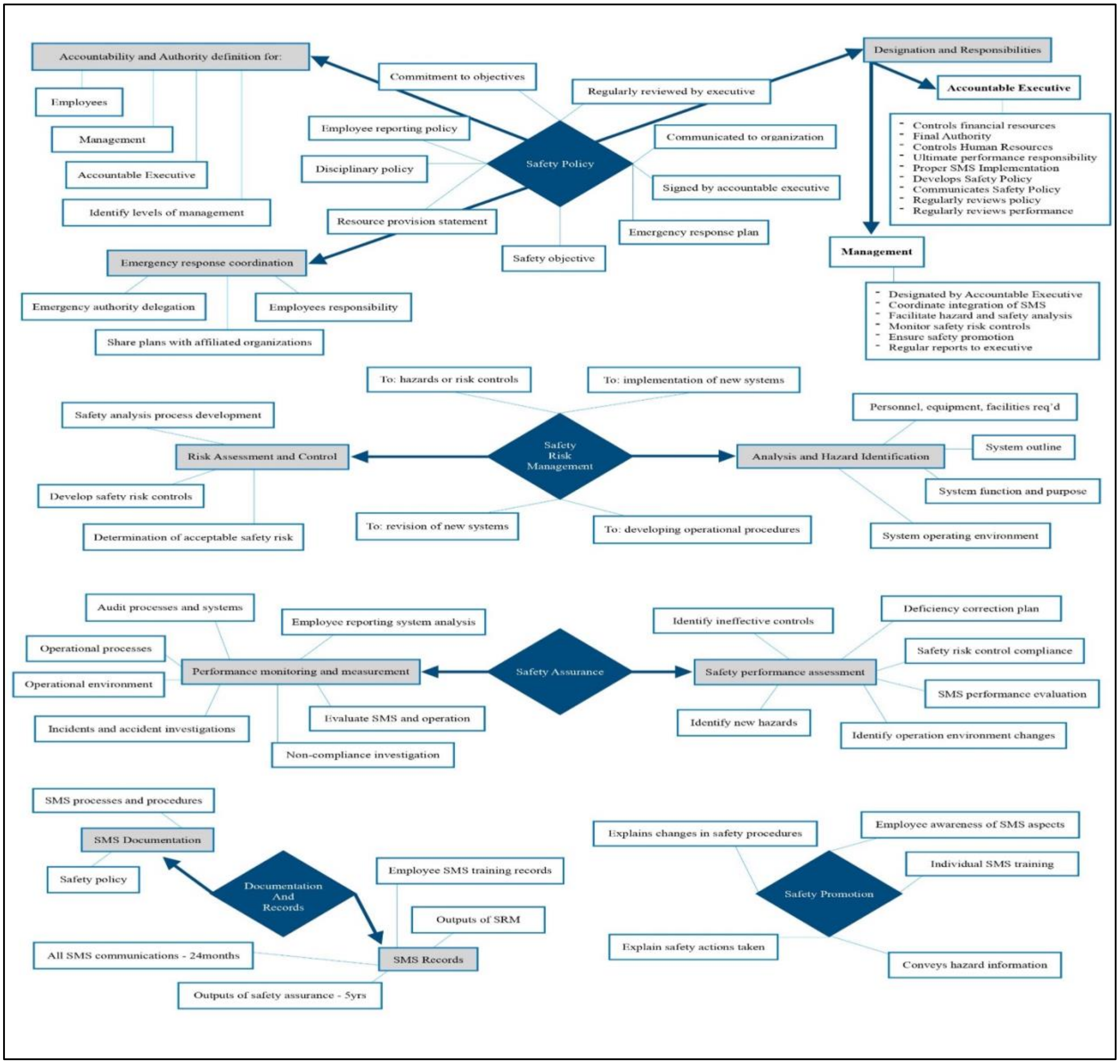


Figure 1. 14 CFR Chapter I Subchapter A Part 5 – an SMS Visual Aid

Source: FAA (2015). AC 120-92B SMS for aviation service providers.

The FAA's voluntary SMS implementation guidance for Non-121 Air Operators, MROs, and Training Organizations was an excellent web resource that we referenced during our abbreviated outline of a Part 5 compliant program. 14 CFR Chapter I, Subchapter A, Part 5.3 (a) stated, "The SMS must be appropriate to the size, scope, and complexity of the certificate holder's operation" (14 CFR, n.d.). The number of safety professionals needed to develop and maintain an SMS was, therefore, dependent on the size of the operation. The organization had to identify an accountable executive, whose responsibilities were outlined in Part 5.25(a). The accountable executive would then identify the safety team and place that group within the organizational hierarchy, where they would then work within Part 5 requirements to design, implement, and maintain an SMS.

Methodology - Risk Management Tools

This systemic analysis attempted to isolate the organizational issues that either led or permitted the crew to act in this manner, based on the assumption that neither pilot was aware that they were placing themselves in mortal peril through their decisions and actions. During stage one of this study, the authors used Fishbone Ishikawa Analysis and Fault Tree Analysis (FTA) that helped reveal contributing factors of the accident and shed light on areas most in need of improvement. Stage two of the study provided an additional level of safety analysis and recommendations to emphasize the need for an SMS program to prevent future accidents and improve the company's safety culture.

Ishikawa Fishbone Analysis

As the first step in accident analysis, the Fishbone Ishikawa Analysis allowed the research team to see an array of all inputs to the outcome. Brainstorming activities following SHELL, 5Ms, or HFACS would later shape a visual fishbone diagram indicating root causes of the undesired event. This effort provided the foundation for the subsequent use of another analytic tool to determine the accident's root cause (Ishikawa, 1990).

Fault Tree Analysis

Fault Tree Analysis (FTA) is a system analysis that is used to determine the root causes and probability of occurrences derived from a specific undesired event. FTA is useful for evaluating large, complex, and dynamic systems in order to understand problems better and implement mitigation strategies (Ericson, 2005). Through its graphic depiction of the relationships between component failures within an overall system (Lu, 2021), Fault Tree Analysis (FTA) proved most useful in the team's analysis of the N542DA accident, even without knowing the mathematical values associated with the probability of each subordinate failure. Given the choice between a deductive approach, which listed the possible causes of a system failure as a means of discovering the possible system failures, or an inductive approach, which began with the undesired outcome and retraced the causal failures throughout the system, the team chose the inductive approach (Vincoli, 2014). If, however, one had applied the deductive approach before the accident, a frank appraisal of the circumstances would have led the team to an accident as the likely outcome.

Validity and Reliability of Analysis

Reliability is the capacity of a test or report to "perform in the future as it has in the past" (Lu, 2020 March). This would mean that multiple renditions of a study would result in the same outcome. While the minimum method error (tool selection) and trait error (researcher conditions) yield the maximum reliability, the triangulation process helps ensure analytical consistency. The inter-rater technique was applied by the authors to secure reliability (Goff, 2005). For validity, the authors found convergence among multiple sources of information to form themes or categories in a study. The bias of each researcher was eliminated by adopting triangulation methods when conducting research (Creswell & Miller, 2000).

Research Questions

Q1. What are contributing factors of the N452DA Learjet crash in 2017, according to Ishikawa Fishbone and Fault Tree Analysis?

Research Hypothesis: Beyond the NTSB's probable causes of the accident, there are upstream contributing factors leading to the N452DA Learjet crash.

Q2. What mechanisms of Safety Management Systems can be used by FAA FAR Part 135 Air Taxi service providers?

Research Hypothesis: There are practical SMS for the budget-constrained FAA FAR Part 135 Air Taxi service providers.

Results

The information in the NTSB report of the accident investigation portrayed a relatively clear accident scenario, two pilots acting in unfamiliar roles with limited or no competence attempted to operate a high-performance business jet in the country's most congested airspace, lost situational awareness, and failed to recognize the imminent low-altitude loss of control until recovery was no longer possible. The report, however, alluded to an unsafe operating environment involving hazardous attitudes (FAA, 2016, p. 2-5) within the company. FAA did little to support and protect these employees or the company's equipment.

Q1. What are contributing factors of the N452DA Learjet crash in 2017, according to Ishikawa Fishbone and Fault Tree Analysis?

Ishikawa Fishbone Analysis & Fault Tree Analysis. In the Fishbone Ishikawa Analysis, each branch represented a different area of the flight where one or more failures were apparent. Specific contributing factors (flight phases including preflight, en-route, and approach) and latent factors (environment, management and equipment, and training) were selected to be analyzed. Contributing causes of each selected factor were also provided based on group discussion and triangulation. Please see Appendix A.

Fault Tree Analysis. FTA diagram is provided in Figure 2 using two branches: PIC and SIC. Full-size diagrams are available in Appendixes A and B. The cut-sets included [SIC's violation to SOPs, Weak PIC airmanship, lack of inflight briefing, inexperienced SIC], [SIC's violation to SOPs, Weak PIC airmanship, lack of preflight, inexperienced SIC], [SIC's violation to SOPs, Weak PIC airmanship, the unwillingness of obtaining information, inexperienced SIC] regardless of the failure probability associated with each root cause. Please see Appendix B.

Contributing Factors

Hazardous Attitudes. On the FTA's left-hand branch, five basic tree initiators contributed to the PIC's distraction involving Anti-Authority, Impulsivity, and Macho attitudes. All five events point to a poor safety culture within the company's flight department. First and foremost, the first officer was performing PF duties for all but the last thirty seconds. Not only was the SIC less experienced, but his participation as PF also exhibited a blatant disregard for company policy. The NTSB's report also mentioned that it was likely not the first officer's first time acting as the PF, further showcasing a systemic lack of rule adherence, namely antiauthority. The first officer's lack of airmanship and attitude of resignation likely overwhelmed the PIC, leading to additional distraction. As a result of the PIC's distraction level, the PIC suffered a complete loss of situational awareness (SA) throughout the flight. This event began when the crew failed to perform their pre-flight duties and chose to depart without the current Teterboro weather and on an unrealistic flight plan, which was one of the operational pitfalls – neglect of flight planning (FAA, 2016, p. 2-22).

CRM issues. During the flight, despite attending the FAA mandatory crew resource management (CRM) training for Part 135 operators, the crew exhibited a disregard for proper checklist and briefing criteria written in the company's General Operating Procedures (GOPs). This combination led to the crew's poorly understanding of the elements of the circle-to-land procedure, which caused a further loss of situational awareness upon entering the terminal environment, which showed the lack of information management. Further compounding this loss was the PIC's inability to ascertain his position throughout the flight, a skill-based error (Reason, 1997). Not only was the PIC lost, but he also displayed an arrogance (a mixture of macho and invulnerability) that hindered his urgency from regaining SA. With the absence of a strong safety culture, lack of communication, teamwork, and workload distribution, the situation exposed the PIC's weaknesses as a pilot when the distracted captain reluctantly accepted the flight controls for the final airborne moments of the flight.

Training and Airmanship. The company's policy clearly stated that the SIC of this flight was prohibited from performing pilot flying duties due to his low total flight time. Several factors attributed to the SIC's inability to aviate without the assistance of the PIC. At the forefront of his shortcomings was his lack of experience in turbine-powered aircraft, namely both knowledge and skill-based errors. Additionally, CAE, the simulator flight training company that administered the SIC's initial training noted several training deficiencies during his initial course. One of those training deficiencies included difficulty performing circle-to-land maneuvers like the Teterboro approach. While on the line, investigative interviews discovered the SIC's line performance to be "hit or miss," yet no corrective action was taken, further highlighting the need to improve pilot qualification training and safety culture.

Non-punitive Reporting System. Without a non-punitive reporting system or working safety system in place, management's ability to identify underperforming crew members was almost non-existent. While a non-punitive reporting system at the company was almost non-existence, many hidden problems were covered up and undisclosed. As if that situation were not troubling enough, the FAA exhibited low levels of safety oversight and a lack of interest in expanding those levels of support due to the lack of legal basis. Worst of all, the NTSB's investigation noted the FAA's Principal Operations Inspector (POI) presiding over the company had never performed an inflight check on a Part 135 carrier.

Q2. What mechanisms of Safety Management Systems can be used by FAA FAR Part 135 Air Taxi service providers?

Even though the language of NTSB safety recommendation A-16-36 only asked that the FAA mandate that Part 135 carriers maintain an SMS, the researchers chose to use 14 CFR Chapter I Subchapter A Part 5 as it demonstrated the FAA's expectations of an SMS. To simulate how Part 5 would challenge Part 135, safety teams, the researchers created Figure 1 to demonstrate a Part 5 compliant SMS' complexity and examined Part 5 with the help of the FAA's voluntary SMS guide for non-121 air operators, as well as the International Civil Aviation Organization's (ICAO) SMS publication, dubbed Annex 19.

The researchers reflect on this accident and its lessons to understand the importance of a focused cockpit, how quickly situational awareness eroded, and the dangerous consequences when it did. A reporting system shall be created to allow anonymous reports, comments, and safety alerts. In fact, the NTSB final report did indicate that, aside from the plan to implement a safety management (which did not occur) and third-party safety audits, little else happened before the accident. A company cannot simply tell its crews not to make the same mistakes and expect that the same circumstances will not recur. Without a change in the company's safety culture starting from a hazard reporting system, the company could have no expectation of significant, lasting change in its safety performance (Leib & Lu, 2013).

Benefits of SMS Implementation

Given the availability of free, voluntary FAA programs for both SMS and data participation, USAIG and Global Aerospace offer a policyholder dividend equaling 5% and 10.6% of the premium, respectively (USAIG, 2021; Global Aerospace, 2021). The greatest benefits, however, will not be financial. As noted by the International Business Aviation Council (IBAC, 2021), an effective SMS would offer enhanced operational safety, a means of measuring safety performance, improved operational performance, improved stakeholder confidence, and improved teamwork, as well as enhanced pride, among the company's employees (ICAO, 2016).

Safety vs. Budget Constraint

Given the small size of the company and the age of the aircraft, a comprehensive FDM program would not be possible, as the original CVR and flight data recorder models did not yet collect enough discreet data or retain it for a long enough period to allow collection and evaluation, not to mention Flight Operation Quality Assurance (FOQA) program (FAA, 2004). Our research also noted that the company was not the owner of any of the aircraft that it operated. According to the broker, the company, therefore, could only recommend conversions to an aircraft's owner(s) if it were so inclined. The Part 135 management and charter of these privately owned aircraft would become far less lucrative if the owners faced an FAA mandate to install FDM equipment costing more than one-quarter of the aircraft's value that would also not increase the value of the aircraft at resale.

However, with the availability of the FAA's Aviation Safety Information and Sharing (ASIAS) program, the company can both learn from the safety information and contribute to safety improvement throughout the industry. To present early concerns on known risks, the FAA designed ASIAS to accept all forms of safety data, including an SMS' manual hazard reporting or other methods that did not necessarily rely on the high-technology methods that would be impractical for companies facing budget constraints at this time. ASIAS' deidentified aggregate safety-related data are available to the airline industry for cross querying, and lessons learned purposes (FAA, n.d.). The FAA has also indicated that it cannot use ASIAS data against operators participating in the program, which will protect the company from enforcement actions based on information submitted directly to the program by the company or its employees.

Mechanism of Safety Management Systems

Commitment. As noted earlier, a successful SMS begins with a commitment from the top management through its safety policy. Given a corporate aviation company's history and its relatively small size, the chief executive officer/president (CEO) should sign this policy and announce the beginning of this program to the employees and other stakeholders in the company. Besides showing visible supports to the program, safety policy should also designate a different employee as the safety program manager, thereby eliminating the current conflict of interest posed by having the director of operations serve in that role.

Reporting and Informed Cultures. As a counterintuitive example, an increased number of safety reports indicates positive safety system performance and an improving reporting culture rather than greater risks to the company. The content of those reports may serve as an unknown risk indicator, e. g. multiple reports of pilots continuing unstabilized approaches beyond the limits prescribed within the company SOPs. The safety committee should then track each safety, incident, and accident report, including the actions taken in response to the report and follow-up assessments of the effectiveness of those actions to shape the informed culture.

Just Culture. The non-punitive policy should come with the establishment of a company safety committee comprised of a representative from each department of the company and chaired by the safety program manager. Embracing the "just" concept, the safety committee would be responsible for recommending safety policies to company management, reviewing incidents, accidents, or other safety reporting, and conducting safety training within members' respective departments. At the outset and with the guidance of the risk management team, the safety committee members would participate in the development and implementation of the SMS.

Learning and Adaptive Culture. Also, for the learning culture, it is essentially rooted in safety assurance. The company must solicit both authored and anonymous safety reporting for continuous safety education and promotion. Continuous Gap Analysis. Part 5, ICAO Annex 19 (2016), and the various SMS audit standards provide comprehensive lists of those policies and activities that will be mandatory subjects of the gap analysis, but committee members should also include other practical activities with potential hazards. This gap analysis would identify and document the current activities that the department performs to mitigate identified risks, in effect taking credit for work already completed, and it would identify and document those hazards and associated risks that the department has either not identified or identified and not addressed.

Continuous Risk Assessment. After compiling the routine gap analysis, the committee members should assess the company's existing and anticipated risks regarding both their severity

(S) and their probability (P), rating in a Risk Matrix as a low, medium, or high risk, according to a rubric adopted by the committee. The committee should also determine the actions necessitated by each level of risk and, after the application of those actions to mitigate the initial risk, rate the residual risk. This risk assessment system must also include the company's policy on conducting activities based on their residual risk rating, e. g. the company might choose not to conduct any activities with a high residual risk rating, activities with a medium residual risk rating might require CEO or director of operations approval, and no action may be necessary for activities with a low residual risk rating. In each area of the company's activities, committee members should also establish a way to measure leading indicators of potentially increased risk or positive safety system performance.

Safety Promotion and Assurance. The participation of each department's representatives in these processes would then become the first stage of SMS promotion within the company. The company should also develop initial and periodic SMS training for its employees, managers, and safety committee members. Senior management should consider the development of a company safety newsletter or regular email, which should include reporting highlights, information of particular interest from the ASIAS database or NASA Aviation Safety Reporting Program (ASRP), and other relevant safety subjects. Many corporate aviation companies also develop incentives for employee contributions to the SMS, and the safety committee would recommend the award of these incentives to the CEO.

Leadership Visibility and Involvement. At each step, employees and other stakeholders should see the senior managers embrace the SMS, especially the CEO. Without the CEO's overt and active support, the SMS would be little more than paperwork and meetings. This engagement would reform the foundation for the company's safety culture. The combination of senior-level engagement, floor manager support, and SMS training/other forms of SMS promotion will begin to create a shift in employee attitudes, leading them to trust that the system exists for their benefit, rather than a mechanism for employees to report each other or managers to punish employees. While an effective SMS does include sanctions against employees who refuse to comply with company policies, including its SMS policy, employees should see the system's more positive outcomes much more frequently in order to remain engaged.

Conclusions

FAA FAR Part 135 air taxi service providers are not required to implement SMS, yet taking proactive action to ensure safety is recommended. While cost is a significant hurdle impeding air taxi providers to implement many optional programs, the cost is much lower than restoring the company's good standing and reputation with its customers, shareholders, insurers, regulators, and, most of all, its employees after a severe accident like the crash of N452DA Learjet in 2017 in Teterboro, New Jersey.

By virtue of the researchers' close analysis of the NTSB accident report using Fishbone Ishikawa Analysis and FTA in conjunction with decades of industry's experiences in air operation and safety, the benefits of SMS toward the improvement of the corporate aviation safety culture are significant. The authors assembled a plan to invigorate the company's safety program and begin rebuilding its safety culture on the solid foundation of safety policy, risk analysis, safety assurance, and promotion. To succeed, the plan requires that top managers demonstrate positive supports and commitment as well as the buy-in from employees and safety committees and the employees' involvement in developing the safety program. This means full involvement is critical to making a safety program successful, while a successful non-punitive hazard reporting system is the starting point.

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12-05-2021

Cognitive State Measurement in Remotely Piloted Aircraft Training

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The purpose of this study is to determine whether Electroencephalogram (EEG) technology - developed for cognitive state estimation in operational settings - can document cognitive workload and task engagement experienced by Remotely Piloted Aircraft (RPA) pilots during their training.

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Electroencephalograms (EEG) have been shown to reflect workload levels and sustained attention during training and learning. However, a limited number of studies have examined their performance in operational settings (Bernhardt et al., 2019; Mathan & Yeung, 2015; Mills et al., 2017; Yuan et al., 2014).

As measures and methods of cognitive states mature and coalesce into fields such as augmented cognition and adaptive automation, applications have emphasized the value of cognitive state monitoring in the interest of safety, acknowledging "... errors could arise from aberrant mental processes, such as inattention, poor motivation, loss of vigilance, mental overload, and fatigue, that negatively affect the user's performance" (Aricò et al., 2016, p. 296).

The potential of cognitive state monitoring for predicting human error in the interest of safety should be neither diminished nor dismissed. However, the capacity of cognitive state monitoring – to recognize subtle differences in performance that cannot be observed by behavioral outcomes alone – is also a demonstrated interest in educational and training settings (Bernhardt et al., 2019; Borghini et al., 2014; Mathan & Yeung, 2015; Mills et al., 2017; Yuan et al., 2014).

Berka et al. (2007) began the process of establishing and validating the EEG metrics utilized by Advanced Brain Monitoring, Inc. (ABM) and the B-Alert X-24. Thirty EEG features were used by Berka et al. (2007) in calculating a workload metric which was recommended for assessing the effectiveness of training and simulation programs. Bernhardt et al. (2019), a recent effort, execute on this interest and acknowledge cognitive state metrics as a viable tool for enhancing Air Traffic Control (ATC) training. This study continues this interest with preliminary data collected during simulated training events of remote pilots.

Purpose of The Study

The purpose of this study is to determine whether the EEG technology - developed for cognitive state estimation in operational settings - can document cognitive workload and task engagement experienced by Remotely Piloted Aircraft (RPA) pilots during their training.

Findings

EEG data (n = 19) has been collected during simulated training events in the MQ-1 RPA at the University of North Dakota. EEG signals were collected during a simulated training event in the MQ-1 RPA. The lesson calls for approximately 1.2 hours of contact time with the remote pilot, a checklist, and a flight pattern with 12 distinct legs.

Estimates of cognitive metrics for high engagement and workload were averaged for the duration of the checklist as well as each leg of the flight pattern. Results of a one-way repeated measures ANOVAs showed that the cognitive state metric for engagement ($F(11,8704)=4.87$, $p<0.001$) and workload ($F(11,8328)=10.03$, $p<0.001$) varied significantly within the flight pattern. The average probability of high workload is presented in Figure 1 below.

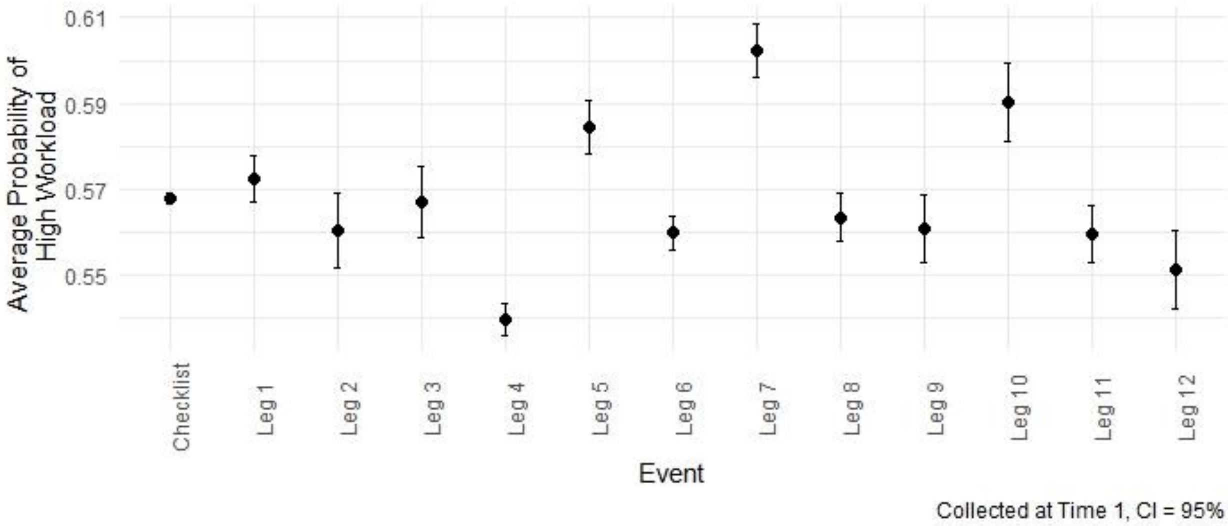

Figure 1. Cognitive State Metric for Workload: ABM's High Workload Metric during Checklist and Flight Pattern Events

Results of a paired sample t-test ($t(8348)=14.21$, $p<.001$) indicated that workload was significantly lower ($M=0.5536$, $SD=0.16$) during legs of the flight pattern assisted by the heading hold function of the autopilot than legs 5 through 10 where remote pilots were unassisted by this automation ($M=0.5718$, $SD=0.16$).

Discussion & Conclusion

As with prior works in operational aviation settings, EEG-based cognitive state metrics demonstrated an ability to detect subtle changes in operator workload (Aricò et al., 2016; Bernhardt et al., 2019). Noted as a limitation in Bernhardt et al. (2019), the NASA TLX was administered following both the checklist and flight pattern tasks in this study to relate the EEG-based workload metric with a subjective measure of workload. Unlike the prominent positive association noted by Aricò et al. (2016), this study noted no significant relationship between the subjective and EEG-based measures of workload.

In this work, EEG-based metrics for measuring cognitive states such as workload and task engagement demonstrate a capacity for distinguishing variation during the training of Remotely Piloted Aircraft (RPA) pilots. These results support the design of a within-subjects methodology using EEG data to assess the effectiveness of RPA training over time.

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Utilizing UAS to Support Wildlife Hazard Management Efforts by Airport Operators

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The FAA requires airports operating under the Code of Federal Regulations Part 139 to conduct a wildlife hazard assessment (WHA) when some wildlife-strike events have occurred at or near the airport. The WHA should be conducted by a Qualified Airport Wildlife Biologist (QAWB) and must contain several elements, including the identification of the wildlife species observed and their numbers; local movements; daily and seasonal occurrences; and the identification and location of features on and near the airport that could attract wildlife. Habitats and land-use practices at and around the airport are key factors affecting wildlife species and the size of their populations in the airport environment. The purpose of this ongoing study is to investigate how UAS technologies could be safely and effectively applied to identify hazardous wildlife species to aviation operations as well as potential wildlife hazard attractants within the airport jurisdiction. Researchers have used a DJI Mavic 2 Enterprise Dual drone with visual and thermal cameras to collect data. Data have been collected in a private airport in a "Class G" airspace. We have applied different risk mitigation strategies to mitigate risks associated with drone operations in an airport environment, including a visual observer during data collection, and an ADS-B flight box to obtain information of manned aircraft at and around the airport. Multiple flights were conducted in different days of the week as well as different times of the day. Noteworthy to mention we have had the technical support of QAWB throughout this study. Preliminary findings suggest that UAS can facilitate the observations made by a QAWB during a WHA, including the identification and assessment of potential wildlife attractants (e.g., wetlands), and the identification of wildlife species (e.g., White ibis). Additionally, initial findings indicate that UAS facilitates data collection in areas that are difficult to access by ground-based means (e.g., wetlands). Another key finding of this study was that our team could observe, and with the assistance of the QAWB identify different wildlife species and habitats simultaneously during each UAS flight. In different words, from a single image (video and/or picture) a QAWB could obtain valuable information about different wildlife species and related habitats. Lastly, results suggest that the versatility and speed of UAS (including their high-quality cameras and sensors) ensure that data can be collected more thoroughly and faster over large areas during a WHA.

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Introduction

Aircraft accidents resulting from wildlife strikes have become an increasing economic and safety concern for the U.S. aviation industry. Wildlife strikes have killed more than 295 people and destroyed over 271 worldwide since 1988. According to Dolbeer et al. (2021), there were 238,654 wildlife strikes in the U.S. from 1990 through 2018. Almost 97% of these strikes involved birds. During this period, 16 and 251 wildlife strikes resulted in 36 fatalities and 327 people injured, respectively. Seventy-four aircraft were damaged beyond repair due to strikes. Annually, conservative estimates suggest that wildlife strikes cost on average $200 million in monetary losses and 110,000 hours of aircraft downtime. Nonetheless, previous studies (DeVault et al., 2018; Dolbeer et al., 2021) have suggested that frequently wildlife strike reports do not provide accurate information regarding the direct and other monetary costs estimates. Yet, many strikes go unreported. Thus, it can be assumed the costs of wildlife strikes could be significantly higher.

Certificated airports are required to complete a wildlife hazard assessment when certain safety events (e.g., multiple strikes involving an air carrier) have occurred at or near an airport. This process should be conducted by a qualified airport wildlife biologist (QAWB). The Title 14 Code of Federal Regulations (CFR) Part 139.337 prescribes the required elements of a WHA, which include the identification of wildlife species to aviation operations as well as the location of habitats and other features that could attract hazardous wildlife species to the airport air operations area (AOA) (Cleary & Dolbeer, 2005). A WHA provides the foundation for an effective wildlife hazard management plan (WHMP). The FAA has provided guidance on the protocols for conducting a WHA and WHMP (FAA, 2018), on land uses and other habitats with the potential to attract hazardous wildlife (FAA, 2020) to the airport environment, and on the most hazardous wildlife species to aviation operations.

Safety programs and other strategies by aviation stakeholders have certainly improved aviation safety. Notwithstanding, information obtained from the analyses of wildlife strike data has indicated that mitigating the risk of accidents due to wildlife strikes will present unique challenges over the next decades. For example, the number of strikes has increased from 9,840 in 2011 to 17,178 in 2019 (a 75% increase). Similarly, the number of damaging strikes increase by 41% over the same period. The rate of strikes and of damaging strikes per million aircraft movements increased by 42% and by 7% from 2011 through 2019. For GA and commercial aircraft, 87% and 82% of the total strikes, respectively, occurred at the airport environment (at or below 1,500 above ground level [AGL]) (Dolbeer et al., 2021).

The effective management of wildlife hazards is a defense in depth, and includes actions by pilots, aircraft and airport certification standards, and safety programs by airport operators (Mendonca et al., 2018). A multifaceted approach for mitigating strikes is vital, and that should include certification standards for aircraft airframe and engines, outreach, and education

(Eschenfelder & DeFusco, 2010). Additionally, it should include the use of new technologies and/or innovative approaches to current technologies. Hamilton et al. (2020a, 2020b) and Prather (2019) have also suggested the investigation of unmanned aircraft systems (UAS) for identifying hazardous wildlife species to aviation operations.

UAS has been experiencing healthy growth in the U.S. over the past years. In fact, UAS has have been used for multiple purposes, ranging from recreation to data collection during research projects. According to Prather (2019), new applications of UAS are frequently being established around the world. UAS application at the airport environment could include construction, security, and emergency management; and wildlife hazard mitigation. Nonetheless, the safe incorporation of UAS and related technologies into an airport environment, still in early stages, presents major safety, economic, regulatory, and infrastructure challenges. Nonetheless, it also presents opportunities and benefits to include cost efficiencies, increased mission effectiveness, and career opportunities. Hamilton et al. (2020a) have indicated that research is needed to evaluate the effectiveness of using UAS in the airport environment. Moreover, empirical data and information can help develop metrics to “determine how the UAS will benefit the airport” (Prather, 2019, p. 40).

To address a gap in previous research, the current study is an attempt to investigate how UAS can be used to support the airport operator's efforts to mitigate the risk of aircraft accidents resulting from wildlife strikes. More specifically, the goals of this ongoing exploratory study are to:

1. Identify the most effective UAS and sensors for data collection during a WHA;
2. Explore best practices for UAS application to identify hazardous wildlife species and related habitats at the airport environment; and
3. Develop operational procedures and workflows that support the effective application of UAS at the airport environment during a WHA.

Concept of Operations

Hamilton et al. (2020a) defined concept of operations (CONOPS) for UAS as “a description of the nature of UAS operations and the resulting impacts on relevant stakeholders and the environment” (p. 3). The ConOps include the UAS flight pattern, regulatory requirements, and safety risk management processes and procedures. Our team utilized Hamilton et al. (2020a, 2020b), Neubauer et al. (2015), and Prather (2019) while developing (and updating) the ConOps for the current study. It is important to mention that a QAWB has provided expertise and guidance throughout this study.

During the first phase of this study (spring 2021) we utilized a DJI Mavic 2 Enterprise drone with visual and thermal cameras. The integrated thermal-visual cameras have multiple functionalities which allowed our team to switch between thermal, visual, or even split-view feeds. The ground position system (GPS) location, time, and date of images (photos and videos) were recorded on GPS timestamping (see Figure 1).

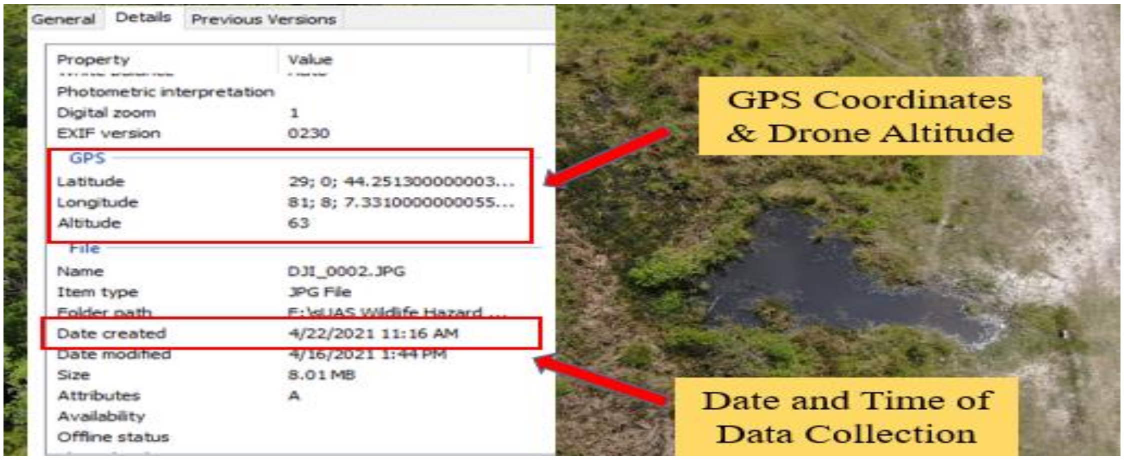

Figure 1. GPS Coordinates, Date and Time, And Altitude of Flight for Each Image Were Recorded

Data were collected on April 16 / 29 / 30 and on May 14 at Coe Field, a private use general aviation airport located in a Class G airspace. Coe Field is located approximately 11 nautical miles southwest of Daytona Beach International Airport (KDAB) at the latitude of 29° 00' 37" N and longitude of 81° 07' 56" W. According to Cleary and Dolbeer (2005), habitats and land-use practices are important elements determining the wildlife species and the size of their populations being attracted to the airport jurisdiction. Yet, land use (e.g., agricultural activity), as well as habitats (e.g., wetlands), will influence the behavior of the wildlife species attracted to the airport environment. Coe Field, which is located in a rural area, is surrounded by trees, farmland, and bodies of water that attract various wildlife species. It is noteworthy to mention that the airport owner raises cattle in the airport premises, which also favors the presence of flocking birds (Cornell Lab of Ornithology, 2021a, 2021b).

Researchers utilized a trailer with different pieces of equipment that included an automatic detection surveillance broadcast (ADS-B) flight box that transmitted a Wi-Fi network that is connectable by a tablet of mobile; two television (TV) sets; and a monitoring station. Once the Wi-Fi network was connected by an electronic device (usually a cell phone), researchers used ForeFlight (ForeFlight, 2021) to identify and monitor manned aircraft at and around the data collection area. The electronic device was connected to a TV (inside the trailer) via a high-definition multimedia interface (HDMI) cable. This process helped our team mitigate the risk associated with UAS operations in an airport environment since we could identify the location, altitude, heading, and speed of any aircraft displayed on the live traffic feed. We determined that if manned aircraft were observed approaching Coe Field at or below 1,000 feet (ft) above ground level (AGL), the drone would be manually flown at a safer (lower) altitude and brought back to the pilot's position. Further risk mitigation strategies associated with manned aircraft operations our team implemented included:

1. All UAS flights were conducted at or below 200 ft AGL;
2. No UAS flights were conducted in the departure, approach, and circling airspaces of the airport;
3. All UAS flights were only conducted during visual meteorological conditions (VMC) and with a visibility of at least 5,000 NM; and

4. A visual observer whose roles included ensuring the drone was always within line of sight as well as warning the drone's pilot of the presence of manned aircraft in the data collection area;

In addition, a flight risk assessment tool was exercised before each flight so that our team could identify hazards, and develop and implement safety measures to mitigate the associated risks (FAA, 2016). Some hazards may not be identified, nor the associated risks are effectively mitigated. Thus, safety measures and aircraft performance margins were built into the ConOps. Most importantly, the ConOps was frequently revised and updated accordingly in order to ensure aviation safety and efficiency, as suggested by Hamilton (2020a, 2020b).

The researchers developed a Wildlife Survey Observation Sheet (WSOS) with the support of the QAWB to record data during data collection. This observation form allowed our team to follow a similar protocol utilized by a QAWB during a WHA. Data were collected in an area of approximately 300x300 meters north of Coe Field. Multiple flights were conducted during four days of data collection so that researchers could capture daily and other factors affecting the presence of and/or the behavior of the observed wildlife species as suggested by the FAA (2018). The "DJI's Go 4 Software", used through the smart drone controller, allowed the drone's pilot to create flight plans as well as to store telemetry data from each flight. The smart controller was hooked up via an HDMI cable to the other TV set inside the trailer, where the outside elements would not affect what was being observed. At least one member of our team stayed in the monitoring station inside the trailer observing the two TV sets and writing down observed wildlife activities, the presence of wildlife attractants, and possible interactions between those elements. In addition, this person monitored possible manned aircraft activities at or close to the data collection area. This process not only enhanced our data collection process but also increased the safety of the UAS operations.

The first and third flights were conducted autonomously in a basic grid pattern at an average height of 150ft AGL. The second and fourth flights were carried out manually based upon the drone's pilot's and team members' (especially the team's member in the monitoring station) observations during the autonomous flights. The manual flights allowed our team to collect images from different altitudes, angles, cameras' parameters. They also allowed our team to identify and especially explore elements (e.g., wildlife interactions with habitats) that are vital during a WHA (FAA, 2018). This multiplicity of flights using different patterns "allowed our team to collect several images that overlapped, giving researchers (and the QAWB) a better and more accurate picture of wildlife hazards and of possible wildlife hazard attractants, and the interactions between those elements" (Cabrera et al., 2021, p.14). Moreover, it allowed the researchers to observe and collect multiple images of a specific area; wildlife species (to include their numbers and locations, local movements, and behaviors); and/or wildlife hazard attractants from multiple viewpoints.

Key Findings

There were 5,020 and 1,195 strikes and damaging strikes involving mammals in the U.S., respectively, from 1990 through 2020. Twenty-nine aircraft were destroyed after colliding with mammals. Three of them involved cattle. Thirty-one and one people were injured and killed, respectively, due to strikes with mammals. The direct and other monetary economic losses resulting from those strikes were estimated to be almost $70 million (Dolbeer et al., 2021). As previously noted, the airport's owner raises cattle at Coe Field. Analyses of wildlife strike data have indicated that Cattle have not been a safety hazard to aviation operations. Nonetheless, other mammals of similar (e.g., Mule deer) or smaller size (Coyote) have caused aircraft accidents in the U.S. White-tailed deer and Coyote are considered the first and 12th most hazardous wildlife species to flight operations in the U.S. (FAA, 2018). Previous studies (DeVaul et al., 2018; Dolbeer, 2020) have identified an association between the wildlife body mass and the probability of a damaging strike. We could observe the presence of Cattle at Coe Field, their behavior, local movements, and preferred habitats. Additionally, our team could observe and record how cattle influence the presence and behavior of flocking birds. Both the visual and thermal cameras hold the potential to identify the presence of "*large*" mammals. Nonetheless, the "*best*" images were collected with the visual camera (see Figure 2).

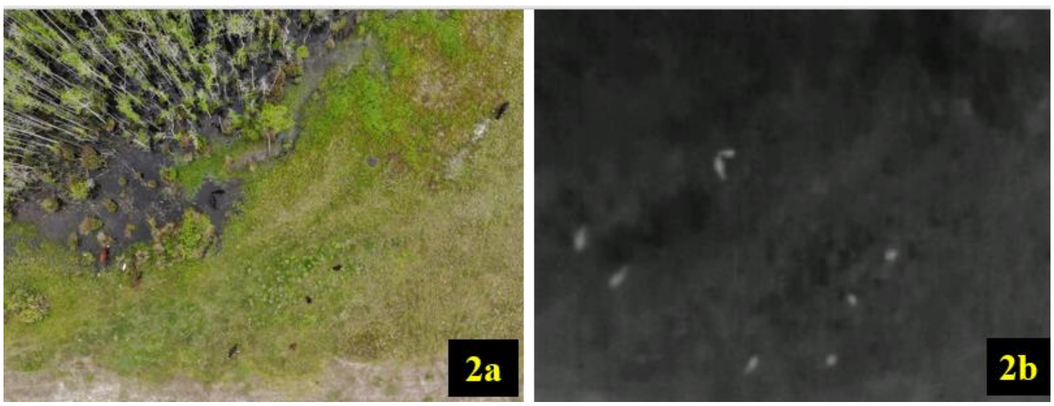

Figure 2. Images of Cattle at the Data Collection Area

Note. Figure 2a and 2b were taken during a manual flight with the visual and thermal cameras, respectively.

There were 654 aviation safety occurrences involving Cattle egrets from 1990 through 2020 in the U.S. Forty-three and 66 of the total strikes caused damage to the aircraft and had a negative effect on flight (e.g., aborted takeoff), respectively. Almost 20% (n=124) of these strikes involved two or more animals. The FAA (2018) listed this bird species as the 14th most hazardous wildlife species to aviation in the U.S. Cattle egrets forage in flocks, usually in fields and pastures where they can stalk small animals (e.g., insects) stirred from the ground (Cornell Lab of Ornithology, 2021c). Our team could observe, with the visual camera and especially during the manual flights, the presence, numbers, and behaviors of Cattle egrets. They were more abundant in the morning feeding on the ground and generally close to the cattle. We also observed them at or close to bodies of water. We could rarely "see" them with the thermal camera. It is important to mention that the drone allowed our team to observe these animals to include their numbers, behaviors, and local movements up to 500 meters from where the trailer was located. In different words, it would be difficult for a QAWB to thoroughly collect this information during a WHA even with binoculars due to the presence of shrubs and other elements between the trailer and the animals. Yet, the grass height can make it difficult for the QAWB to collect data and information on "small" birds that are foraging on the ground (see Figure 3).

Figure 3. Images of Cattle Egrets the Data Collection Area

Note. Figure 3a shows 34 Cattle Egrets foraging close to cattle. Figure 3b show man-made and other structures between the trailer and the location where we observed Cattle Egrets with the drone.

From 1990 through 2020 there were 178 strikes involving Sandhill cranes in the U.S. (Dolbeer et al., 2021). This bird species is listed as the fifth most hazardous wildlife species to aviation (FAA, 2018). This heavy-bodied animal’s preferred habitats include pasture and prairies, and open grassland and wetlands. We could observe Sandhill cranes at Coe Field a few times with the UAS during the manual flights, usually during sunny weather. They were frequently in groups of three to five animals roaming in bodies of water or foraging close to wetlands.

“Land-use practices and habitat are the key factors determining the wildlife species and the size of wildlife populations that are attracted to airport environments” (FAA, 2018, p. 2-8). The identification of these land-use practices and habitats as well as the recording of the impact they have on the identified wildlife species is fundamental during a WHA. We could, using the visual camera during the autonomous and visual flights identify those land use-practices (e.g., livestock production) and habitats (e.g., wetland) and the relationship between the identified species and those sources of attraction. For example, Cattle in the data collection area is a factor determining the number and behavior of Cattle egrets (Cornell Lab of Ornithology, 2021). Moreover, our team observed and recorded the presence, numbers, and behaviors of Cattle egrets, Mottled ducks, Sandhill cranes, and White ibises being attracted to wetlands at Coe Field (Cornell Lab of Ornithology, 2021a, 2021b, 2021c).

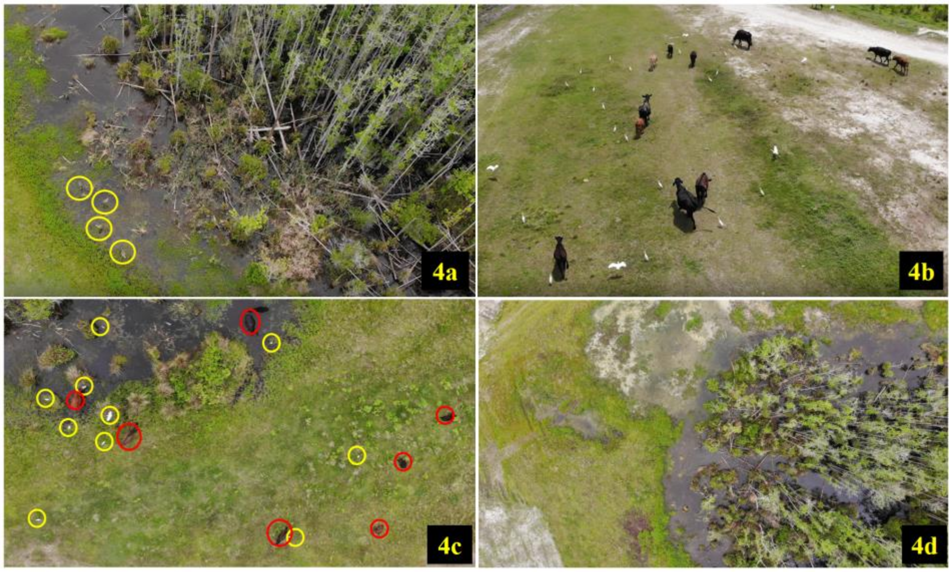

Figure 4. Multiple Images Collected with the UAS with the Visual Camera

Note. Figure 4a shows four Sandhill Cranes roaming in a Wetland. Figure 4b shows the interactions between Cattle and Cattle Egrets at Coe Field. In Figure 4c, yellow and red circles indicate Cattle Egrets and Cattle, respectively that were attracted to a wetland. Figure 4d shows habitats with the potential to attract hazardous wildlife species to the airport environment.

Conclusions

The increased risk of mishaps due to wildlife strikes (Dolbeer et al., 2021) and the forecast growth for the U.S. aviation industry (FAA, 2020) require new strategies and great effort in order to continuously improve aviation safety. Multifaceted and innovative approaches to mitigate the risk of aircraft accidents resulting from strikes are fundamental. Findings from this ongoing study suggest that that UAS facilitates data collection in areas that are difficult to access by ground-based means (e.g., wetlands). Another key finding of this study was that our team could observe, and with the assistance of the QAWB identify different wildlife species and habitats simultaneously during each UAS flight. In different words, from a single image (video and/or picture) a QAWB could obtain valuable information about different wildlife species and related habitats. Moreover, results suggest that the versatility and speed of UAS (including their high-quality cameras and sensors) ensure that data can be collected more thoroughly and faster over large areas during a WHA. The use of UAS during a WHA can allow a QAWB to collect data that are difficult to access by ground-based means. Our findings also suggest that the risk associated with UAS operations at the airport environment can be reduced through the development of a ConOps that incorporates robust risk management processes and procedures. Findings also indicate that the ConOps must be periodically revised to incorporate procedures that improve aviation safety and efficiency. Most importantly, results suggest that the use of UAS during a WHA can enhance the data collection process by:

1. Collecting data and information on wildlife species, habitats, and land-uses at the airport environment faster and thoroughly;

2. Establishing a relationship between habitats and/or land uses and hazardous wildlife species;

3. Obtaining information of different wildlife species and habitats / land-uses simultaneously;

4. Obtaining information on wildlife species in areas that are difficult to access by ground-based means.

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12-07-2021

Collegiate Flight Education Using the Cockpit Evolutionary Model

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The art of teaching students to fly safely has continued to evolve for over a century. The training community has had to adapt their teaching techniques and methodologies to keep up with changes in aircraft powerplant, airframe, and avionics installed on the aircraft and simulators used for training. The last 20 years have brought about a blistering pace of innovations, especially in the area of avionics and the use of Electronic Flight Bags (EFB). Flight training professionals have had to keep up without a corresponding pace of training technique revolution to serve that growth. This article will discuss the "cockpit evolutionary" training methodology used by [submitter university] and details the process of changing the training platform designs of the past to one that will most benefit students as they transition to professional pilot employment.

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Traditionally, training aircraft utilized a standard round dial, analog cockpit design. Students received their primary training in small two or four place trainers and would not see any glass cockpit displays until they transitioned to a jet either in corporate or the transport industries. The training community assumed that the hiring organizations would provide the transition training, and the hiring organizations gladly assumed this role because they wanted students trained to their Standard Operating Procedures (SOP). The challenge was that the learning curve was steep for students as they moved into the large aircraft cockpit. Students received little primary training consideration for their ultimate future flying platforms. The "Law of Primacy" suggests that a person will revert to the way they were initially trained if no other experience in their training would overshadow or drive their behavior while under performance stress.

Figure 1. Analog Cockpit Instrumentation

The general aviation industry has gradually phased out the production of analog instrument training aircraft as the attractiveness and dependability of the Garmin and Avidyne cockpits in general aviation, and Rockwell and Honeywell glass cockpit designs in larger aircraft continue to grow. Today, it is impossible to find an aircraft with an analog cockpit without going to the used aircraft market. This has caused many trainers produced in the 1980s through early 2000s to be continually sold and resold, driving their resale prices to well over their retail price when manufactured.

When the FAA released regulatory guidance in 2003 about what constituted a Technically Advanced Aircraft (TAA), it finally set a standard that the airframe and avionics manufacturers could integrate aircraft design around (TAA Safety Study Team, 2003). 14 CFR 61.1 (Aeronautics and Space, 2021) defines a Technically Advanced Aircraft as one which has an "electronically advanced avionics system". So, the TAA aircraft must have an electronic, glass Primary Flight Display (PFD), a Multifunction Display (MFD) and a two-axis (minimum) autopilot. Not mentioned in the regs, but equally important is a Flight Management System (FMS), which integrates all the pieces together. The computer integrates all the pieces of the system together and does self-checking should any component sense data that is out of tolerance or needs pilot intervention.

The Flight Management System on a jet is usually a centrally mounted keyboard or touch screen, which allows the crew to input flight plans and other data into the system, which ultimately can be flown through a coupled autopilot. Each segment of the flight is input into the FMS, and the autopilot simply follows the plan. If an error exists in the plan, then the FMS would not accept the inputs, thus double checking the first officer whose primary task is to keep the flight programmed to the ATC clearance. This model is how modern TAA training aircraft operate, except it is much easier to hand fly a TAA aircraft than it is to hand fly a jet. This TAA Training experience does not translate well back to an analog instrumented aircraft since each instrument is independent of the others and requires the pilot to truly understand instrument readings and to determine if an instrument or system has malfunctioned.

FAA and Aircraft Owner and Pilots Association (AOPA) data suggest that there are 220,000 aircraft currently registered in the United States as of 2020, and 90% of these represent general aviation (Aircraft Owners and Pilots Association, 2019). It is hard to get an accurate estimate of how many of those aircraft are considered Technically Advanced Aircraft (TAA), but we can, for the purposes of discussion, assume that at least 70% of the aircraft registered today do not meet the TAA definition. It stands to reason that a pilot trained from day one in a TAA glass cockpit aircraft might never encounter an analog instrumented aircraft if they are hired directly into corporate or airline operations. Experienced training professionals would probably agree that the mental process of interpreting critical flight parameters on an analog instrument takes training and practice and considering the law of primacy, that students may not ever have received instruction on that platform. In the worst possible flight scenario, a pilot is flying solid IMC, at night, over a great expanse of water and encounters an electrical failure in an unfamiliar aircraft. In a TAA aircraft, everything is routine until the electrical power is interrupted. We train them how to load-shed power consumption and how to make critical decisions before the panel goes dark. Take the same pilot in an analog cockpit who was never formally trained in that cockpit (The FAA has never mandated any transitional training either way), and analog instrumentation may be downright confusing and disorienting if they never had training in it. It stands to reason that since there are so many aircraft still flying with traditional analog cockpit instrumentation, it is quite possible that a pilot could end up in this scenario with little to back them up except pure instinct.

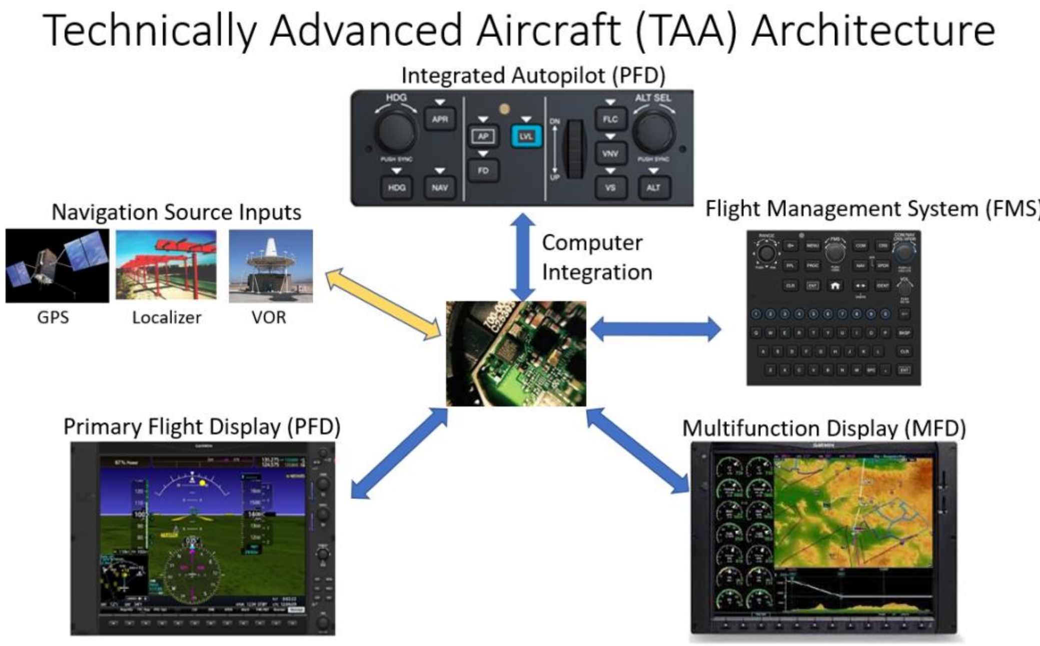

Figure 2. Technically Advanced Aircraft architecture

In the July 2007 FAA News magazine, I authored an article entitled "No Going Back," which discussed this concept in detail (Gaffney, 2006). A student who is trained in analog first and then transitions to TAA has at least a mental primacy to revert back to analog instrumentation in a pinch even if they have not flown such an aircraft in a while. The training community, aided by OEM trained instructor pilots, determined ways to transition analog pilots from analog to TAA since the electronic displays were designed to mimic the analog instrumentation while supplementing the pilot with the need-to-know information. This transition worked as long as the pilots were trained to understand the menu topology of the system and to use the correct "buttonology" to configure the screen and its functions. This takes a combination of ground training, practice in a simulated environment, and eventually training in an actual aircraft. Training providers quickly determined that training a pilot to fly a TAA aircraft without the prerequisite ground instruction only led to improper system interpretation and operation. We still find pilots who try to program GPS navigators with the **D->** (Direct to) button rather than the **FPL** Flight Plan Button. This is a quick recipe to fly through restricted airspace or through an obstacle by accident and inhibits the system from offering the pilot critical and timely information regarding their flight path and instrument procedures and frequencies associated with the waypoints along that flight path.

Figure 3. Cockpit Evolutionary Model

No major General Aviation manufacturer is currently producing an aircraft with analog instrumentation and, with the eventual disappearance of analog instrumented aircraft from training fleets through obsolescence. It is imperative that we consider our training strategy to ensure pilots get some type of training in the analog environment even though in their eventual professional career, they may never experience one. [The submitter university] has developed its training syllabi to follow this evolutionary cockpit model. We provide initial training using analog instrumented Cessna aircraft. We teach the instrument rating in analog aircraft and then move the students through ground school courses, classroom training, and Garmin Perspective Plus Kiosk training before moving them into the Cirrus SR20. We then use a scenario-based training syllabus to transition the student to advanced TAA cockpit operations. After the Commercial Instrument Multiengine certification is completed, the students move to the multiengine training phase, where they will use a TAA PA44 Piper Seminole. Then they move to the transport aircraft portion of the curriculum where we utilize classroom, CBT, and eventually a fully tactile 737 MAX AATD where we hone their CRM and flight management skills using crew-based Line Oriented Flight Training (LOFT) scenarios to emulate operations in a large transport aircraft environment. After conferring with our airline development partners Southwest, Delta, and Envoy, we believe we are going to produce the safest and most effectively trained graduates using this model even though the airline will retrain the graduate to use their SOPs and checklists. In self-assessment for our accreditation reaffirmation with our accrediting agency, Aviation Accreditation Board International (AABI), we also believe this strategy is sound and produces graduates to meet or exceed published Student Learning Outcomes.

While this stepped process of training is not revolutionary, the process of migrating a legacy flight training program to a technology-driven evolving cockpit training paradigm in the span of a few short years is. What makes this process special is that we are shifting the focus of our AABI accredited program from a “tried and true” 14 CFR 141 based program into an integrated cockpit model where we use technology building blocks to develop our students’ aeronautical decision-making skills to prepare them for a technology-based career field.

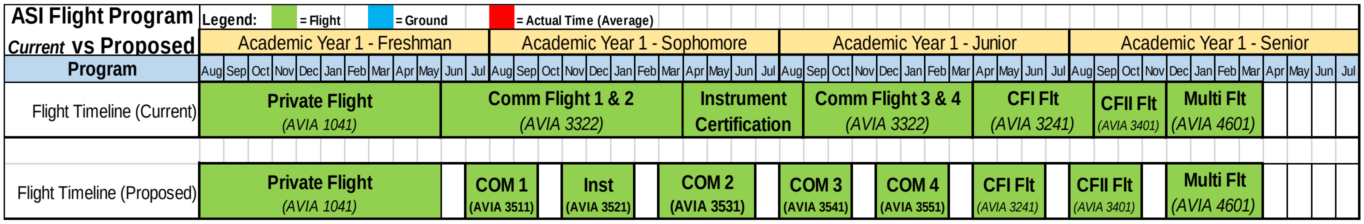

Figure 4. Traditional 14 CFR 61/141 Training Flow

To prevent training disruptions, we are keeping our FAA 141 syllabus intact with the exception of migrating the complex-high performance phase of the Commercial syllabus from maintenance-intensive Cessna 182RG to the Cirrus SR20 TRAC aircraft and incorporating the necessary technology training using Frasca RTD and Garmin Perspective Plus training Kiosk ground training devices. While this Commercial stage still accomplishes the high-performance endorsement with the 215 HP IO-390 Cirrus SR20, the Complex endorsement is deferred to the Multiengine phase of the program.

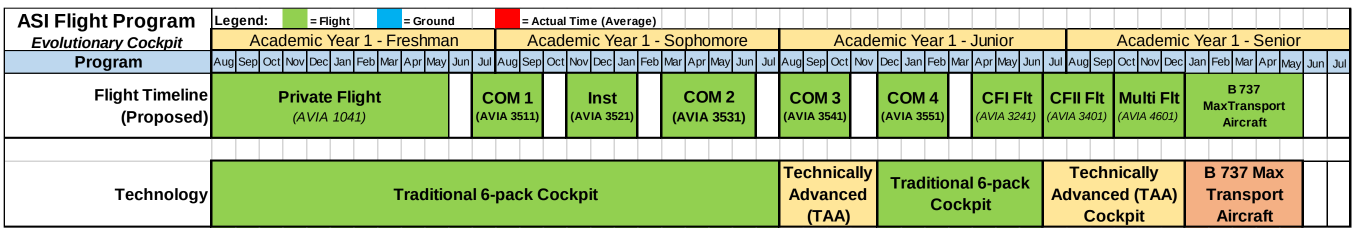

Figure 5. Cockpit Evolutionary Model Training Flow

While these fundamental changes give our students the technology boost they need to move from the analog 6-pack Cessna to the Garmin Perspective Plus Cirrus and the Garmin equipped Piper Seminole, it still does not completely prepare them for the transport category aircraft cockpit. We were seeking a way to bridge the gap, so our students were not only prepared for interviews with regionals and our pipeline partners, but they would also be competitive with the "best of the best" students coming from other heavy-weight university programs. Southeastern has moved forward with the installation of a Boeing 737 MAX AATD training device that will be used in three junior and senior year courses, including the program Capstone course. This device will be in place by January 2022. We will provide each student with 20 hours in the 737 Max AATD, 10 hours in the right seat, and 10 hours in the left seat. While we do not intend for the student to be type trained in the 737 Max, we want each and every student completely capable of performing turbine engine starts, system operation, taxi, FMS programming, emergency and abnormal procedure response, and demonstrate CRM proficiency using a series of scenarios in three of the transport category aircraft courses in the Professional Pilot program.

Another area that must be discussed is the role of electronic flight bags (EFB) and their use in training in our evolutionary cockpit training model. Traditionally, we taught students to navigate using pilotage, then dead reckoning, then electronic navigation using the VOR, ILS and the ADF platforms. Enter again the quickening pace of technology innovation, and we see the

Global Positioning System (GPS) navigation devices taking a prominent place in aircraft cockpits and we see the FAA rapidly decommissioning both VORs and NDBs and hear that the FAA will start decommissioning some ILS systems giving way to WAAS based RNAV-GPS approaches to near ILS accuracy. At the same time, we see paper sectional charts disappearing from pilot's hands and being replaced by iPads utilizing Foreflight or Garmin Pilot. How do these innovations affect training? What new training methodologies should we employ to keep our students prepared for the future?

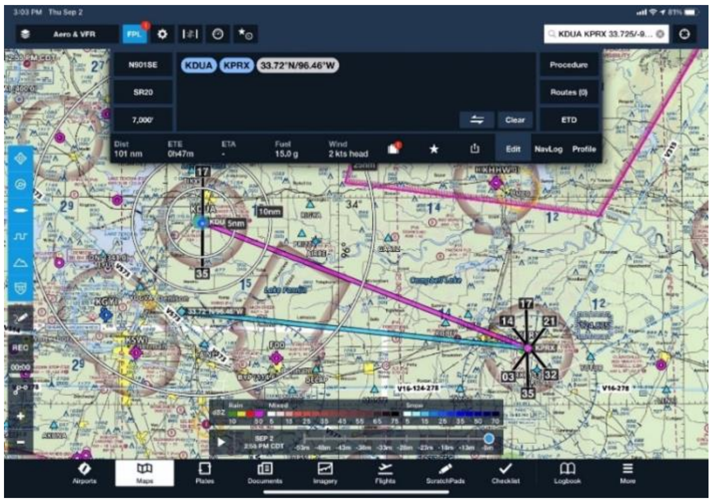

Figure 6. Foreflight on an iPad as an EFB

It was predicted in 1999 that by 2010, 90% of US aircraft would have GPS units installed (United States General Accounting Office, 2000). It is not known the accuracy of that prediction or where we stand in 2021, but for discussion purposes, let's assume that 65% of aircraft equipped with electrical systems have a panel-mounted GPS navigation unit. What does that mean for pilot training? Do we stop teaching pilotage and dead reckoning techniques? How do we ensure that previously trained pilots can operate safely in the modern National Airspace System (NAS) using the growing popularity of GPS navigation? How do we ensure that pilots can transition from paper-based VFR and IFR charts over to electronic versions based upon iPad or tablet-based systems using Foreflight or Garmin Pilot?

Southeastern Oklahoma State University is maintaining the strategy that we will continue to train Private Pilots to fly with traditional navigation techniques using pilotage and dead reckoning using sectional charts and nav logs before transitioning them to use GPS navigation and EFBs in the cockpit. We are developing a standardized transitional approach for doing this so it is covered in collegiate courses, in pre and post briefings, and then in the cockpit to ensure the highest degree of safety and flight proficiency. Once we transition a student to using a panel-mounted GPS having an EFB backup instead of paper charts, we have to ensure that they are trained and prepared for in-cockpit issues such as device overheats, dead batteries, and other issues that could affect flight safety. Having a cockpit backup strategy was never so important in our training environment. It is part of our risk management process and a critical part of our Safety Management System (SMS). We must prepare pilots to actively manage their navigation process and not just navigate staring at a "magenta line" on the GPS panel. We do not believe that we can do that effectively without training them in the traditional pilotage and dead reckoning models first.

In summary, Southeastern is actively designing a collegiate training environment that prepares our students in the most robust and worldly manner possible. We are upgrading our equipment, our Standard Operating Procedures (SOP), and our training curriculum to prepare our graduates for operating in the real world. We do not believe that our cockpit evolutionary strategy is holding on to the past, but rather we believe that it is boldly bridging the past to the future for our students and our graduates. We anticipate our hiring industry partners will agree and appreciate this for many years to come.

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Effective Social Media Strategy for Collegiate Aviation Programs

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As Generation Z becomes college aged, establishing an effective presence on social media is becoming increasingly important for higher education institutions. Prospective students are using social media to help guide them in their college decisions, which illustrates why it is increasingly important to have an effective social media strategy. The Oklahoma State University School of Educational Foundations, Leadership, and Aviation has gathered important information from social media analytics and industry resources that assists in the development of an effective social media strategy. Other collegiate aviation programs can use this information to develop or refine their existing social media strategies.

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Introduction

It is important for collegiate aviation programs to understand the importance of developing and refining an effective media strategy. An important component of an effective media strategy is the development of the collegiate aviation program's brand image. Every collegiate aviation program has a brand image, so it is important to establish a compelling brand image. What is more, an effective social media strategy will assist collegiate aviation program recruitment, engagement, and promotion of core values. The Oklahoma State University (OSU) School of Educational Foundations, Leadership, and Aviation has shared with the researcher what social media practices have worked well and what practices were ineffective. Also, collegiate aviation programs need to be adaptive as social media platforms continue to evolve in the future.

Why is developing a social media strategy important?

It is important for collegiate aviation programs to learn about their target audience, Generation Z before they develop a social media strategy. Thirty percent of students reached a university's website through the university's social media platform. Generation Z students are increasingly relying on social media platforms to guide their decisions regarding which university they will attend. They are quick to determine if they are interested in a social media post, so engaging and compelling posts are important. Furthermore, the students do not respond to aggressive marketing and sales tactics (Upton, 2019).

To appeal to the target audience, the social media posts need to be authentic, personalized, user friendly, and well designed. Eighty percent of students indicate "authenticity of content" is an influencing factor on social media platforms (Mendes, n.d.). Posts need to provide information students find useful and interesting. The social media platform needs to be user-friendly because 62% of students will leave a social media platform if it is not easy to navigate (Rhyneer, 2021). Next, the social media platform needs to be well designed. Eighty-seven percent of students indicate an effectively managed social media platform improves their opinion of a university (Rhyneer, 2021).

It is paramount for collegiate aviation programs to understand demographics for Instagram and Facebook to ensure the correct posts are being placed on the appropriate platforms. Thirty percent of internet users have an Instagram account, and 90% are under 35 years old, and 60% of Instagram users log in to their accounts daily (Upton, 2019). Instagram has over 1 billion monthly active users, over 500 million daily Instagram Story users, and a 4.21% engagement rate (Mendes, n.d.).

Engagement rate is determined by the amount of engagement divided by the number of followers. Engagement is defined as the number of user interactions with content. Instagram's engagement rate is much higher than Twitter and Facebook. Conversely, Facebook users are over 35 years old, which is the social media platform used by alumni and parents, and has 2.3 billion monthly active users (Mendes, n.d.).

Determine Your Brand Image

When developing a brand image, there are several crucial questions that need to be answered. The answers to these questions will provide the collegiate aviation program with the information needed to develop an effective brand image.

- What are the program's core values?
- Who is the target audience? What content does the target audience want to see?
- What are the program's goals?
- How will the program engage the target audience?
- What are the competitors doing?

All collegiate aviation programs have a brand image, so the goal is to develop and refine the brand image to accurately represent the program's mission statement. Videos and photos are very compelling, so Instagram, being an image-heavy platform, is very effective at building a brand image. The brand image conveys the program's mission statement, which should coincide with the university's mission statement. This consistency is needed because many students will link from the university's social media platforms to the program's social media platforms. Furthermore, collegiate aviation programs need to maintain consistency across their social media platforms.

Oklahoma State University's brand image encompasses diversity, family atmosphere, and the Cowboy Code. OSU's aviation program uses social media to celebrate diversity by posting content that celebrates events such as National Hispanic and Pride months. OSU seeks to promote a sense of community amongst their students. They achieve this through announcing social events on social media, such as "Movie Nights" at the Cowboy Hangar. This social involvement amongst students promotes the value of a family atmosphere, as it is important for students to feel as if they are a part of a community. Finally, the Cowboy Code conveys the foundational values that direct OSU's brand image on social media platforms. The posts on social media need to adhere to and promote those values provided in the Cowboy Code.

An effective brand image will establish the program as the "must attend" collegiate aviation program. Remember that brand image is paramount as 58% of aspiring students use social media platforms to investigate schools they are considering (Sehl, 2020). Of those students that use social media platforms to investigate schools they may attend, 17% stated the school's social media platform was extremely influential when making their decision of which school to attend, while 61% stated it was somewhat influential (Sehl, 2020).

Recruitment

To effectively recruit students for the program, the program must first understand the values of these aspiring students. Aspiring students value:

- Inclusion

- Diversity
- Equity
- Social justice
- Environmentalism
- Social connection
- Value alignment (Sehl, 2020).

It is important to understand that the presence of inclusionary policies within a collegiate aviation program will promote diversity. Aspiring students need to know the program values differences among people. Furthermore, students want to see the promotion of social connection within the program. They want to feel like they will be part of a community if they attend the program. The values listed above can be promoted on a program's social media platforms. This will enable students to achieve value alignment with the program. It is important for the program to demonstrate that the program's values align with the students' values.

To effectively recruit, it is necessary to feature faculty, alumni, and staff to establish these individuals as leaders in the industry. Feature their industry experience, publications, research, and awards. This will allow the program to convey to students how the program can help them achieve their career goals. In addition to the industry leaders associated with the program, it will be important to highlight internships, pathway programs, and job placement statistics as they will enable students to see tangible evidence of the program's ability to help them achieve their career goals.

Lastly, for the purpose of recruitment, it is essential for students to envision themselves at the university. Feature campus life through virtual tours and photos. For example, you can post appealing photos of the campus on Instagram or a list of the top 10 places to hang out on campus. This will assist the student when answering the question – Can I see myself there?

Promotion of Core Values

Social media platforms can help collegiate aviation programs promote their core values. First, the program needs to determine its core values. What values does the program stand for? This question needs to be answered first, and the answer will be unique for every program. How will the program promote those core values? It is important for the program's core values to be consistent with those of the university. Also, it is necessary for the program to remain consistent across the social media platforms when promoting core values. Your program can start by promoting the "value of a degree" in aviation. Why should students pursue a degree in aviation? Highlight the positive aspects of pursuing a career in aviation and the opportunities within the industry.

Posts that feature statistics about flight operations, including the number of flight hours safely flown over the past year, convey to users the program values safety. Featuring scholarships for minoritized populations and student organizations for minority students promote diversity and inclusion. This will assist a student when answering the question – Are there others that are like me at the program? Conveying the program's core values allows students to achieve value alignment with your program. Students experience value alignment with the program, meaning the students have the same values as the program.

Engagement

Engagement on social media platforms is important to Generation Z students. These students are looking for more than "likes" on social media posts. They want to see students, faculty, parents, and alumni interacting with each other on social media. This develops a sense of community that students value as they want to feel as if they are part of a community where they will be accepted and flourish. Instagram is very effective at promoting user engagement. There are many methods that can be used to promote engagement; however, there are several that have shown to be very effective such as "takeovers." There are alumni, faculty, and student takeovers that enable a specific individual to take over the program's social media account for the day. For example, an alum can take over the social media account while they are at work and post pictures and videos highlighting their careers. The alum is also available throughout the day to interact with students and faculty and answer questions. Some programs have students who are social media ambassadors who are involved with managing the programs' social media platforms and performing student takeovers. It is imperative that the individuals conducting the social media takeovers are well screened and understand the program's brand image to avoid any problematic posts.

Featured posts are another great way to promote engagement on social media platforms. For instance, engagement amongst alumni can be encouraged through "Throwback Thursday" posts. It is helpful to feature alumni in "where are they now" posts as it gives alumni a chance to reconnect with prior classmates. This also provides confidence in the program from aspiring students as this demonstrates that the program will successfully prepare them for the career they are seeking in the aviation industry.

There are many ways to engage students on social media. Pictures and videos are featuring "Top 10 Lists" of things to do around campus. Another option is to post contests, polls, and games for students. Another option is to encourage students to post about themselves so ask students to post pictures and videos asking students to "check in" and let everyone know where and what they are doing during the summer. Encourage students to use specific hashtags when they post. Finally, engagement can be promoted by simply providing useful information regarding events and important dates. Students respond favorably to information they find useful, such as scholarship and internship deadlines. Also, student organizations can post information about social events and ask students to use a poll to indicate if they plan on attending.

What Works

There are a few things collegiate aviation programs can do to assist with developing a successful social media strategy.

- The use of a content calendar is recommended for several reasons. A content calendar assists with focusing on the overall strategy rather than daily posts. However, it is important to remain flexible and make unscheduled posts when needed. The calendar will also help keep track of important dates, deadlines, and holidays. More importantly, scheduled posts will help the program avoid posts that may be problematic.

- The development of Key Performance Indicators linked to analytics will help the program set goals and evaluate the efficacy of the social media strategy.
- A "trial and error approach" is needed to determine what works for the program's social media platforms.
- The use of hashtags works well at promoting content. You should create some of your own hashtags and use 3-5 hashtags for each post. Hashtags identify who you are and should correspond with your brand.

It is important to remember that engagement is a key component of a successful social media strategy. The following types of posts are effective at creating engagement:

- New and interesting pictures
- Compelling videos
- Student achievement
- Opportunities for students

What Works – Instagram

- On Instagram, the target audience is junior high students through mid/late 20s, so posts on Instagram need to target students and younger alumni from the program. It is imperative the content posted appeals to this demographic, as they are the target audience (Upton, 2019).
- Interactive posts are popular on Instagram if they are simple. Interactive posts that require multiple steps are typically not well received.
- An Instagram story is a great way to convey information quickly to students.

What Does Not Work?

- Any post that is placed on a platform with the incorrect target audience. For example, if a post's target audience is students, the post should not be placed on Facebook because the students are not on Facebook.
- A "cookie-cutter approach" is not effective because each program is unique. What works for one collegiate aviation program may not necessarily work for another.
- Be certain to research hashtags before using them.

What is Next?

You may want to consider using these social media platforms in the future, as these social media platforms are becoming increasingly popular with junior high through college students.

- TikTok
- Snapchat
- Instagram Reels

Social media will continue to evolve over time, requiring the adjustment of the program's social media strategy. Social media platforms will continue to become an increasingly important tool for collegiate aviation programs to communicate, recruit, engage, and convey core values. Social media can provide many positive results for collegiate aviation programs but can become a liability if not managed properly. It is advised to answer the following questions before posting on social media.

- Who is the target audience?
- Is the program posting on the correct social media platform to reach the target audience?
- Does this post convey our core values?
- How will the target audience receive this post?

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Teaching Diversity, Equity, and Inclusion in Aviation Education

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Over the last decade, many companies have begun to recognize the value of a diverse workforce, equity within the workforce, and inclusion practices. Recent global events have pushed the promotion of diversity, equity, and inclusion (DEI) in the aviation workplace and education higher on the priority list for many. Unfortunately, the aviation industry continues to have difficulty in attracting and retaining a diverse workforce. Notwithstanding this struggle in the industry, those in education must find ways to educate our students on topics relating to DEI. It is critically important that this training is rooted in research. The aviation industry is starting to see increased research initiatives to promote DEI among all generations. However, integrating DEI in the aviation classroom can be challenging, as many faculty members might not feel comfortable addressing the topic in relation to their courses. Therefore, this research focused on inclusive teaching and dynamic lecture strategies that will enable educators to reflect on critical consciousness, be mindful of implicit bias, and handle resistance while fostering a safe space.

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Practice Grounded in Research

It is important to start this conversation with a consideration as to what defines diversity. Within a corporation or an educational institution, the definition typically falls in line with how that entity is measured. Equal Employment Opportunity, United States Bureau of Labor Statistics, and others measure corporations based on gender and ethnicity. However, people can be broken down into any number of groups based on factors such as socioeconomic status, social-psychological characteristics, and team interaction abilities, to name a few.

The airline industry has struggled to diversify its workforce based on gender and ethnicity measures. The most recent statistics published by the U.S. Bureau of Labor (2021) show that airline pilots are 94% White, 3.4% Black, 2.2% Asian, 5% Hispanic, and 5.6% Female, and aircraft mechanics are 84.3% White, 10.8% Black, 3.2% Asian, 23% Hispanic and 5.4% Female. Research shows us that striving for greater diversity is also good for business. A 2009 study found that companies with greater diversity had better sales, more customers, and larger market shares than those with less diversity (Herring, 2009). Additional research conducted in 2010 found that the more social psychological aspects of diversity play an equal or greater role in company success than the biodemographic measures of diversity (McMahon, 2010).

Challenges of Teaching DEI

Equally as important as maintaining a diverse workforce is an education program to support employees. A large meta-analysis of Diversity, Equity, and Inclusion training looked at the effectiveness of this type of training and the factors that impacted training effectiveness. Bezrukova et al. (2016) found several characteristics that made a positive impact in training. Training that was longer was more successful. Training that focused on diversity awareness and skills development resulted in more learning than training focusing on just awareness or just skills. The researchers also found that training that was supported by other programs within the company resulted in more positive outcomes. The training was also examined to determine factors that did not have a significant effect on training outcomes. The type of instructional mode and whether the training was mandatory or voluntary did not have a significant effect. Additionally, there was no difference between training that focused on one minority group (for example, women) versus training that took a more generalized approach. This meta-analysis serves as a general guide to some considerations when designing diversity, equity, and inclusion training. Unfortunately, not all training is well received. For example, a Washington Post article (Garvey, 1994) describes a diversity training seminar designed for FAA (Federal Aviation Administration) air traffic controllers in the early 1990s. The male controllers experienced a very "in-your-face" type of training that was intended to help them understand the problems of harassment in the workplace, in this case, specifically the harassment of women. The air traffic controller union stopped the training under an unfair labor practices complaint, and later one of the participants sued the Department of Transportation. This is just one example of training that had all the right intentions, but it was not executed appropriately. It is crucial to consider the audience and remember that many strong feelings are tied to the subject matter. That is not to say brush over the material, but be ready for challenging conversations and beware of an in-your-face type of approach.

DEI in Aviation and Aviation Education

Research on DEI training in the aviation industry is almost nonexistent. A research study in 2004 took two metrics that airlines are constantly looking at safety and customer service and found that the more training dollars were spent on diversity and other human resources, the better the company fared (Appelbaum, 2004). There is certainly a lot more work to be done in this area. Our role in the classroom is critical in preparing our students to head out into an industry that is striving for diversity, equity, and inclusion. There is a vast amount of research relating to this topic at all levels of education. (Wasserberg, 2014; Fischer, 2010). But, again, there is limited research on DEI and aviation education. The consensus is that making our classrooms more diverse, equitable and inclusive, has the potential to better educational outcomes and increase student retention. At an institution with aviation degree programs, the lack of enrollment diversity in the most basic measures gender, and race, are glaringly obvious. This leads to a classroom that may have only one female student or two students of color.

Furthermore, the lack of diversity in the aviation degree programs could also lead to students experiencing stereotype threats. Stereotype threat is defined as a fear of being judged based on belonging to a specific group or group-based stereotype (Spencer et al., 2016). For example, girls are bad at math. The effects of stereotype threat can lead to a reduction in working memory (Scmader & Johns, 2003), impaired performance (Steele & Aronson, 1995), and reduced sense of belonging (Good et al., 2012). This is just one example of why it is so important to consider our classroom environment and the opportunities to make it more inclusive.

While DEI practices in aviation education can pose a daunting challenge to overcome; however, Gannon (2020) suggested some ways professors might consider making their classroom more equitable and inclusive. Course design is one consideration: everything from the supporting materials, who is represented in those materials, what format they take to assignments, and how they allow students to demonstrate their knowledge. Gannon (2020) also emphasized identifying what biases professors may be taking into the classroom and finally creating a sense of belonging in the class. These are just a few of the many ways to strive for a better classroom environment for students of all backgrounds and experiences.

Best Practices

Inclusive teaching can be defined as a learning process that enables students to fulfill their learning needs in formal and informal educational environments (Figueroa, 2016). Furthermore, it allows teachers to feel comfortable in the open exchange of diversified thinking while enriching the learning environment, rather than just focusing on a particular problem (Figueroa, 2014). In a nutshell, inclusive teaching practices explore the importance of community and belonging as a foundation to student retention and success. Yet, because student needs change over the years, "being aware and sensitive to all learners and adjusting our teaching to factor each student's prior experience" (Figueroa, 2014, p. 49) ensures that teachers create a sense of belonging in the classroom.

Similarly, dynamic lecturing provides a framework that allows faculty to proactively optimize teaching and learning for all students. Dynamic lecturing principles enable the delivery of course content in multiple ways to reach all students. Primarily, faculty should make every effort to activate the students' prior knowledge as experiences influence what they perceive as important (Harrington & Zakrajsek, 2017). Questioning for critical thinking is one strategy within dynamic lecturing that enables students the opportunity to retrieve previously stored information that can be applied in class (Harrington & Zakrajsek, 2017). Therefore, to maximize the usefulness of dynamic lecturing, faculty should consider four simplified steps: 1) linking lessons to course goals, 2) exploring the lecture content, 3) exploring delivery methods, 4) timing sequence. Effective planning begins with a focus on goals. Faculty members should begin by documenting the course-level learning outcomes followed by a few goals for the lecture (Harrington & Zakrajsek, 2017). Then, for each learning objective identified, the faculty member should make the best effort to help all students learn the content. This could range from connecting prior knowledge to new content, multimedia tools, or questions that lead to big picture ideas (Harrington & Zakrajsek, 2017). Consequently, when exploring the different delivery methods options, faculty should keep a keen eye for the use of reflective exercises that bring attention to and emphasize the key learning objectives (Harrington & Zakrajsek, 2017). Lastly, teachers should lay out the sequence in which the content will be presented to distribute the time appropriately to incorporate active learning opportunities.

Benefits of Integrating DEI in Aviation Education

Slee and Allan (2001) argued that while the benefits of integrating DEI practices in education are endless, the systematic implementation of DEI practices remains ambiguous. Though many factors play a role in the consistent implementation of inclusive practices, Hymel and Katz (2019) point out that there has to be a link between the feasibility of the academic curriculum and the ability for students to truly engage with one another and learn from their cross ingroup boundaries. Therefore, the first three steps towards integrating DEI practices in aviation education are using critical consciousness, recognizing implicit bias, and learning through handling resistance while fostering a safe space.

Critical Consciousness

Scholars have defined critical consciousness as "the ability to recognize systems of inequality and the commitment to take action against these systems" (El-Amin et al., 2017, p. 18). Some of the most noticeable results of practicing critical consciousness are higher academic achievement and higher professional aspirations. The Latino Pilot Association (LPA) is a clear example of critical consciousness in practice. The first collegiate chapter established by the LPA at Embry-Riddle Aeronautical University (ERAU) took the initiative of embracing critical consciousness. The Eagles chapter at ERAU formed and established the Empowering Latina Leader Aviators subcommittee (ELLAs) of LPA. ELLAs is comprised of a group of people who self-identify as either cisgender females, transgender females, or non-binary, committed to investing expertise and resources to support Latina pilots in the aviation industry. The ELLAs primary goals are to build confidence during flight training and spread awareness of mental health among pilots. It becomes evident that when people develop critical consciousness, they also develop resilience towards an industry that has created a barrier for them (El-Amin et al., 2017).

Furthermore, it is crucial for faculty to capitalize on teaching the language of inequity within critical consciousness. The concepts of the language of inequity refer to recognizing how racism is transmitted among people, which could be between individuals or by internalized racist beliefs (El-Amin et al., 2017). For example, it is known that in the aviation industry, women of color feel their gender first, followed by their race. These subtle microaggressions have been one of the main targets of ELLAs. By recognizing the language of inequity, individuals can develop resilience to face racism and break the oppressive social forces shaping our society.

Implicit Bias

Academic institutions should engage their female and male students equally, yet they should also recognize how gender-related issues affect implicit bias in the classroom. Educational research has shown that implicit bias can foster negative attitudes that lead to stereotypical behavior resulting from unconscious associations (Jackson et al., 2014; Staat, 2016). Staat (2016) further affirms that while implicit bias might not be a part of an individual's awareness, "[…] they can have a tremendous impact on decision making" (p. 30). Jackson et al. (2014) suggest that to reduce resistance to implicit bias teachings, the presenter should employ non-confrontational language to increase group cohesion as the dynamic takes place. A few strategies that faculty members can put forward are becoming mindful of their prejudice while increasing kindness and empathy towards others.

Handling Resistance

In any discussion involving DEI initiatives, there is a good chance that students will showcase resistant behavior. Research has confirmed that the teacher is the main reason students portrait resistant behavior (Baker & Hill, 2017; Winckler & Rybnikova, 2019). One of the most effective practices to reduce resistance in the classroom is to foster a safe space. Students who feel that their voices are heard without any sense of retribution tend to engage more in the class dynamic. Moreover, faculty members should be open to understanding the reasons for student resistance. Winckler & Rybnikova (2019) point out that resistance from students is also a mechanism that enables them to reflect and change social conditions. Therefore, one could assume that when resistance is encountered in the classroom, the teacher has enabled the students to experience opposition as an expression of empowerment (Winckler & Rybnikova, 2019) and has genuinely engaged in inclusive teaching practices.

Another strategy that faculty members could implement is ensuring that the learning objectives are free from personal worldviews. Faculty members who abstain from including their worldview as part of the lecture also ensure that their learning objectives are free from prejudice and unconscious bias. However, it would be ideal if the teacher could engage students in discussing their shared experiences. Nevertheless, the instructor should also require all experiences and opinions to be supported with evidence. Even difficult dialogues related to DEI in aviation education can be grounded in research. Ultimately, the discussion should lead towards shared understanding.

Conclusion

All in all, teaching and integrating DEI initiatives in aviation can be intellectually and emotionally challenging. Therefore, a good habit to develop is asking the students to reflect and suggest characteristics of practical discussion that they have engaged in previously. Even if the students ask for the teacher's experience, they should keep in mind not to generalize the experience of others. As challenging as the topics may be, the rewards benefit all involved. When students feel engaged, they are more successful and can experience a greater sense of belonging. Higher education institutions that promote DEI practices in aviation education are rewarded with greater retention of a diverse population. Businesses that employ students with DEI exposure gain employees with valuable skills beyond those required in a job description. Further research should explore the aviation students' perspectives of integrating DEI practices in their core courses. This research will enable leaders in the education field to refine their strategies and ensure that student and industry needs are met.

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Utilizing Organization Change Management Tools to Implement Safety Management System (SMS) Principles

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This paper presents an exploration of organizational change management tools and their usability to the Safety Management System (SMS) principles. The objective is to provide three tools to embrace the three dimensions of organizational change management, aiding leaders to adopt to a magnitude of different changes or initiatives while following the same blueprint consistently that promotes a positive safety culture and identifies new hazards or ineffective risk controls within that operation. With SMS becoming the aviation industry standard for safety program management it is vital to not only comply with the regulations set forth but to be able to embed functionality and adaptability within an operation in a systematic, explicit, and comprehensive way that can be applied consistently time and time again when a new hazard or ineffective risk control is identified within an organization. Addressing the actions required to comply with the regulations and leveraging the organizational change management dimensions will create enhanced sustainability and resilience for the overall safety program. This exploration and design solution will create future research and analysis on the implementation of the guides in operation.

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Introduction

Problem Statement

Safety Management System (SMS) contains four components (Safety Policy, Safety Risk Management, Safety Assurance, and Safety Promotion). When implemented into an operation, they create a robust safety culture and safety program. How an organization implements these components are left undefined by the regulators and open to creative interpretation by the operators and organizations. While this may first appear to be an ideal situation, this often fosters confusion, inconsistencies, and margins of error in the applications of the operator's programs which can lead to improper or nonfunctional mitigation controls into an operation. This can result in safety concerns such as injury or damage to people or equipment.

Background

Safety Management System (SMS) principles and organizational change management at their core focus on identifying changes, creating systematic approaches to change, and creating effective solutions for the operation with a people focus. Evidence of the linkage between SMS principles and organizational change management is described in their definitions. AC 120 – 92B explains the purpose of Safety Management System (SMS) as:

> An SMS is an organization-wide comprehensive and preventive approach to managing safety. An SMS includes a safety policy, formal methods for identifying hazards and mitigating risk, and promotion of a positive safety culture. An SMS also provides assurance of the overall safety performance of your organization. An SMS is intended to be designed and developed by your own people and should be integrated into your existing operations and business decision-making processes. The SMS will assist your organization's leadership, management teams, and employees in making effective and informed safety decisions. (FAA, 2015)

An article titled Innovation-Based Change Management (GAM, 2015) defines change management as "a systematic approach to dealing with change, both from the perspective of an organization and on the individual level...proactively addressing adapting to change, controlling change, and effecting change."

Applying organizational change management tools to implement SMS principles into an operation will create a solid framework for operators to successfully comply and articulate the needs of the program to the population while verifying critical aspects are completed consistently throughout the organization.

Literature Review

Safety Management System

Understanding the makeup of SMS and its components is important to understand because it helps connect the framework of the guides to its effectiveness of complying with the SMS principles while embracing organizational change management dimensions that will be impactful for lasting change and acceptance in an organization.

Safety Management System (SMS) is becoming the industry standard throughout aviation. The program is now recognized by Joint Planning and Development Office (JPDO), International Civil Aviation Organization (ICAO), and Civil Aviation Authorities (CAA) (Safety Management System, 2016). The program focuses on integrating safety risk management and safety assurance concepts into repeatable and proactive systems, which results in risk identification, evaluation and mitigation, which plays a role in accident prevention. Operators benefit from using the program concepts (four components) and principles by having:

- A structured means of safety risk management decision making
- A means of demonstrating safety management capability before system failures occur
- Increased confidence in risk controls through structured safety assurance processes
- An effective interface for knowledge sharing between regulator and certificate holder
- A safety promotion framework to support a sound safety culture (Safety Management System, 2016)

SMS is structured by four components; Safety Policy, Safety Risk Management (SRM), Safety Assurance (SA), and Safety Promotion. By achieving the primary objectives of SMS and embracing the components, operators will have, "a well-structured SMS that provides a systematic, explicit, and comprehensive process for managing risks" (Ludwig, 2017).

Safety Policy

The Safety Policy component articulates the expectations of the policies and procedures and their related performance thresholds/goals, which creates the SMS program foundation. Even though senior leadership owns the commitment and responsibility to continually improve safety, it is up to all levels of the operation to be good stewards of the program and provide appropriate resources within their management levels authority. The output of this component is defined as,

"methods, processes and organizational structure needed to meet safety goals

- Establishes management commitment to safety performance through SMS
- Establishes clear safety objectives and commitment to manage those objectives
- Defines methods, process and organizational structure needed to meet safety goals
- Establishes transparency in the management of safety
    - Fully documented policy and processes
    - Employee reporting and resolution system
    - Accountability of management and employees

- Builds upon the processes and procedures that already exist
- Facilitates cross-organization communication and cooperation" (Safety Management System, 2016).

Safety Risk Management

Understanding the makeup of SMS and its components is important to understand because it helps connect the framework of the guides to its effectiveness of complying with the SMS principles while embracing organizational change management dimensions that will be impactful for lasting change and acceptance in an organization.

Safety Risk Management (SRM) is comprised of five parts: system description, hazard identification, risk analysis, risk assessment, and risk control. This process is used to aid in the operator's practices for their operation, which identifies hazards and mitigating risks that are best suited for them. By participating in this activity, it ensures compliance with the commitment to "consider risk in their operations and to reduce it to an acceptable level" (Advisory Circular, 2015).

Safety Assurance

Safety Assurance is the evaluation component of an SMS program. Within the program, it assesses the effectiveness of implemented risk controls and supports the identification of new hazards being introduced. Aspects included in the component are as follows;

- SMS process management functions that systematically provide confidence that organization outputs meet or exceed safety requirements
- Ensures compliance with SMS requirements and FAA orders, standards, policies, and directives
    - Information Acquisitions
        - Audits and evaluations
        - Employee reporting
    - Data Analysis
    - System Assessment
- Provides insight and analysis regarding methods/opportunities for improving safety and minimizing risk
- Existing assurance functions will continue to evaluate and improve service (Safety Management System, 2016).

Safety Promotion

The Safety Promotion component embeds safety culture aspects within which helps support a positive culture within all levels of an operation. Aspects of Safety Promotion include:

- Providing SMS training
- Advocating/strengthening a positive safety culture
- System and safety communication and awareness

- Matching competency requirements to system requirements
- Disseminating safety lessons learned (Safety Management System, 2016).

Regardless of an employee's position within an organization, everyone has a vital role and a need to participate in promoting safety. It can be as simple as a one-on-one coaching conversation between a supervisor and an employee related to a potential safety hazard or as large as developing the training content that is deployed organization-wide educating on SMS training.

Organizational Change Management

Organizational change management can be broken up into three dimensions. Leaders of the intended change must balance the three dimensions in order to facilitate any type or magnitude of change to have a successful implementation or transition within an organization. The three dimensions are;

- Outcomes; developing and delivering clear outcomes
- Interests: mobilizing influence, authority, and power
- Emotions: enabling people and culture to adapt (Green, 2020).

When embedding the three dimensions into a structured process "Organizational change can be planned and managed through an understanding a set of sequential steps" (Burnes, 2009). This is one of the leading benefits of organizations adapting to these principles because they can be applied to a magnitude of different changes or initiatives while following the same blueprint consistently without investing design and assessment efforts for the overall framework of the change model.

Change Management Tools

Applying change management tools to SMS requirements will create a framework for organizations to successfully comply with regulatory requirements and articulate the needs of the program to employees while verifying critical aspects of work to be completed. A few tools to aid in this process are;

1. Project plan: identifies the milestones that must be completed to have a successful project outcome. This is especially beneficial when the change affects multiple unit groups, with work occurring simultaneously. This tool facilitates Safety Risk Management (SRM) by creating document the aids in identifying the system description listed out in the SMS requirements within the regulation and controlling risks within it.

2. Metrics and data collection: utilizing data throughout the project keeps the organization making decisions based on facts and not assumptions. This tool complies with the Safety Assurance component in SMS, where the requirement is to trend and review data of the operation on a regular basis to identify when a policy and procedure is becoming an ineffective risk control and needs to be processed through the Safety Risk Management process.

3. Process mapping: shows a series of events that produce an end result that includes the who and the what and the workflow to achieve it. This tool applies to the Safety Risk Management (SRM) requirements and creates a system description and analysis and Safety Assurance.

Problem Solving Approach

The three tools (Safety Risk Management Documentation Tool, Safety Assurance Processing Mapping, and Communication Checklist) are created with utilizing the organizational change management dimensions' concepts with design requirements to meet 14 CFR Part 5 SMS regulatory requirements. The output creates workflows that the leaders can adopt to a magnitude of different changes or initiatives while following the same blueprint consistently that promotes a positive safety culture and identifies new hazards or ineffective risk controls within that operation.

Safety Risk Management (SRM) Documentation Tool

The SRM Documentation Tool was created to be utilized as a working document when participating in a SRM triggered from a new hazard or ineffective risk control in the operation that is a requirement of the Safety Risk Management component of the SMS. This tool is a resource developed under the Interests and Outcome of the organizational change management dimensions. By completing all aspects of the tool, it will verify the regulatory requirements are met, but it also acts as a user-friendly tool to assist the facilitator thru the overall process consistently regardless of the focus area, with mobilizing the stakeholders to develop business outcomes usually resulting in the form of new policy and procedures within the operation. Refer to Appendix A for the SRM Documentation Tool in its entirety.

To best leverage the tool, the facilitator of the SRM would complete the Overview section providing as much detail about the new hazard or ineffective risk control, its history within the operations and the trigger of the need to launch the SRM. Then send the document to all related stakeholders within the operation to provide insight from their Subject Matter Expert (SME) perspective. The request would include hazard conditions, data, and worst credible outcomes. Once this is complete, the facilitator would merge the information into a centralized document and facilitate a meeting where all the active participants would work through the rest of the SRM such as;

- Finalize hazard conditions
- Initial risk assessments
- Mitigation plans
- Document lessons learned
- Mitigated risk assessments

Safety Assurance

Process mapping is a powerful tool for the Safety Assurance component in SMS. This tool is a resource developed in Emotions and Outcomes of organizational change management dimensions. It showcases the required steps of the process and provides a way for different management level reviews to be embedded into the process in an easy-to-read and visual way for all facilitators and/or stakeholders to use when reviewing their safety performance data in a systemic way. Most commonly the data used in this process is de-identified safety reporting reports. This tool can also be used for promotional purposes to share how the data (i.e., safety reporting or metrics) is reviewed on a regular basis. Figure 1 depicts the steps included in the Safety Assurance process map.

A way to use this process is having the Safety Manager facilitate a monthly review (first Wednesday of the month) and analysis of safety metrics and related operational metrics with the operations stakeholders. During this review time the stakeholders would decide the appropriate actions (i.e., continue to monitor or identify new hazards or ineffective risk control) best suited for the operation. Once the meeting is concluded and the action items are addressed. The management level review meeting would occur during the second or third week of the month. At this review session, the Safety Manager would present the outcomes from the monthly analysis and assessment meeting to receive final approval or edits prior to the new or edited policy and procedures when living into the operation. The overall review process would start again. This ensures the operation is meeting the continuous improvement and monitoring requirements of the SMS program. While verifying organizational change management dimensions are being met to meet the most effective and sustainable amount of change within the operation.

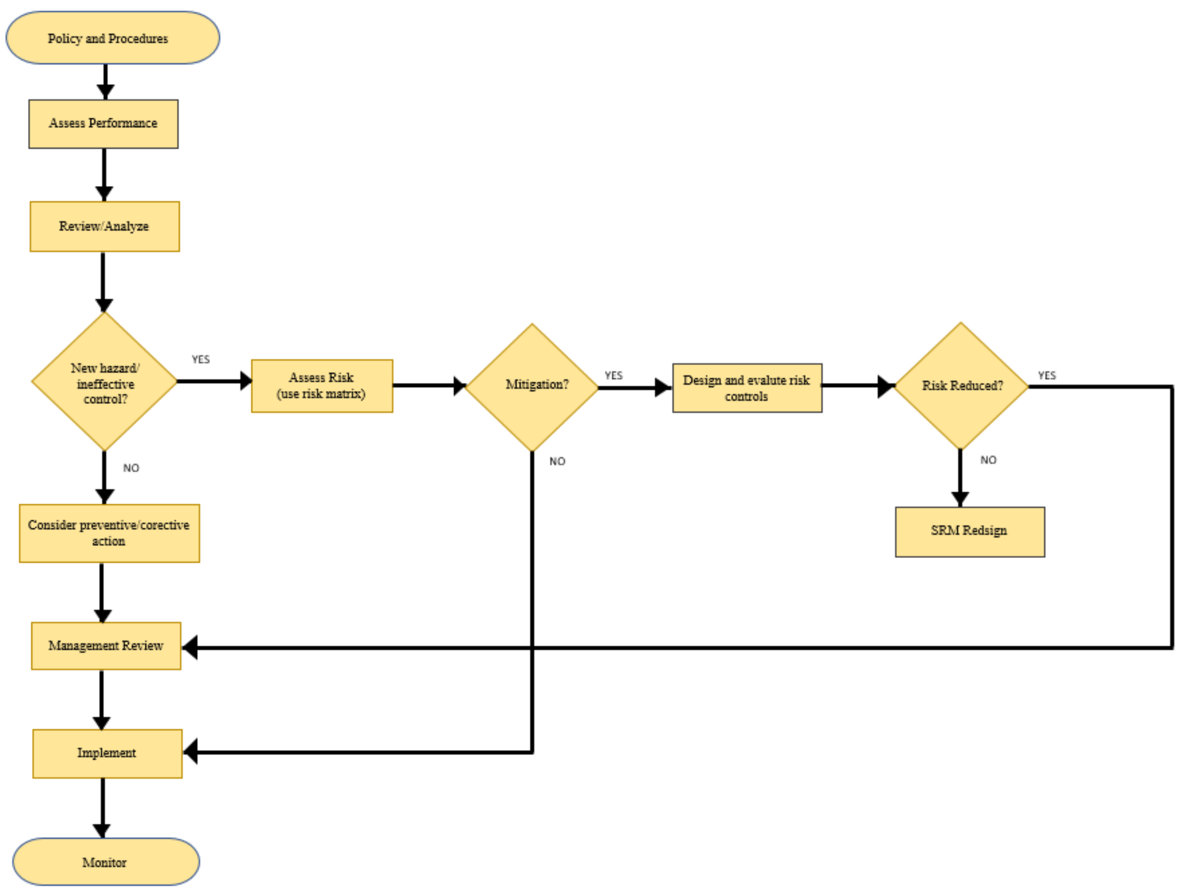

Figure 1. Safety Assurance Process Map

Safety Promotion

The Safety Communication Checklist is designed to facilitate the needs of the Safety Promotion component of SMS while utilizing the Emotions dimension of organizational change management. The safety promotion component is the most vital when it comes to safety culture and receiving the "buy-in" from individuals within an organization and speaks how it is linked to the Emotions of organizational change management dimension.

Ad hoc communications are needed when various risk levels of events occur within the operation. This is more reactive communication needs within an operation. The weekly summarizing of operational safety concerns helps keep safety a focus and embeds concern within the operation itself. The monthly efforts are a part of the proactive measures of the SMS. Continuous improvement efforts build towards maintaining a positive safety culture. The yearly recommendations are embedded as part of the SMS requirements of the regulations. This tool was built in mind to provide communication direction for the Safety Manager of the operation.

The three tools (SRM Documentation Tool, SA Process Map, and the Safety Communication Checklist) are created to embrace the three dimensions of organizational change management, aiding the leaders to adopt to a magnitude of different changes or initiatives while following the same blueprint consistently that promotes a positive safety culture and identifies new hazards or ineffective risk controls within that operation. The SRM Documentation Tool is a step-by-step project plan that identifies milestones to achieve a consistent risk assessment throughout an operation. The document facilitates achieving the outcomes to make business decisions and involves stakeholders who have strong influence and power within an organizational structure. The documents also could be used as a promotion of how a decision was made, enabling the people and culture to adapt to the changes. SA Process Map is a blueprint in how to perform assessment processes and its life cycle within the Safety Assurance component. Lastly, the Safety Communication Checklist provides dynamic usability that addresses the third dimension of organizational change management directly by providing transparency and information updates to the employees that enable a positive safety culture. Developing these tools with Organizational Change Management principles to meet the SMS regulatory requirements provides certificate holders an execution plan but tools that will create sustainable and effective change in operation that will promote positive continuous improvement efforts that builds a robust safety culture.

Application

On April 12, 2019 the Purdue University Board of Trustees approved the purchase of thirteen single-engine Piper Archer aircraft. These aircraft were the replacement of the Cirrus trainer fleet which was designated as "aging and will require significant investment to maintain compliance with FAA regulations." (Purdue.edu). To manage the transition, the School of Aviation and Transportation Technology (SATT) complied with 14 CFR Part 5 Safety Management Systems (SMS) requirements on a voluntary basis. The integration of the SMS program was targeted to provide a comprehensive and preventive approach to manage safety hazards related to the transition of aircraft, Certified Flight Instructors (CFI) and students. During the aircraft transition, the three tools outlined in the report were used as primary tools to help ensure systematic, explicit, and comprehensive implementation that was applied consistently repeatedly when a new hazard or ineffective risk control is identified within the organization. These efforts were highlighted within safety communications, monthly review meetings and assessments on various operational levels, and implementation of new procedures.

SRM Documentation Tool

For the aircraft transition a Manual Fleet Approval Board and a subcommittee were created to complete the SRM requirements and work through the policy and procedure changes. The Manual Fleet Approval Board is made up of the Chief Flight Instructor (Flight Operations), Two Flight Faculty Members (Course Work), Director of Maintenance (Maintenance), and the Aviation Safety Manager. These members were the risk acceptors in their areas of responsibility related to hazards, mitigation plans, and overall functions of the Safety Risk Management (SRM) pillar. The SRM trigger for the fleet transition is listed as a primary example of the demonstration of section 5.51 in the 14 CFR Part 5 described in Advisory Circular 120 – 92B. How the team complied with the five-part SRM requirement is by utilizing a subcommittee that identified and documented the;

- System descriptions
- Hazard identification
- Risk analysis
- Risk assessment
- Mitigation plans
    - Predicted residual risk
    - Substitute risks

The subcommittee consisted of four full-time flight instructors (two Assistant Chiefs, Flight Instructors), seven students, which include traditional students and part-time flight instructors. The Board and the subcommittee met periodically to review the proposed changes, address edits and action items before the Board accepted the risk of each manual content change. Once the SRM process was completed and accepted by the risk acceptors the manual changes were completed and prepped for the “Ghost Manual” that was ultimately reviewed by the FAA and became an active manual revision in operation.

With any tool or program there are limitations to the usability of its design. The SRM Documentation Tool was designed in a way that was user-friendly for the stakeholders to share information. A pitfall of this mindset occurred when the facilitator was merging information with multiple hazards into one centralized document and it created an additional administrative workload for the facilitator. Since there were hundreds of hazards proactively identified, it became challenging to log them into the sample form. To mitigate that administrative pain point, the decision was made to keep the context of the form but migrate it into Excel to make it easier to manipulate the hazards and the related information.

Safety Communication Checklist

The Safety Communication Checklist was used primarily as a job-aid for the safety team to successfully meet the timeline requirements of each communication style established within the organization prior to the aircraft transition. A secondary use was utilizing the checklist as a training tool during the aircraft transition kickoff meeting that occurred during a safety meeting that included Instructors, Dispatchers, and Students. This assisted in providing the expectation of communication for each style of communication that would be sent out. This allowed the focus to be on the content and not be distracted in the format and actions required from each style of communication.

Safety Assurance Process Map

The primary functionality of the Safety Assurance Process Map was used for training purposes, and job-aid reference for understanding in what life cycle a hazard was currently in and assured the regulatory steps could be met efficiently since they were embedded in the process flow. This was helpful for the subcommittee because many people in the working group were not regularly attending management meetings and did not have the need to have a robust understanding of the administrative process flow. A limitation to this map was its non-interactive nature which left the current status interpretation to the stakeholder working the process. In order to overcome this limitation, the Aviation Safety Manager audited the process on a weekly basis.

Conclusion

Using these tools met compliance with the SMS regulatory requirements but also provided a pathway for Purdue University to implement safety practices with a solid framework to successfully comply and articulate the needs of the program to the active operation while verifying critical aspects were completed consistently that reduced confusion and missteps during this process of change management. The tools and processes utilized the three dimensions of organizational change management for effective and adopted changes within the operation. The results of this paper open new avenues for future research with applying and studying a certificate holder utilizing these tools in an active operation. Further quantitative research will provide gaps and possibly other tools needed within the safety policy component.

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Impacts of Modality Change and Preventative Measures as a Result of the COVID-19 Pandemic on Students' Satisfaction and Engagement

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A number of research studies have been performed with regards to the distinction and impact of modality differences between face-to-face and distance education modalities. However, with the worldwide spread of the Coronavirus / Covid-19 in the Spring of 2020, primary education to graduate institutions were forced to change modality in order to reduce the spread of the disease. A vast number of students, as a result, were forced to transition from traditional face-to-face courses to online distance education courses, with very little warning. This study analyzed what impacts those changes have on the students that are studying for degrees as part of the Aviation Sciences Department at a University within the State of Utah by utilizing a three-part survey that included a demographic question section, a series of Likert statements and three open-ended questions. Emphasis was given to try and understand the impact on student satisfaction and student engagement as a result of the changes that were required as a result of the Coronavirus / Covid-19 pandemic. Descriptive statistical findings of this study, along with a qualitative trend analysis of the responses to the open-ended questions, showed a drop in perceived engagement among the sample population to distance education modalities. In addition, the study showed a trend of negative student perception of the precautions taken as a result of the pandemic, along with instructor preparation to the modality changes. The study found that while there was strong student perception of satisfaction within the Likert statements, that a strong degree of frustration was exhibited in the open-ended questions.

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The Coronavirus / Covid-19 pandemic hit every facet of life to varying degrees. This caused a paradigm shift for some within the learning community, changing from traditional face-to-face classes to classes delivered purely online to limit the spread of the virus among students and school employees. According to the U.S. Census Bureau, “93% of people in households with school-age children reported their children engaged in some form of “distance learning” from home” (Mcelrath, 2020). This change was feared to have an immediate and profound negative impact on those students that suddenly found themselves learning through computers and other distance education methods rather than in face-to-face classes (Goldstein, 2020).

Distance education, virtual classrooms, online learning, massive open online courses are just a few names that digital learning has gone by. According to Simonson and Seersaud (2019), distance education can be defined as “institution-based, formal education where the learning group is separated, and where interactive telecommunications systems are used to connect learners, resources, and instructors” (p. 1).

A comparative review of distance education through different media types undergone in 1999 found that there was no significant difference and that the delivery medium contributed little to the effectiveness of the instructional outcome (Russell, 1999). A 2017 study found that students in online classes that received instruction via video or other digital delivery methods did as well as students taking face-to-face classes (Chingos et al., 2017). Conversely, a 2018 study showed that when students were randomly selected to either take a distance education course or a face-to-face course, students in the face-to-face class performed better on tests and post-test instructor questions (Arias et al., 2018). There can be a clear differential between those courses that had a deliberate and methodical development process before being delivered to students and those courses that found that they had to be shifted to a distance education format in an emergency setting (Hodges et al., 2020).

One aspect that can reliably be linked to positive student outcomes, such as a measure of critical thinking and higher grades, is the student’s engagement (Carini et al., 2006). The concept of student engagement can be broken down into four areas, which are emotional engagement, physical engagement, cognitive engagement in class, and cognitive engagement out of class (Burch et al., 2015).

The other aspect of student learning, either in a face-to-face class or via a distance education course, is the satisfaction of the student to the class. Student satisfaction can have many different factors related to the student’s overall satisfaction within a course, including instructor presence within the course, quality of the course itself, and the amount of work versus the perceived learning by the student (Caskurlu et al., 2020). Previous studies have indicated that student satisfaction is higher for those students that complete coursework in a face-to-face modality (Furlonger & Gencic, 2014). Other studies have shown that students show higher satisfaction levels when enrolled in face-to-face classes (Johnson et al., 2000). One 2016 study showed that, while student satisfaction was higher for face-to-face classes when viewed from the metric of instructor communication, there was no difference between face-to-face and distance education courses (Cole, 2016). Some studies have found that when courses are transitioned from a face-to-face modality to distance-based, student satisfaction goes down (Guest et al., 2018).

Research Methodology

The study utilized a mixed-method methodology that was delivered in the form of an anonymous survey. The mixed-method style of research enables narratives to be added to studies that traditionally have only had quantitative data, giving a greater picture of the studied subject (Hesser-Biber, 2010). Furthermore, mixed-method research considers "multiple viewpoints, perspectives, positions, and standpoints" when trying to understand the subject being studied (Johnson et al., 2007). Permission to perform this research study was approved by the Institutional Review Board at the University (IRB Protocol #684).

The study was conducted at a public, dual mission university. The student population chosen for this study were students that were currently enrolled in classes during the Spring of 2021 semester.

At the beginning of 2020, classes within the Aviation Sciences Department encompassed a wide range of modality and delivery methods, including in-person face-to-face classes, hybrid classes that would occasionally meet face-to-face, but also had a significant online aspect, and courses that were taught entirely online. In March 2020, it was announced that almost all classes at the university would transition to an online-only environment, including current classes that had a face-to-face aspect to the teaching modality in order to safeguard both students and instructors.

Research Questions

The following research questions guided this study in determining the perceptions, satisfaction, and engagement that current, active students taking courses within the Aviation Sciences Department have in response to changes as a result of the Coronavirus/COVID-19 pandemic.

Research Question 1 (RQ1): What is the perception of the impact of the Coronavirus/COVID-19 pandemic amongst Department of Aviation Sciences students at Utah Valley University?

Research Question 2 (RQ2): What has been the impact on student satisfaction as a result of instructional and modality changes within the Department of Aviation Sciences in response to the Coronavirus/COVID-19 pandemic at Utah Valley University?

Research Question 3 (RQ3): What has been the impact on student engagement as a result of instructional and modality changes within the Department of Aviation Sciences in response to the Coronavirus/COVID-19 pandemic at Utah Valley University?

Research Question 4 (RQ4): What preferences do Department of Aviation Sciences students at Utah Valley University have with regards to instructional and modality types in the context of a continued Coronavirus/COVID-19 pandemic?

Survey Instrument

The population for the research instrument was students, full-time or part-time, that were enrolled in any class within the Aviation Sciences Department at the university within the State of Utah. An email was sent to all potential participants utilizing university-provided student email addresses. The population group for the survey consisted of approximately 740 students that were currently enrolled at the university.

Content validity was assured by forwarding the survey to several other faculty members for review. These suggestions were incorporated into the final research instrument. Student satisfaction and engagement questions were also developed after a review of the 2020 National Survey of Student Engagement Survey Instrument (Center for Postsecondary Research, 2020).

Data for the survey instrument was collected utilizing the Qualtrics system of online survey software. A total of 741 students were emailed, and of those potential participants, 94 individuals clicked the link to go to the study page, with a further 91 agreeing to the study consent form and answering the study questions. Thus a response rate of 12.28% was obtained.

Demographic Questions

Once within the survey instrument, participants were asked a number of demographic questions. The first demographic question asked the gender identity of participants. Of those that participated in the survey, the majority identified as male (82.42%, N=75), a much smaller number identified as female (14.29%, N=13). 2 participants preferred not to respond to these questions (2.2 %), and one identified as another category (1.1%).

The participants were next asked to identify their degree at the university. Of the degrees represented within the study, the majority of participants were students enrolled in the Professional Pilot major (79.12%, N=72), while the rest were students enrolled in the Aviation Management majors (19.78%, N=18). One student (1.1%, N=1) responded that they were enrolled in both majors.

The next demographic question asked the participants how many years they were enrolled as a student within the university. Here the majority of participants had been enrolled for two years (37.36%, N=34), 19 participants (20.88%, N=19) had been enrolled less than one year, while 10 (10.99%, (N=10)) had been enrolled for one year. 15 participants (16.48%, N=15)) had been enrolled for three years, while 12 (13.19%, N=12) had been enrolled for four years. One participant (1.1%, N=1)) had been enrolled for six years.

Participants were then asked if they required a student visa to attend classes, and 4 participants indicated that they did (4.4%, N=4). The remainder of the participants (95.60%, N=87) indicated that they did not need a visa.

The final demographic question asked participants to select the different types of classes they had been part of. At the time of the study, students were only enrolled in either synchronous or asynchronous classes. However, the instrument only recorded one option per participant. This demographic variable was omitted from any further analysis.

After the demographic questions, a total of 24 Likert scale statements were presented to the participants (Table 1).

Table 1
Summary of Likert Statement Responses

	Likert Statement	Strongly Disagreed	Disagreed	Agreed	Strongly Agreed	Total
1	The Coronavirus/COVID-19 pandemic has had a significant impact on my studies at UVU.	5	12	34	40	91
2	The Coronavirus/COVID-19 pandemic has had a significant impact on my studies within the Department of Aviation Sciences at UVU.	4	13	32	42	91
3	The Coronavirus/COVID-19 pandemic has required me to make changes to the way I study for classes and assignments.	5	13	38	35	91
4	I feel that the Aviation Sciences Department at UVU has done everything they can in response to the Coronavirus/COVID-19 pandemic.	3	18	50	20	91
5	I feel that the Aviation Sciences Department at UVU could have done more in response to the Coronavirus/COVID-19 pandemic.	13	49	19	10	91
6	I feel that the Aviation Sciences Department at UVU did too much in response to the Coronavirus/COVID-19 pandemic.	14	50	13	14	91
7	I am more interested in class/course material in a face-to-face classroom setting when taking classes.	3	16	23	49	91
8	I am more interested in class/course material when taking asynchronous online classes. Asynchronous classes do not require a student to "attend" class online at certain times.	20	32	27	12	91
9	I am more interested in class/course material when in synchronous online classes. Synchronous classes are online but have a scheduled time that students are required to "attend", such as scheduled times for instructors to teach via a live-stream video format.	22	38	25	6	91
10	I feel I am more focused on class content, activities, and assignments in a traditional face-to-face class.	4	12	25	50	91
11	I feel I am more focused on class content, activities, and assignments in an asynchronous class.	29	33	23	6	91
12	I feel I am more focused on class content, activities, and assignments in a synchronous class.	24	35	27	5	91

13	I feel I more focused on class content, activities, and assignments in a class that has an online component (hybrid, synchronous, asynchronous).	18	34	35	4	91
14	As a result of the changes within the Aviation Sciences Department in response to Coronavirus/COVID-19, I concentrate more on class discussions and activities.	15	47	24	5	91
15	As a result of the changes within the Aviation Sciences Department in response to Coronavirus/COVID-19, I am more interested in the work I do in my classes.	17	42	30	2	91
16	As a result of the changes within the Aviation Sciences Department in response to Coronavirus/COVID-19, I devote more effort to class discussions and activities.	19	34	35	3	91
17	I am satisfied with the changes that occurred within the Aviation Sciences Department in response to the Coronavirus/COVID-19 pandemic with regard to class delivery methods.	16	26	43	6	91
18	I am satisfied with the changes made to the flight training program within the Aviation Sciences Department in response to the Coronavirus/COVID-19 pandemic.	11	32	43	5	91
19	I am satisfied with previous and current protection efforts put in place by the Aviation Sciences Department in response to the Coronavirus/COVID-19 pandemic, including temporary suspension of the flight program in order to protect students and instructors, along with current increased testing and checks.	17	18	47	9	91
20	I am satisfied with the ability of instructors within the Aviation Sciences Department to make changes to the delivery of classes in response to the Coronavirus/COVID-19 pandemic.	6	13	63	9	91
21	I am satisfied with the communication that was provided to me regarding changes to class delivery within the Aviation Sciences Department in response to the Coronavirus/COVID-19 pandemic.	5	20	59	7	91
22	I am satisfied with the speed of class delivery changes within the Aviation Sciences Department in response to the Coronavirus/COVID-19 pandemic.	4	18	61	8	91
23	Given the changes that happened to class delivery methods in response to the Coronavirus/COVID-19 pandemic, overall, I am satisfied with my classes within the Aviation Sciences Department.	12	23	46	10	91
24	Given the changes that happened to class delivery methods in response to the coronavirus/COVID-19 pandemic, overall, I am satisfied with all my classes at UVU.	13	25	45	8	91

Analysis of Likert Statements

The Likert-scale statements listed in the research instrument were analyzed for internal reliability by using Cronbach's alpha. Cronbach's alpha is a general formula for estimating internal consistency based on a determination of how all items on a test compared to all other items and to the total test (Gay, Mills, & Airasian, 2006). George and Mallery (2003) have established the following Cronbach's alpha acceptance scale: " - > .9 – Excellent, - > .8 – Good, - > .7 – Acceptable, - > .6 – Questionable, - > .5 – Poor, and - < .5 – Unacceptable" (p. 231). Calculated alpha's approach 1 as the reliability increases, with .8 or higher being regarded as a good value for the alpha (Peterson, 1994). Using data results from all participants, the internal reliability of the instrument was found to have an alpha coefficient of .664. Given that this was the first use of these Likert statements, coupled with the uniqueness of the pandemic situation, this is understandable.

To better understand the relationship between the department variable and the Likert statements, a Pearson's correlation was computed utilizing the SPSS statistical software between the demographic variables and the Likert statement. Some significant correlation was found (Table 2).

Table 2
Pearson's correlation between demographic variables and Likert statements

Demographic Variable	Likert Statement	Pearson Correlation
Gender Identity	I feel that the Aviation Sciences Department at UVU has done everything they can in response to the Coronavirus/COVID-19 pandemic.	-.277
Degree	The Coronavirus/COVID-19 pandemic has had a significant impact on my studies at UVU.	.365
Degree	The Coronavirus/COVID-19 pandemic has had a significant impact on my studies within the Department of Aviation Sciences at UVU.	.409
Degree	The Coronavirus/COVID-19 pandemic has required me to make changes to the way I study for classes and assignments.	.272
Years Enrolled as a student at UVU	As a result of the changes within the Aviation Sciences Department in response to Coronavirus/COVID-19, I concentrate more on class discussions and activities.	-.341
Do you require a student visa to attend classes at UVU	The Coronavirus/COVID-19 pandemic has required me to make changes to the way I study for classes and assignments.	.221

Survey Open Ended Question Responses

Question 1: What thoughts, if any, do you have on the changes made to the Aviation Department's class delivery methods at UVU in response to the Coronavirus/COVID-19 pandemic?

A strong desire to have face-to-face classes developed from the responses (13.19%, N=12). Other trends included the desire for instructors to actually teach and deliver material rather than reduce the classes to self-taught lessons (14.29%, N=13). This was especially true for those students within the Professional Pilot program. Another trend commented on the cost associated with the change in class modality (3.30%, N=3). There was also a trend that some participants enjoyed the increased flexibility of the now online classes (5.49%, N=5). A final significant trend was the devotion and adaptation of the instructors to the courses being taught (5.49%, N=5).

Question 2: What thoughts, if any, do you have on the changes made to the Aviation Department's flight training program at UVU in response to the Coronavirus/COVID-19 pandemic?

This question was limited to those participants that either were new to the Aviation Sciences Department and thus not taking flying lessons or those that were not enrolled in the professional pilot program. As such, the majority (61.54%, N=56) either had no comment or admitted that they were too new to the program. Of those that did respond substantially (38.46%, N=35), a significant trend was frustration with preventative measures put in place to allow flight training to continue (12.09%, N=11). There were a noticeable number (7.69%, N=7) of participants that were supportive of the precautions put in place that enable flight lessons to continue.

Question 3: What changes, if any, would you make to the Aviation Department's response to the Coronavirus/COVID-19 pandemic?

The most significant trend here was once again a desire to have at least some face-to-face classroom instruction. Of those participants that entered information, thirteen (14.29%, N=13) expressed some sort of desire to have face-to-face classes, while only four (4.40%, N=4) expressed a desire for continued or increased online class modality. Other trends included comments on instructors' ability to instruct and operate in online modalities (7.69%, N=7). The precautions implemented within the department against the pandemic were also highlighted, with twelve (13.19%, N=12) participants mentioning either the mask requirements, testing requirements, or both.

Findings

The data from the Likert statements from all participants did yield a few notable strong agreements and disagreements. After the Likert statements were transferred into an ordinal series, any means greater than 2.5 indicated that more individuals agree with the statement than disagree. In looking at the first group of statements in regards to the pandemic in general (Table 1, Statements 1-6), the majority of participants agreed with the statements. The notable exception was statement 6, which stated, "I feel that the Aviation Sciences Department at UVU did too much in response to the Coronavirus/COVID-19 pandemic." The mean for this statement was 2.3.

With regards to the set of statements regarding students engagement (Table 2, Statements 7- 16), the statements with the majority of participant agreement are those that indicated a preference for face-to-face classes, with statements 7 and 10 having a mean value of 3.30 and 3.33, respectively. The rest of the student engagement statements (Statements 8, 9, 11-16) all received mean values less than 2.5. Notable was the mean for statement 11, which was 2.07.

The final group of Likert statements was regarding the satisfaction of the participant about the changes to their classes and coursework in the context of the pandemic (Table 3, Statements 17-24). Participants generally agreed with these statements, with not a single statement mean being less than 2.5. Critically, statement 20 and statement 22 received a mean of 2.82, and 2.80 respectively.

The open-ended survey questions were analyzed utilizing trend techniques in order to discover any similarities within the responses. After analyzing this qualitative data, three trends emerged from the responses to the open-ended questions. These trends were the desire for a face-to-face modality, frustration with the precautions put in place for the pandemic, and the importance for quality instructors in light of the modality change.

The desire for face-to-face modality was particularly evident from questions 1 and 3. Participants expressed a strong desire to return to some sort of face-to-face modality, either through traditional face-to-face classes as well as some sort of hybrid classes. Statements from participants include "I feel that I have suffered in learning as a result of being forced to take online classes", and "like saving a seat for a classroom or take it online and live stream the lessons". Also, participants expressed a desire to work within the precautions put in place within the pandemic if it resulted in more face-to-face modality classes. Such desire was expressed with comments such as "all aviation classes back in person, a waiver for illness risk, special care of those who are not baseline low risk".

The frustration with the precautions put in place was evident across all three open-ended questions. Participants were frustrated not only with the types of precautions but also the frequency of requiring them to follow such precautions. Typical statements included things such as "going to campus once a week to get tested is extremely inconvenient. Wearing masks while flying at higher altitudes is uncomfortable and unpleasant", as well as "I'm fed up with the masks and the weekly tests. I feel like the restrictions have degraded the training that I'm paying for, and that's eaten into my motivation and satisfaction with the program".

The final trend that emerged during the analysis of the open-ended questions was the concept of ensuring that instructors were prepared to handle the change in modality. Participants expressed frustration that some of their instructors seemed to not be prepared to handle even the most basic responsibilities with regards to online instruction. One statement in response to question 3 in particular, which was "figure out who's horrible at teaching online and fix it" seemed to encompass the frustration with the instruction. Participants expressed frustration with both the way that instructors embraced the online modality, as well as instructor's ability to function within that modality. In addition, it was also expressed by one participant in response to question 1 that "online classes make for lazy teachers".

Conclusions

While the population of the study was limited to a singular aviation department within the State of Utah, this study revealed that, while participants were satisfied with the changes to modality and precautions in light of the COVID-19 pandemic, they experienced a reduction in engagement to their studies, as well as a desire to return to face-to-face classes. However, participants did express some frustration, both with those precautions, as well as the perceived reduction in the quality of the instruction they received. These trends were developed out of the responses to the open-ended questions, as well as the agreement or disagreement to the Likert statements.

Critically, some of this lack of engagement does indeed seem to stem from the un-preparedness of some instructors to the online modality, whether asynchronous or synchronous types. Instructors need to be better prepared to transition to or fully embrace online modalities while still also having traditional face-to-face class modalities as well. Participants expressed frustration with online classes that seemed to either be too student self-motivated or lacked a perceived instructor presence.

Participants also expressed frustration with the precautions taken in light of the pandemic but seemed to be satisfied with what was implemented. Some frustration could possibly be attributed to "pandemic fatigue" or a reduction in the desire to accomplish preventative measures in the light of the extended timeframe of the pandemic since at the time of the study, it had been exactly one year since precautions were implemented at the university in response to the pandemic (Badre, 2021).

Stories have been published since the Spring of 2020 that report the fact that students are struggling with online classes when they potentially would not have had as much difficulty with face-to-face classes (Hall & Batty, 2020; Richards, 2020; May & Hirschi, 2020). This study, while focused on the response to the COVID-19 pandemic with the sample population from the Aviation Sciences Department at the university, does open some potential areas for improvement and benefits across all of education.

At this time, there continues to exist some uncertainty about the status of the pandemic. It should also be noted that, while the changes made to education systems, both within the sample population and worldwide, were unprecedented, there is now a precedent for future events to cause other drastic changes to education systems. Thus, the focus should be given to increasing training and development of education pedagogy with regards to asynchronous or synchronous distance education.

Finally, the focus should be given to developing more effective plans for any transition to a distance education format within each education institution. With current technology, those situations have the ability to be mitigated to reduce the impact on students' education progress. These plans would hopefully serve to increase student satisfaction perceptions in those changes, as well as mitigate frustration when time-sensitive instruction is interrupted.

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Certificated AMTs: What Will Encourage More Women to Become Aviation Maintenance Technicians?

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This paper examines practices that are used in STEM fields to attract women. According to the FAA, the estimated active mechanic certificates held as of December 31, 2020 was 306,301. Of those 306,301, it is estimated that 7,860, or 2.5%, were held by women. In 2009, there were 329,027 active mechanics certificates held, and 6,980 or 2.1% were held by women. There was a steady growth of certificated women mechanics from 2009 through 2015 – growing from 2.1% to 2.5%, respectively. In 2016, there was a drop to 2.3%. The percentage for 2017 and 18 was 2.4%. In 2019, the number increased from 2.4% to 2.5%, with a slight increase to 2.56% in 2020. With the increased need for AMTs, it is imperative to determine best practices for engaging women in Science, Technology Engineering, Aviation, and Math (STEAM) fields. There is limited data available specific to women in the aviation maintenance fields. What is known is that in 2018, women earned more than half of all bachelor's degrees in science and engineering fields. Women earned 42.3% of bachelor's degrees in mathematics and statistics and 22.2% of bachelor's degrees in engineering in 2018. Conversely, in 2018, the number of certificated women aviation mechanics was 2.4%. What is drawing women to the fields of mathematics, statistics, and engineering? Can those methods be successful in attracting women to the field of aviation maintenance? Examining the tactics used in STEM disciplines may lead to successful practices to increase the number of women AMTs.

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This paper examines practices that are used in STEM fields to attract women to understand how those tactics may entice women to join the ranks of certified AMTs. According to the FAA, the estimated active mechanic certificates held as of December 31, 2018 was 292,002. Of those 292,002, it is estimated that 7,133 or 2.4% were held by women. Comparing the change over time for female AMTs indicates limited growth. In 2009, there were 329,027 active mechanics certificates held, and 6,980 or 2.1% were held by women. There was a steady increase of certificated women mechanics from 2009 through 2015 – growing from 2.1% to 2.5%, respectively. In 2016, there was a drop to 2.3%. For 2017 and 2018, the number remained at 2.4% (Federal Aviation Administration, 2019). In 2019 and 2020, the industry experienced a slight increase in female mechanics with 2.5% in both years (Federal Aviation Administration, 2021). Although the percentage has increased in the past few years, there is an opportunity for further expansion. The industry is experiencing an increased need for AMTs; it is imperative to determine best practices for engaging women in aviation maintenance and Science Technology Engineering Aviation and Math (STEAM) fields.

STEAM is only recently gaining traction as opposed to STEM. There are not much data available that speak specifically to women in the aviation maintenance fields. What is known is that in 2016, women earned more than 40% of bachelor’s degrees in mathematics and statistics and more than 20% of bachelor’s degrees in engineering. Conversely, in 2016, the number of certificated women aviation mechanics was 2.3% (National Center for Science and Engineering Statistics, 2019). In 2018, women earned more than half of all bachelor’s degrees in science and engineering. The number of women that earned a bachelor’s degree in mathematics and statistics was 42.3%, while those earning a bachelor’s degree in engineering was 22.2% (National Center for Science and Engineering Statistics, 2021). At that time, there were 2.4% female certificated AMTs. What is drawing women to the fields of mathematics, statistics, and engineering? Can those practices be successful in attracting women to the field of aviation maintenance? Examining the tactics used in STEM disciplines may lead to successful practice to increase the number of women in AMT’s.

History of Women in STEAM Fields

There have been studies conducted through the years to examine why females do or do not choose to go into or continue through matriculation in STEM fields. There is not much agreement on the why. There is a long-standing precedent for research regarding the lack of diversity in STEAM disciplines. Research has developed many well-meaning but often controversial results. Many of the studies that have been performed are not congruent with the next. As early as 1965, Alice Rossi asked why there were so few female scientists in academic careers when she wrote “Women in science: Why so few?” (Rossi). Now, 56 years later, that same question is still being asked. Is it because males are inherently more intelligent than females? As shared by Sarseke, the study by Smith and Gorard (2011) “did not find any evidence to claim that there was a consistent out-performance of males over females in scientific subjects between 1965 and 2009" (Sarseke, 2017, p. 92). It is not clear if we have made strides in the number of women in STEAM fields or not.

In 2008, the American Association of University Women (AAUW) Educational Foundation released *Where the Girls Are: The Facts about Gender Equity in Education*. The work of the AAUW has provided a comprehensive longitudinal view of girls' educational success in the past 35 years (AAUW Educational Foundation). This report did not specifically examine the educational path or specific degree women seek but looked at the numbers of enrolled students of all ages, racial and ethnic groups, at different milestones. The report showed that the number of female college graduates has increased in recent decades, and "white and Asian American women are overrepresented in college compared to their respective percentages in the general population" (AAUW Educational Foundation, p. 64).

There have been multiple studies in STEM fields which have focused on engineering. Engineering is a field that is traditionally male-dominated. According to the National Center for Science and Engineering Statistics (NCSES), the percentage of women to men in science and engineering occupations is 15.1% to 33.7%, respectively (2019). According to the National Survey of College Graduates, 2019, there are a total of 7,466,000 men and women employed in science and engineering fields. Of those, 29% are female, and 70% are male. The numbers are much more staggering when examining those specifically in engineering, which equate to 16% female and 84% male (NCSES, 2021). These percentages are much higher than the number of women who are certificated AMTs, but the difference still indicates a disparity. Examining the research conducted in the STEM fields may provide more insight.

Within the science and engineering fields, the National Center for Science and Engineering Statistics states that "women were more likely than men to work in an S&E-related occupation" (2019, para. 2). The data indicate the "net result is that female scientists and engineers were more likely than male scientists and engineers to work in a non-S&E occupation (48% versus 42%)" (para. 2). Sarseke (2017) posits:

> Although this research has found various gender differences in many abilities, these studies do not claim that they are key reasons for the shortage of females in science. Instead, most scientists conclude that biology might be a part of the explanation of why women do not aspire to scientific careers. (p. 96)

A study completed for the National Science Foundation (NSF) indicated, "Within the fields of science, technology, engineering, and mathematics (STEM), excluding the social sciences, women only comprised 39% of the bachelor's degrees conferred nationally in 2012" (as cited in Settles et al., 2016, p. 488). A study by Catalyst of women in post-secondary institutions in the U.S. during 2015 and 2016 shows similar results to the NSF study. The Catalyst findings of degrees earned by women in post-secondary institutions indicate women comprised 35.5% of the undergraduate degrees in STEM (Catalyst, 2019).

The under-representation of women in STEM may have a link with biological and social-constructivism theory. Possible factors for the scarcity of women in the sciences, which have been discussed in the work of Sarseke (2017), embrace both the influence of socio-cultural factors and the influence of genetics. The work has highlighted the subject of "gender and science" and has been examined for at least three decades; the results obtained have not changed significantly. There was a positive shift in the number of female students in the professions of mathematics and biology; however, the fields of engineering technologies and physics remained unchanged (Sarseke, p. 96).

In 2013, Jagacinski conducted a study on competence perceptions and achievement goals of women engineering students. A specific area investigated was "the potential indirect sequential effect of gender on grades through perceived ability and then performance-approach goals" (p. 652). The study found "women report lower perceived ability than men which in turn is associated with lower performance-approach goals and ultimately lower grades" (Jagacinski, p. 652). When examining the study by Robnett and Thoman, similar results were indicated, "The self-doubting achievers were lower than men in success expectancies despite statistically equivalent academic performance" (2017, p. 96).

The studies of women and STEM span many decades. Is the difference all gender-related? A study by Settles et al. examined the perceptions and identity interference with undergraduate women, specifically the role of gender identity (Settles, 2016). The results reveal that those students who were further along in their school program felt there was less woman-scientist identity interference experienced than those in earlier stages of their academic careers. Those students that were at a more advanced stage in their studies were more confident about their science performance and reported greater psychological well-being. Seemingly, as women progress in their major, they feel their identities are more compatible with their chosen field.

History of Women in Aviation Maintenance

Women came to the forefront of aviation maintenance during World War II. Women were called to assist in the factories to replace the men that had been sent to war. To encourage women to join the workforce, "Rosie the Riveter" was created. Women took over the positions that men had traditionally held. By 1944, there were more than 3 million women working in the trades and holding union membership. This number represented 22% of all trade union membership in the U.S. at that time (Hawkes, 2020, p. 1). After the men returned from war, the experience for many women changed. Many women went back to being homemakers, but not all. Those who remained employed at the factory in the riveting and manufacturing sector began working side-by-side with men and experienced both gender and racial discrimination.

In the early 1970s, the number of women in the aviation maintenance industry began to increase. This was a time when women began challenging stereotypes and social restrictions on what women could do for a career. This is not including those involved during the war effort – the now-famous "Rosie's." Women were challenging the idea of doing something different. Mary Ann Eiff, maintenance instructor for American Trans Air at the time, stated, "I was a licensed A&P for six years before I ever met another female aircraft mechanic" (Benoff, 2002, p. 67). During this time, there were many who did not feel women belonged in the hangar, wrenching on aircraft. Mary Linhart shared her experience as a business owner with her husband, stating, "It was easier to work as a mechanic myself and cheaper to hire office help than for me to stay in the office and hire a mechanic" (Benoff, p. 66). Linhart went on to add, "I still remember I would have to drop the wrenches and run to the office because several of our customers were 'macho men' who would take their business elsewhere if they found a girl working on their planes" (Benoff, p. 67).

The number of certificated female Aviation Maintenance Technicians (AMTs) has not changed significantly over the years. Per the Federal Aviation Administration (FAA), in 2004, there were a total of 317,111 certificated AMTs. The number of female AMTs was 5,932, which represented 1.87% of all certificated AMTs. In 2015, there was a high of 8,419 or 2.45% of certificated female AMTs. In 2016, that number dropped to 6,536 or 2.33% of all AMTs. In 2017 the numbers began to increase again, and for the data available for 2020, there were 7,860 or 2.56% of female AMTs, the highest reported numbers to date (FAA, 2021). Although the numbers are increasing, the percentage of female AMTs has not changed significantly over the years. Comparing the number of female AMTs to the number of female engineers poses a stark contrast. What is happening in other STEM industries to bring women to the field and, more importantly, to keep them there?

Retaining Women in STEM Fields

Is engineering a male-dominated profession? Author Julie Mills (2010) posits the solution is simple. She proposes gender-inclusive engineering education. She also states that there are very few resources (time or money) dedicated to this (Mills). She pointed out, rightly so, to increase the number of females in the classroom…more females equal more female engineers, but is there more to it?

> The culture of science was evolved largely by able bodied heterosexual white men, and people who do not fit this mold may encounter discrimination ranging from the subtle to the overt: "Outsiders" may not be able to integrate easily with - or may simply dislike - the dominant culture. (Ambrose et al. 1997, as cited in Mills et al., 2010, p. 10)

In reviewing the research of what has and has not worked to retain women in STEM fields, there is a common theme, mentoring. Research indicates positive academic experiences and increased retention for females in STEM-specific majors, more specifically engineering, if they have a mentor. What is a mentor? An article by Hernandez et al. defined a mentor as:

> A mentor is someone who provides guidance, assistance, and encouragement on professional and academic issues. A mentor is more than an academic advisor and is someone you turn to for guidance and assistance beyond selecting classes or meeting academic requirements. (2017, p. 7)

The National Academies of Sciences Engineering and Medicine defines a mentor a bit differently.

> In the realm of science and engineering, we might say that a good mentor seeks to help a student optimize an educational experience, to assist the student's socialization into a disciplinary culture, and to help the student find suitable employment. These obligations can extend well

beyond formal schooling and continue into or through the student's career. (nap.edu, 1997, p. 1-2)

For STEM success and positive experiences that lead to retention of female students in the field of engineering, a mentoring program is the place to start. Early engagement or intervention by female faculty members helps to create a sense of belonging within the scientific community. It must be noted, however, that not all mentoring programs are created equal. It has been posited that receiving encouragement from same-gender mentors and same-gender role models is particularly important for women in STEM (Dennehy & Dasgupta, 2017; Hernandez et al., 2017; Robnett & Thoman, 2017). According to Hernandez et al., “Theory and evidence indicate that female undergraduates with a female faculty mentor report receiving higher levels of mentoring support compared to female undergraduates with a male faculty mentor” (2017, p. 3).

A 2017 study by Dennehy and Dasgupta focused on peer mentoring between advanced students and first-year students and the long-term effects of having a peer mentor. Throughout the year-long study, the mentor-mentee met once per month. There appeared to be no difference in how mentors perceived their quality or quantity of interactions with mentees. There was no difference noted in the connection that the mentees perceived of the mentor support. For women with female versus male mentors, the only significant mediator to emerge was social belonging. Women who were paired with male mentors in the first year showed a “consistent decline in belonging” (Dennehy & Dasgupta, 2017, p. 5967). The results indicated that 100% of women with female mentors remained in engineering majors, as compared to 82% with male mentors and 89% with no mentor (p. 5966). In examining the post-degree aspirations of those in the study, “those with female mentors maintained consistent intentions to pursue advanced degrees in engineering over time” (p. 5966).

Peer mentoring is an important key to the success and retention of females in STEM fields. Social support and social integration equate to more positive academic outcomes for those who are underrepresented in STEM fields (Estrada et al., 2011; Hernandez et al., 2017; Hughes & Chen, 2011; Robnett & Thoman, 2017). Robnett and Thoman posit that universities may benefit by establishing a peer mentoring program that will allow connections between self-doubting achievers and confident high achievers in the STEM fields with the thought that shared academic achievement will leverage complementary success expectancies of the self-doubting achievers (2017, p. 98). Interventions that foster social belongingness may contribute to STEM identity among women who doubt their abilities to succeed.

In 2018, Mullen and Baker completed *Gender Gaps in Undergraduates Field of Study: Do College Characteristics Matter?* and concluded institutions with tenured female faculty members might positively influence the institution in ways that shape the educational setting and “directly or indirectly” support women in non-traditional majors, including the establishment of “mentorship programs within male-dominated fields such as engineering” (p. 9). The Association for Middle Level Education (AMLE) has asserted that middle school girls thrive and find success when they have an advocate or mentor to support them (Hayes, 2018). In addition to traditional faculty members, it has also been noted that female students gain valuable experience by visiting their role models and mentors in the workplace. A female mentor that also works within the industry has a positive impact on female students. It is important that women “see female role models in the workplace that look like them” (Hayes, p. 27).

Other than most of these studies being conducted within the realm of engineering education, the findings could apply to any occupation or field of study that is thought of as gender-based, regardless of gender. There are indications that the institution plays a pivotal role in the success of the female student in non-traditional majors (Estrada et al., 2011; Hayes, 2018; Hernandez et al., 2017; Mullen & Baker, 2018; Robnett & Thoman, 2017). Student success in engineering has been evident with those engaged in a mentoring relationship.

Conclusion

In Conclusion, it has been shown that there are not as many females in the STEAM fields as there are males. Studies on gender-based STEM involvement are not new, have spanned decades, and do not agree on the causal factors that are holding women back from these fields. There are a few consistencies within the studies. It is evident that men are not inherently smarter than women. Men and women have certain traits that may afford a separate subset of skills, but those skills are not mutually exclusive. Females thrive when they experience support within their field of study from the early days of college. Connecting with a mentor in the field of study the female student has chosen has shown time and time again to have a positive and lasting effect on the student. All mentors are not the same. Peer support of the same gender appears to have the largest benefit and positive outcome for the student.

As far back as the 1940s, women have been stereotyped into roles such as homemaker, teacher, seamstress, and others. During World War II, it was demonstrated that women have the skills necessary for manufacturing, physical labor, and doing what is necessary to get the job done in the role of “Rosie.” Although the world has evolved, there is still stigma attached to the male and female-dominated roles. Having a mentor will assist those that enjoy and are excited by taking things apart and putting them back together, figuring out why something electrical is not working the way it is expected, watching that aircraft soar into the sky for its first test flight after an avionics upgrade, and to realize their gender is not a reason to not pursue a dream.

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Creating More Engaging Course Lectures

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Modern students expect a lot out of their college experience. With increasing economic uncertainly, they are also evaluating the value that a college education can provide beyond many of the free, professional-quality resources available across the internet. This means post-secondary educators need to adapt to the learning expectations of their students and create more engaging course presentations that can capture and retain their students' attention. Common lecture formats remain effective in efficiently presenting new ideas and concepts to large groups, but visual aids used alongside a lecture are usually uninspiring. Even worse, the design of many PowerPoint slide decks used during a lecture can cause cognitive overloading, sensory conflict and hinder effective communication. In this paper, I will discuss how to make PowerPoint presentations more visually appealing and more effective when used in a classroom lecture. Additionally, I will discuss the techniques and tools available when developing an effective PowerPoint presentation.

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Modern learners have come to expect a lot out of their educational experiences. The age range of traditional post-secondary students, from freshman through senior, places them in "Generation Z." This generation has lived their entire life in a connected society with access to high-speed internet and mobile devices, putting them on a "track to be the best-educated generation yet" (Parker & Igielnik, 2020). This ease of access also introduces a competition to attract and retain their attention during traditional classroom experiences. Cell phones, tablets, and laptop computers are an inviting distraction, and professional quality online content offers a compelling substitute for traditional education techniques. Additionally, early data showed Generation Z was hit particularly hard due to the COVID-19 pandemic through job losses and pay cuts (Parker & Igielnik, 2020). This may lead many Gen Zers to re-evaluate the value of higher education weighed against the benefits of taking more expeditious routes into the job market. Modern educators must adapt to the expectations of this generation and modify teaching styles to keep students interested in and continue to provide value to traditional classroom experiences.

This paper will explore methods that can be implemented by course instructors to develop more engaging and effective presentations. Throughout this paper, when specific instructions are given, it is specific to Microsoft PowerPoint. Similar functionality may be available in other software but is not discussed in this paper. Suggestions are also provided for software or content sources, but I have no affiliation with any of the listed companies. They are simply the resources I have used and am familiar with personally.

Visualizing a New Teaching Style

The teaching technique used in most collegiate courses continues to be the lecture method. This is largely due to its effectiveness in conveying new information to large groups in a time-efficient manner (U.S. Department of Transportation, Federal Aviation Administration, 2020). A commonly used visual aid accompanying a classroom lecture is a "slide deck" given through either Microsoft PowerPoint, Apple Keynote, or other similar software. However, these visual aids are commonly developed in a way that is contrary to effective human communication techniques. The root of the problem can be tied to limited instructor training for visual aid creation but also in the displayed guidance given to course developers when building out new slide decks. As an example, try building out a new presentation in PowerPoint, and the placeholder text of any new slide instructs you to "Click to add text." This instruction is usually taken literally, resulting in numerous bullet points, full sentences, or even paragraphs being added and presented to a learner during the lesson.

Why this method is not effective in communicating with a learner relates back to the basic elements of communication as outlined in the Aviation Instructor's Handbook (U.S. Department of Transportation, Federal Aviation Administration, 2020). All communication (including classroom lectures) involves three distinct elements: the source, the symbol, and the receiver. In classroom settings, the "source" is the teacher/lecturer/instructor/professor, and the "receiver" is the student/learner. The "symbol" is the bridge that connects the source to the receiver and includes anything that is used to convey the ideas of the lesson, like language, images, text, mock-ups, or physical items the learner can examine and manipulate.

The symbols used in communication are further divided down into one of three channels, representing how the receiver processes them: visual, auditory, and kinesthetic (U.S. Department of Transportation, Federal Aviation Administration, 2020). The overall learning process can be improved when more than one channel is engaged. For example, verbally presenting a lecture while displaying an image of the topic being discussed engages both the auditory and visual channels, leading to better retention than if only one of the methods was used. However, care must be taken not to overlap multiple symbols through the same channel. This concept has been explored by Chandler and Sweller (1991), with their research indicating instruction was hindered when learners were required to "integrate disparate sources of mutually referring information" (Chandler & Sweller, 1991).

As an example, figure 1 shows a sample slide from my own PowerPoint slide deck discussing airspace, which was presented to a private pilot ground school course. During the course lecture, this slide would be displayed via projector while I spoke to each bullet point regarding class A airspace, adding additional information and context as required.

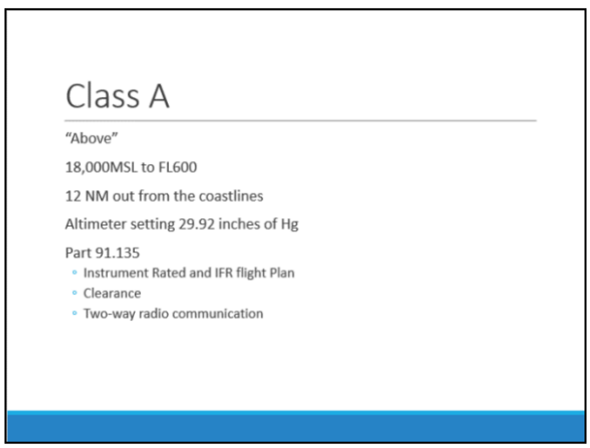

Figure 1. Sample lecture slide for class A airspace

One may assume that this lecture format is adhering to the multiple-channel concept discussed above: the visual channel is being engaged via the PowerPoint slide, while the auditory channel is being engaged via my explanation. In reality, this setup has forced an overlap and confliction of the auditory channel. At a foundational level, it is true that the student "views" the slide, thereby experiencing it through the visual channel. However, the true content of the slide (the textual descriptions of class A airspace) is processed in the brain through the auditory channel as the text is "read" internally by the learner.

To demonstrate this concept, figure 2 provides a sample training slide for a topic outside the familiar aviation domain: woodworking. By using non-aviation content, I hope to remove any previous knowledge and bias in the example. In this slide, the elements of a common woodworking joint known as a bridle joint are discussed. Imagine trying to read through the content of this slide while a presenter talks over the top of it, verbalizing the basic description and presenting additional details as necessary. If that's difficult to imagine, you can also simulate this by trying to read through the slide while listening to your favorite podcast instead. This example represents the presentation technique used in many lecture environments.

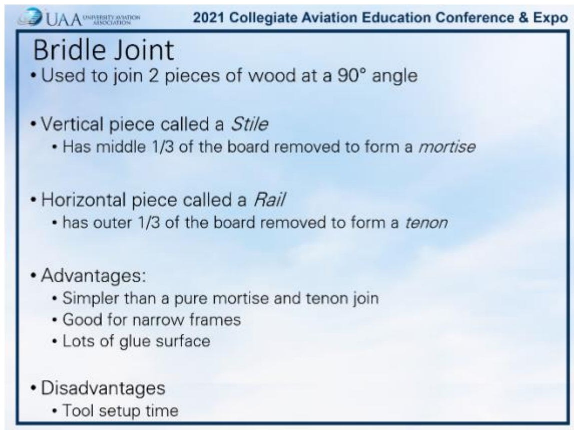

Figure 2. Bridle joint training example

In the above example, would it have been difficult to focus on reading and listening to a presenter at the same time? Which symbol would you have ignored in favor of the other? If a learner chooses to ignore the slides and focus on the verbal message from the presenter, the time spent developing the visual aid was time wasted. Instead, if a learner chooses to ignore the presenter and read the contents of the slide, then the presenter has made themselves obsolete, and the student can learn simply by reading content on their own. Instructor obsolescence is also a major problem if the presenter chooses to read the slides word for word; they are not providing any additional value to the presentation. If the above demonstration was difficult to fully simulate, the same results could be achieved by attempting to read a newspaper while listening to a podcast or listening to a spouse while reading an email. In these examples, one or both tasks will suffer because they overlap through the auditory channel.

So how can traditional lecture presentations be enhanced to take advantage of multi-channel processing and avoid overlapping content through a single channel? At a basic level, avoid the temptation presented by PowerPoint to "Click to add text." Rather than conveying information through textual bullet points on a slide, represent concepts through simple images or diagrams instead, and provide a more specific description through a verbal lecture. Utilization of this technique has been shown to improve learner interest in the lesson as well as information retention (Napper, 2014).

To illustrate this concept back in the aviation domain, figures 3 and 4 depict other sample slides from my ground school courses related to motion sickness symptoms (figure 3) and methods to overcome them (figure 4). The "before" image on the left is how the slides were presented for numerous semesters, while the "after" image on the right is how they are currently presented to students.

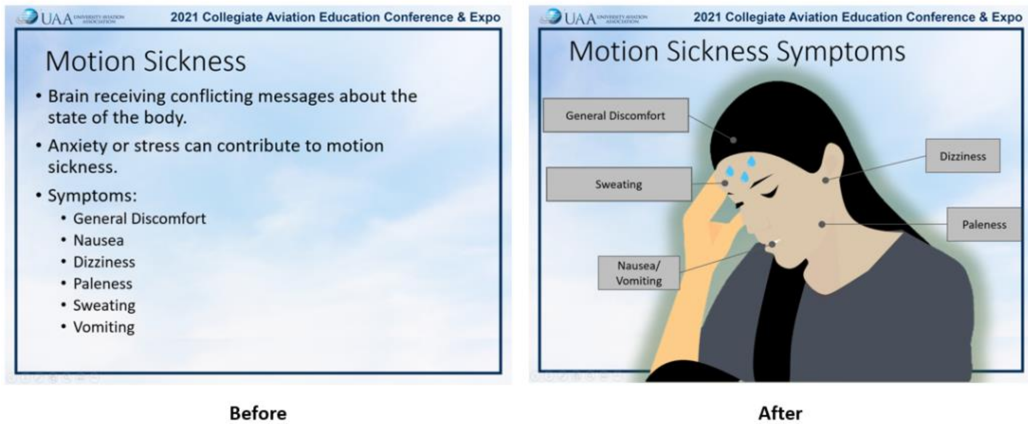

Figure 3. Before and after of a motion sickness symptom slide (Pinclipart, 2019)

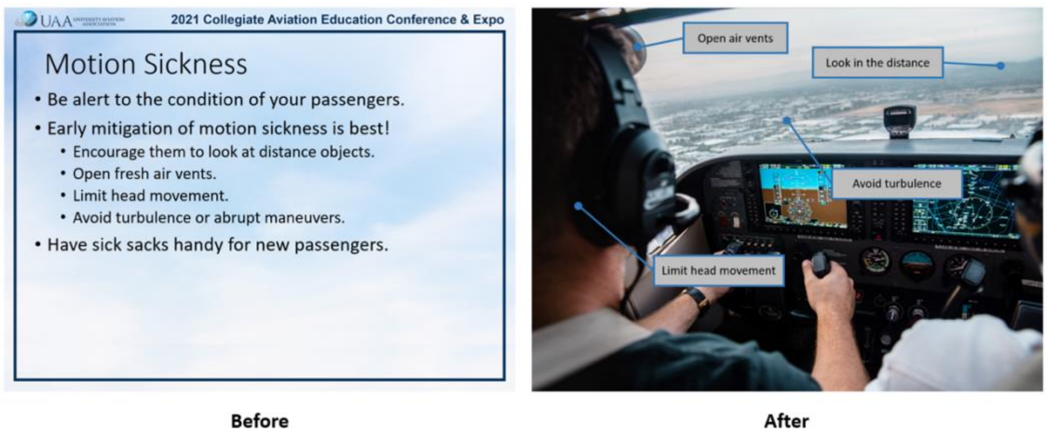

Figure 4. Before and after of a slide to illustrate methods of overcoming motion sickness (Allison, 2017)

While the text is still presented in the slides, it's significantly less than the "before" example, allowing learners to quickly read the labels and return to focusing on the content I provide verbally. Additional PowerPoint animation functionality is also utilized in the presentation to display and hide each label individually, allowing me to focus the learner's attention on one element at a time while it's being discussed. Specific guidance for creating these PowerPoint animations would not be conveyed well in this paper, but an excellent resource is the Bright Carbon YouTube channel, found at www.youtube.com/c/Brightcarbon.

Occasionally, bullet points must be used as the best way to present information to a learner. In these instances, PowerPoint animations can also be utilized to present each bullet one at a time. This helps to retain the learner's focus and prevents them from moving ahead with the content before you are ready to discuss it. However, generally with animations, subtle is more effective than exciting. Text that flies in or spins into place can be distracting and detract from the professionalism of the presentation. I personally prefer a simple "fade in" and "fade out" animation in almost all instances.

Speaker Notes and Note Pages

Arguments in favor of text-heavy presentations can still be made from both an instructor and student perspective. In my own experience lecturing, displaying text-heavy PowerPoint presentations served as presentation notes for what needed to be discussed during the lesson. From a learner's perspective, text-heavy slides, especially those provided digitally for use outside of class, serve as a study tool to later review the concepts discussed during the lesson. Thankfully, these advantages of text-heavy presentations can be retained while still visually presenting lesson concepts as discussed above.

When developing your presentation, rather than placing the key points of the topic textually in the slide itself, they should instead be added to the “Speaker Notes” section. This section is commonly found just below the slide image, but if not, clicking the “Notes” button on the bottom toolbar or in the “View” ribbon menu will make it visible. Any text entered here is not displayed to a learner during a slideshow presentation. However, it can be set to display for the instructor when presenting. This is done by selecting the “Use Presenter View” option on the “Slide Show” ribbon menu.

The speaker notes can also be provided to students for later review through the creation of a note page. To access the note page, select the “View” ribbon menu, and in the upper left corner, select “Notes Page.” The default layout for the notes page is a visual depiction of the slide on the top half, with the speaker notes presented below. These pages can be customized and even branded for the institution or course, then provided to students digitally or via physical copies. Once again, specific instructions to do this are best suited for online video tutorials, and numerous offerings are available online, including a well-done presentation on Bright Carbon’s YouTube channel (www.youtube.com/c/Brightcarbon).

A debate can also be had about whether the note pages should be provided prior to a lesson to help a student take notes or at the conclusion of a lesson as a means of lesson review. Advantages and disadvantages exist for both methods, so instructors should determine which works best for the instructional style of the class.

Finding and Capturing Images

Once a commitment has been made to depict lesson concepts visually rather than textually, the hard work of finding effective images begins. A common source for many instructors is through image search functions of internet search engines like Google or Bing. The legal requirements surrounding copyright and fair use won’t be discussed in this paper, but care should be taken regarding the source of images retrieved via online sources.

For open-source, professional-quality photos provided under creative commons licenses, www.pexels.com, www.pixabay.com, www.unsplash.com, and commons.wikimedia.org are all great resources. For drawings, cartoons, and other miscellaneous images in PNG formats, options include www.pngtree.com and www.favpng.com. These websites offer many free images, with additional paid tiers and unlimited downloads for a small fee. Finally, www.thenounproject.com offers millions of icons to visualize just about any word or concept. This site also contains many free options in addition to paid offerings.

In the aviation domain, there's also access to hundreds of high-quality images available, copyright-free, through familiar FAA handbooks like the Pilot's Handbook of Aeronautical Knowledge, Airplane Flying Handbook, and others. Lesser-known handbooks, especially useful for those teaching aircraft systems, are the Aviation Maintenance Technician Handbooks. This series of handbooks has images for just about any system or component found on an airplane. A full list of current FAA handbooks can be found at https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/.

When utilizing images from FAA handbooks, an additional step of copying, cropping, and pasting the image into a PowerPoint slide is required. Thankfully, both Microsoft Windows and macOS have built-in functionality to achieve this. Windows users can utilize the Snip and Sketch program, which can capture a selected region of the screen and automatically place it on the Windows clipboard. The "Print Screen" key can even be tied to activate the screen snipping tool for quick and easy access. Instructions to do so can be found at https://pureinfotech.com/set-print-screen-key-screenshot-screen-sketch-windows-10/. For macOS users, built-in key commands give the ability to capture an entire screen, a selected window, or a portion of the screen. Instructions can be found at https://support.apple.com/en-us/HT201361.

The screen snipping options above have the benefit of being free but offer the only limited capability for artistic edits and mark-ups to the captured images. For more robust editing capabilities, TechSmith offers SnagIt with more screen capture options and a more powerful image editing interface, although it does require the purchase of a software license. A similarly capable open-source offering is provided by greenshot.org. Both options are available on Windows and macOS.

Optimizing Images

Even perfectly selected images can sometimes be overwhelming to a learner or simply look out of place on a PowerPoint slide. For example, figure 5 depicts an improved bridle joint training slide from the example presented earlier, but there's still room for improvement. First, the image includes several mark-ups and text callouts that may pull the learner's attention away from the instructor. This may be great for circumstances where the learner is expected to explore concepts on their own, but not in a format where the instructor is attempting to add value to the presentation and direct the learner's focus on key elements. Another minor issue with the image is the white background, especially when inserted over a non-white slide background. This tends to make the image look out of place and pasted into the presentation quickly.

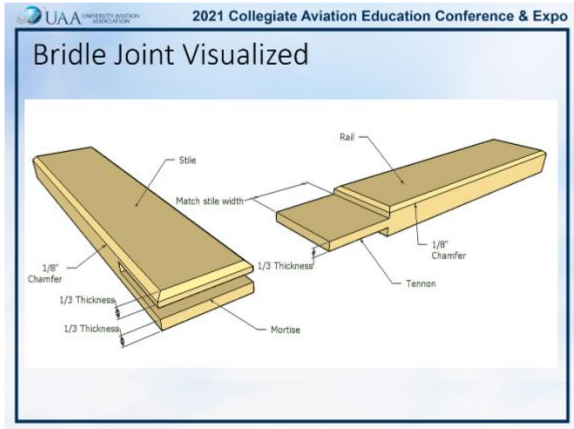

Figure 5. Bridle Joint visualized with text labels

Figure 6 shows an even more simplified depiction of the bridle joint as an improvement from figure 5. First, the image was simplified to remove the text mark-ups and callouts. An instructor could choose to discuss elements verbally or add their own animated PowerPoint callouts instead. Second, the white background of the image has been removed, giving a slightly more professional appearance as though the elements are integrated into the slide itself. Finally, a faint shadow has been added to the image to give more depth to the visual.

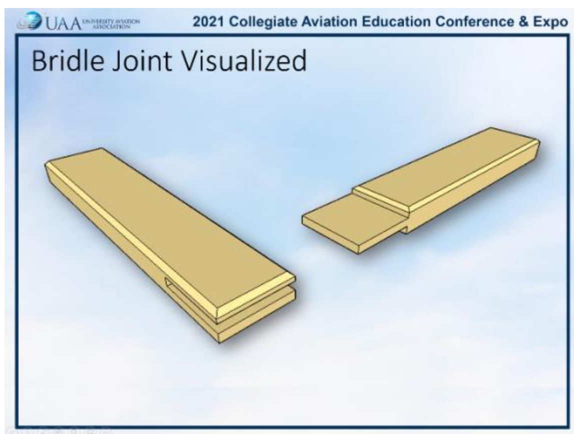

Figure 6. Improved bridle joint visualization without text labels

Depending on the quality of the image, removing the background from images can be a relatively easy task using built-in PowerPoint tools. The easiest method to attempt first is the "set transparent color" tool. This works especially well for high-quality images where the background is a consistent shade. If that method doesn't work, the "Remove Background" tool allows for specific adjustments to what should be retained or removed from the image. Numerous step-by-step tutorials for either of these tools can be found online by searching "PowerPoint set transparent color" or "PowerPoint remove image background." If a lower quality image is used, these two methods may not yield acceptable results, and a photo frame effect from the "Picture Format" ribbon menu can be utilized to add some visual interest instead.

Editing FAA Images

As discussed above, FAA handbooks contain hundreds of high-quality images, all copyright-free. But in many cases, they can still be cluttered with excessive text labels and callouts that detract from the lesson presenter. Thankfully, the PDF versions of most FAA handbooks allow course designers to edit the images and remove unwanted elements. For an example of this technique, the left-hand image of figure 7 shows a diagram of a carburetor from the Pilot's Handbook of Aeronautical Knowledge (U.S. Department of Transportation, Federal Aviation Administration., 2016). The graphical representation of the carburetor is desired, but the numerous callout boxes and textual descriptions are overwhelming and distracting. In the right-hand image, the image in the PDF file has been edited to remove these elements, and the carburetor diagram has been captured via the screenshot techniques described above. Simplified PowerPoint callouts and animations can then be used to focus the learner's attention as the lecture progresses. This example is interesting because it closely mimics experiments done by Chandler and Sweller (1991), which demonstrated learners presented with simplified diagrams required less time to learn the material and scored higher on follow-up evaluations.

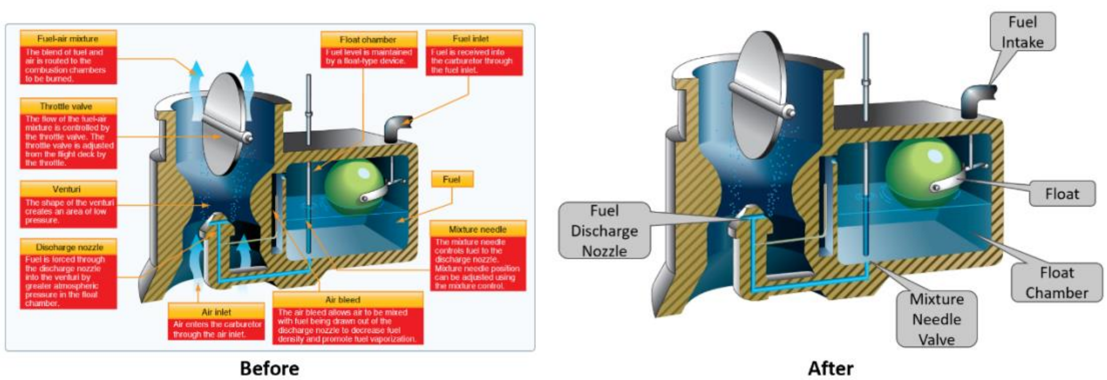

Figure 7. Carburetor diagram before and after. (U.S. Department of Transportation, Federal Aviation Administration., 2016)

This technique is possible if you have an Adobe Acrobat DC software license, which does require a paid subscription. The free version of Adobe Reader will *not* support this functionality. To begin, open the FAA handbook in Adobe Acrobat, find the desired image, then select the "Edit PDF" option. This tool can be found either under a "Tools" tab at the top of the window or in the tools pane on the right side of the window. Once selected, all drawing and text elements in the PDF become editable, allowing them to be adjusted, changed, moved, or deleted from the document entirely (figure 8).

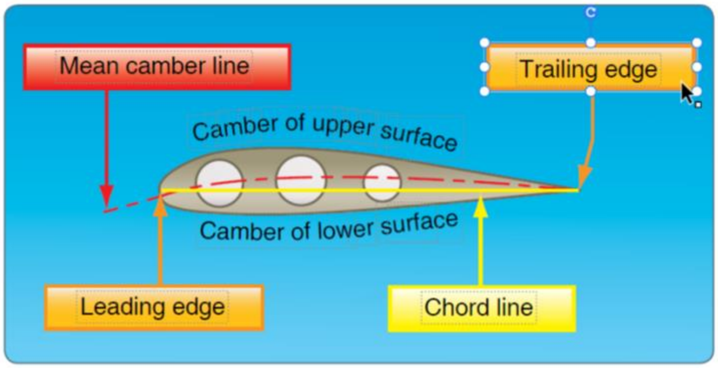

Figure 8. Editing FAA image in Adobe Acrobat. (U.S. Department of Transportation, Federal Aviation Administration., 2016)

Once the edits are complete, selecting “Close” in the upper right-hand corner closes the edit tool, and a screenshot of the modified image can be captured.

An added benefit of the edit tool is that it allows instructors to pare down FAA readings to focus a learners’ effort outside the classroom. For example, on a lesson regarding ATC clearances for IFR operations, you may wish to assign reading from the “Clearances” Section on pages 10-3 through 10-5 of the Instrument Flying Handbook (U.S. Department of Transportation, 2012). Instead of conveying that and hoping the learner selects the appropriate section, the handbook can be edited to extract the desired pages and remove the sections that do not apply. The resulting PDF file can then be uploaded to a learning management system for the student to review.

Conclusion

Some of the methods discussed in this paper describe a simple yet effective way of incorporating more engaging and visually appealing content into traditional PowerPoint presentations. Yet others admittedly require a more substantial investment in time and creativity to implement effectively but can yield greater results in learner engagement and content retention (Napper, 2014). Another element not discussed in this paper is the creative difficulty in finding ways to represent concepts visually (Napper, 2014), which was a significant personal hurdle when implementing these methods. As with many things in life, I suggest starting your own personal course conversion in small steps. In my own experience, starting out with the intention of re-inventing all course material at once is an overwhelming and impossible endeavor, so focus on small implementations where you can. If you come across one or two slides per presentation that you can easily update to an image-based depiction, start there. Over time, you will become more comfortable with the tools and methods, resulting in a reduced time commitment. You may also find your personal creativity grow with more practice, making those more difficult visual representations easier to achieve.

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Aviation English in a Bilingual Context

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With over one thousand fatalities attributed to language errors within the field of aviation, pilots' level of self-efficacy in English, the official language of aviation, relates directly to their level of comfort in the cockpit and ability to perform their flight duties safely. There are international standards that evaluate a pilot's ability to read, speak, write, and understand English before a pilot is permitted to test for his or her license. However, issues still arise and can be attributed to a pilot speaking limited English register of aviation English. This study investigates the use of English and Spanish in the applied context of aviation by researching bilingual cockpit interactions. Data pooled from a survey of pilots who speak Spanish as a native language were used to recognize patterns between language acquisition and proficiency within the cockpit as well as understand the frequency with which pilots hear their native language over the radio. The primary research question attempted to evaluate pilots' comfort level in professional aviation situations that involved the use of non-native language. Additional research questions investigated how bilingual pilots react linguistically to emergency situations and how this affects their abilities to perform flight duties. Understanding pilots´ in-flight experiences in relation to language proficiency may contribute to a proactive safety culture by providing recommendations that could help prevent future accidents.

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With the advent of global aviation and worldwide involvement in the rapidly expanding industry of aviation, effective collaboration necessitates standards be set in place that regulates the industry's operating procedures. As early as the Chicago Conference and the founding of the International Civil Aviation Organization (ICAO), English was determined to be utilized as the "de facto" language of aviation, and this has since been the standard upon which all further regulations have been built. Standard phraseology has been established, using the English language, that creates an Aviation English register, or language used for a specific purpose, and in this case, within a specific professional context. Each pilot is expected to learn to operate using this register for all radiotelephony communications, which can pose a challenge, especially for pilots who do not speak English as a native language. Although flying the aircraft itself is a pilot's first priority, when they are taught to "aviate, navigate, communicate," communication plays a critical role in safe operations and involves a human factor that can be trained and therefore has the potential for improvement to increase overall safety in aviation. Despite standards and requirements for compliance being set in place, communication continues to be a threat to aviation safety (Fowler et al., 2021).

Purpose

This research focuses on pilots' levels of self-efficacy in the cockpit, in various flight scenarios, when asked to rate their comfort level using and performing in English, a language that, for the group under study, is not their native language. By evaluating differing levels of English proficiency and corresponding proficiencies in performing cockpit operations, this research analyzes different language decisions by pilots whose native language is not English. The research aims to provide information as to where potential latencies in pilot language training exist and aims to offer concrete suggestions to improve the current situation.

Research Questions

1. *How does exposure to the English language influence pilots' levels of self-efficacy of Aviation English proficiency in the cockpit?*
2. *With what frequency are pilots exposed to their native language while performing aviation duties, and what effect does this have on their ability to perform their duties*
3. *What is the preferred language (the official aviation language, which is English or another language) for bilingual (or multilingual) pilots for processing a situation and performing their piloting tasks during an emergency, and how does this affect their ability to perform related tasks?*

Literature Review

Aviation English

ICAO's language standards divide English proficiency into six categories, with the requirement to test to at least a level 4. Having tested at this level of proficiency indicates that the individual should have a pronunciation that only sometimes interferes with understanding, has well-controlled grammar, with errors only occurring in unexpected situations, and has the vocabulary necessary to effectively communicate in the register required. These categories are based on linguistic aspects such as Pronunciation, Structure, Vocabulary, Fluency, Comprehension, and Interactions. The standard aviation phraseology that all of this is based on includes about 400 words (Friginal et al. 2020). Although understanding may be slower when situations occur outside of the standard phraseology, the pilot is expected to be proficient with the language in a way that has been determined not to interfere with flight safety. Even ICAO acknowledges, however, that "no set of standardized phraseologies can fully describe all possible circumstances and responses" (ICAO 2010).

Accidents Relating to Aviation English

There have been over 1,000 fatalities attributed to language errors within the field of aviation; this loss of life has at least partially been attributed to human factors caused in part by a lack of proficiency in English or by miscommunications due to cross-cultural communication breakdowns (Friginal et al., 2020). Accidents occurring that can be attributed, at least in part, to language issues necessitate the creation of additional standardized practices to mitigate the risk of complicating human communication factors in aviation. One accident that was affected by language barriers was that of Avianca Flight 052. This flight is considered to represent a lack of proficiency in Standard Aviation Phraseology. In this case, native-speaking Spanish crew members were coming in to land at JFK during a storm in 1990, where traffic was heavy because ATC was attempting to land planes as quickly as possible. The Avianca aircraft had minimum fuel and failed to convey this appropriately to ATC. They never declared an emergency as they should have but rather simply requested priority. When the plane had to go around, the plane was completely depleted of fuel and crashed, even though the crew members had communicated with each other, in Spanish, about the low fuel and were aware of the issue. The Captain in this situation seemed completely reliant on the First Officer's English communications, but even though the FO was communicating with ATC, he never actually conveyed how dire their condition really was (Friginal et al., 2020).

The Cali, Colombia accident, in 1995, which involved a Boeing 757 with a native English-speaking crew and a native Spanish-speaking controller resulted in the death of 160 people. Such accidents have prompted the need to evaluate how communication breakdowns contribute to unfortunate situations that can end in incidents or accidents. Although the most known cause of the accident was faulty navigation, unclear communication could possibly have prevented the severity of the situation. The ATC on duty at the time later reported that if the crew had been native Spanish speaking, he would have informed them that their transmissions regarding their navigation did not make sense. He admitted that his limited command of English prevented him from increasing the crew's situational awareness in a scenario where clear communication could have saved their lives, along with the lives of the other people (Ladkin 1996). This situation reflects the usefulness of plain-language English, especially in emergency scenarios; the limited standard aviation phraseology that the ATC was trained in was not enough to communicate the situation the pilots were in or to understand why their navigational requests did not make sense (Friginal et al., 2020).

Language Processing in Non-Native Speakers

There are many factors surrounding pilots' acquisition of their non-native language of English that can relate to proficiencies in the cockpit and must be taken into consideration when assessing a non-native English speaker's ability to respond to flight scenarios in English safely. The age for the onset of bilingualism and the context in which they learned the language each contribute as factors in this process. In order to improve training practices, it is also crucial to understand the intricacies of how non-native English speaking pilots process language while performing aviation tasks; this aids in understanding best practices in teaching and learning the aviation register, as well as any other necessary language, to contribute to a safer flight environment. By evaluating cockpit interaction, and cockpit conversations, of pilots who speak a native language other than English, conclusions can be drawn regarding a pilot's comfort level using their non-native language to perform tasks in different flight scenarios.

Methodology

The research study was conducted in two stages, namely the primary stage and the secondary stage. During the primary stage, two research questions were addressed, while the secondary research stage explored an additional research question. After each survey was developed to address the respective research questions, they were distributed to various individuals to receive feedback and suggestions for improvement. The primary research survey tool was evaluated by several pilots, ranging from 3-10 years of experience in aviation. Since this survey was also distributed with the ability to complete the questions in Spanish, the Spanish version was edited and improved by a professor with a Ph.D. in Second Language Acquisition and Teaching, with a specialization in Spanish sociolinguistics, as well as a native Spanish speaker. This survey was distributed through a snowball method of recruitment, with the primary researcher contacting several pilots through various methods and asking that the survey be distributed to other pilots who fit the participant pool criteria.

The primary stage of the research focused on pilots who speak a native language other than English. For this study, it was the Spanish language. The research questions attempted to measure how pilots' levels of self-efficacy in the English language correlate to their overall proficiency in the cockpit. In addition, in order to understand more about the flight environment from a bilingual perspective, the research questions examined the frequency with which participants heard their native language in the cockpit. To that end, the following variables were studied: *pilots' English language proficiency in the cockpit* and *English language exposure*. The data collection instrument for the primary research consisted of a 44-question survey which utilizes both the Likert scale and other categorical responses. The survey instrument utilized six-point Likert scale questions to evaluate how comfortable pilots felt in different flight scenarios; these questions aimed to rate pilots' own levels of self-efficacy on their comfort level performing tasks in their non-native language of English. Additional Likert-scale and categorical questions examined the frequency with which pilots were exposed to their native language over the radio and on the ground, as well as inquiring about experiences they have had flying with people who speak a native language that is different from their own. The study assumed pilots were already proficient in the Spanish language as native speakers; the survey questions focused on their overall experience with English. Out of the 44 questions that made up the first survey instrument, 12 questions were related to the demographics of the participants. These demographic questions directly assessed each participant's language experience as well as aviation background to allow for a comparison of language acquisition to presumed flight proficiency. Using this survey and the variables mentioned earlier, the research allowed for an examination of the relationship between English language exposure and Aviation English proficiency to evaluate plain-language English exposure's relation to Aviation language proficiency. In addition, questions addressed pilots' exposure to their native language while performing flight duties and their corresponding comfort level with performing flight tasks in English, and their language of choice compared to their flight proficiency. The survey was distributed to the participants through a link generated by the Qualtrics software; the participants were given an opportunity to respond between February 16, 2021, and March 28, 2021.

The secondary research went more in-depth to examine what bilingual pilots' preferred language is inside the cockpit and whether the language they choose to use affects their ability to perform flight tasks. To better understand the role of English proficiency in aviation accidents, the study examined how multilingual pilots react linguistically, especially in emergency or high-stress scenarios. The goal was to further evaluate the *pilot's level of comfort* in these scenarios and see how their *preferred language choice* affected their *ability to perform in the cockpit*. A survey was developed that took information learned from other Spanish-English research and investigated deeper into which language pilots think in and how this affects their self-efficacy when performing tasks in the cockpit. As such, this second stage of research sought to evaluate which is the preferred language of pilots when processing a situation and performing their piloting tasks during an emergency, as well as how the language they instinctively use affects their ability to perform. The intent was to evaluate whether pilots would prefer to use English, the official language of aviation, or their native language, in which they may feel more comfortable. The survey instrument consisted of 34 questions; 10 questions were demographic ones. Like the primary stage survey instrument, the participants were provided with a link to the survey. The survey was administered through the Qualtrics software; the participants were provided with a time window between July 26 and October 24, 2021, to complete the survey.

An interactive survey was developed that asked aviation students to respond to a pre-recorded Air Traffic Control audio prompt which simulated actual flight scenarios, then evaluate their linguistic processing and level of comfort responding to the scenario. Each of the ten scenarios represented different phases of flight as well as flight conditions. The audio prompts also established differing intensities, based upon whether the situation was a standard situation that happens regularly during flights or if the prompt was asking the student to respond to an irregularly occurring experience, such as a bird strike. Each of the prompts was recorded by a former Air Traffic Controller and utilized standard aviation phraseology. Below is a sample of the audio prompt which the participants were asked to listen to:

Air Traffic Control Audio: *November 123 Alpha Bravo Kennedy Tower. Wind 180 at 5, runway 22 left, cleared to land. Caution wake turbulence, 5 and a half miles in trail of a heavy Airbus A350.*

Participation was requested from aviation students that attend two different university flight departments, a public, mid-sized institution in the Midwest and a private university in the Southern United States. Participants were typically at the beginning of their aviation training and provided insight into how they establish a basis for developing their English skills inside the cockpit. These students represent a group that is at a critical level to benefit from strategic English language education. Demographic questions gauged where participants were in their flight training, as well as experiences they had with each language. Data for these surveys were based on pilots' own ratings of themselves. Similar to the primary research, the survey for the secondary research was evaluated and improved by a former Air Traffic Controller with over eight years of experience, who now works for the FAA. Survey questions were also reviewed by multiple pilots, ranging from 10-21 years of experience in the field. Since this research focused on collegiate flight program students, it was distributed through university emails and professors, requesting participation from flight students who met the criteria of speaking a native language other than English.

Analyzing data for the purpose of this research involved a focus on those who were least comfortable and assessing how their language acquisition or language processing differed from those who felt they were more comfortable. Based on the small data pool, this analysis focused on descriptive statistics and measures of frequency to determine the percentage of participants that responded similarly to each prompt. Analysis of the data involved the use of non-Parametrics statistical tests and comparisons of qualitative data based upon the self-efficacy and levels of experience of the respondents.

Results

Demographic Analysis

Twenty-three (n=23) participants gave their consent to participate in the primary part of the research study. Participants for initial research included pilots from several countries, including Chile, Colombia, Costa Rica, Ecuador, France, Mexico, and the United States, with several from Puerto Rico. Their exposure to English, the number of years they have spoken English relative to their age, as well as their purpose and methods for learning the language all varied between participants. 48% of the participants had aviation experience in the airlines, but the pilots ranged from types of aviation such as the military, general aviation, flight instructors, cargo transport, passenger charters, or others. While a larger number of participants were skewed to a lower end of flight hours and years of experience, there were several with over 10,000 flight hours, and 50+ years of experience, with many in the middle of these two extremes as well. The average age of the participants was 40 years. Regarding the reliability of the survey scale items, a Cronbach's alpha (α) value of 0.7 or higher was selected for this study. The SPSS software was used to determine the reliability of the scale items. The reliability was found to be (α = 0.67 for 4 items) for language proficiency and (α = 0.97 for 2 items) for language exposure. For the second stage of the research, nine (n=9) participants agreed to participate in the study. For the questions that tested the ability of the participants in processing the given flight situations, the Cronbach's alpha (α) value was found to be 0.897. Participants were all attending collegiate flight programs and therefore represented a population at a low level of overall aviation experience. These flight students represented student pilots, private pilots, commercial pilots, and several with an instrument rating. They had between 64 and 210 flight hours logged and had been pilots for between 1 and 5 years. The students had spoken English for between 7-19 years, with 44.5% of the respondents having seven years of experience with English. Participants spoke native languages of Korean, Mandarin Chinese, and 44.5% of the participants spoke Spanish natively.

Research Question One: *How does exposure to the English language influence pilots' levels of self-efficacy of Aviation English proficiency in the cockpit?*

Gauging how English exposure influenced pilots' levels of self-efficacy in the cockpit was done through a comparison of those whose responses indicated they were less comfortable to those who were reportedly more comfortable with their use of English in the cockpit. 17% of the respondents indicated that they had experienced a situation in which they were less situationally aware due to a lack of language proficiency. Of this percentage, 94% of their responses were ranked moderately comfortable or lower. 75% of these participants preferred Spanish in the cockpit, and they were much less likely to use English outside of the workplace. 13% of the total respondents indicated that they *never* use English outside of the workplace, and 48% of participants had little to no experience with English outside of aviation. In addition, pilots also tended to rate their ability to speak Aviation English higher than their ability to speak English in general. The one-sample Wilcoxon Signed Rank Test (significance level of 0.5) indicated that pilots were at least moderately comfortable using (both hearing and speaking) English while in the cockpit. Also, pilots indicated being most comfortable using English while they were in the cruise stage of the flight, followed by the taxiing stage. On the other hand, about 50% of the pilots preferred to use the Spanish language while in the cockpit, assuming this was caused by the pairing of the staff at their respective jobs, still about 30% of them indicated feeling less comfortable communicating with their peers while in the cockpit. This points to the possibility that when pilots are required to utilize English outside of the aviation register, such as during the circumstances of the Cali, Colombia accident, limited English proficiency can decrease situational awareness and ability to respond appropriately.

17% of the participants indicated having experienced a lack of situational awareness due to their own language proficiency; 52% of the participants also indicated a lack of situational awareness due to someone else's language proficiency. Pilots who responded that they had experienced this lack of proficiency due to language were more likely to indicate that they were less comfortable overall with English, heard Spanish over the radio more frequently, had learned English specifically to become a pilot, and used English less outside of the workspace. One of the respondents who indicated they had been less situationally aware because of language responded that they spoke English a little but that they spoke Aviation English Very Well. This disconnect in the way pilots rate themselves and their own English proficiency is indicative of the types of discrepancies that future training procedures need to take into consideration to best teach English to future pilots. When asked if there was ever a time they did not speak up because they felt they could not say what they needed to in English, 35% responded yes. These situations represent critical moments in which accidents or incidents could occur because of a pilot's language experience, not necessarily even related to their actual ability to fly the aircraft.

Research Question Two: *With what frequency are pilots exposed to their native language while performing aviation duties and what effect does this have on their ability to perform their duties?*

Of the pilots surveyed, 96% reported *always, often,* or *sometimes* hearing their native language over the radio. According to the participants, checklists and placards are mostly provided in English, but 48% still preferred to use Spanish in the cockpit. Operational wise, 42% of the participants indicated hearing Spanish over the radio the most in high traffic zones; also, 88% of the participants indicated hearing Spanish over the radio in the regions of South America, Central America, and Spain. This indicates the extent to which a locally used language plays in aviation operations. Only 39% of pilots surveyed responded that their flight lessons were conducted completely in English, and 56% had flight lessons conducted, at least partially, in Spanish. Most of the participants also indicated speaking Spanish for most of their livelihood; on the other hand, the participants indicated speaking English for significantly less time during their lifetime. This is also supported by other findings in the study in which 60% of them indicated speaking the English language with their family sometimes or not at all; similarly, 47% of the participants responded that they used the English language at their workplace only sometimes or not at all.

Research Question Three: *What is the preferred language (the official aviation language, which is English or another language) for bilingual (or multilingual) pilots for processing a situation and performing their piloting tasks during an emergency, and how does this affect their ability to perform related tasks?*

When participants indicated that language processing of a given scenario occurred in English, they were more likely to feel comfortable responding to the prompt and communicating as expected to ATC. 90% of the responses indicated that participants were internally processing in English, while only 10% indicated that they were processed in a native language. Although infrequent, when participants internally processed in their native language, they reportedly felt less comfortable overall, indicative of hesitations that can occur during in-flight language breakdowns. While participants indicated that it was rare for them to process scenarios in their native language, when they did so, they indicated a tendency to experience difficulty in formulating a response and thereafter performing a given task. When responding to emergency or high-stress scenarios given by ATC, they were more likely to feel less comfortable overall. Responses indicated stuttering, difficulty with vocabulary, feeling the need to repeat a response, or other levels of discomfort when performing the given task.

Conclusions

Lack of proficiency in the register of aviation still exists and is negatively contributing to latencies within the safety culture of aviation. Considering linguistics in aviation accident evaluations represents a relatively recent area of research, and although standards of language exist, improvements in training practices and the standards themselves are still necessary in order to contribute to a greater safety culture overall. Acquiring language from a source outside of aviation, or having experience with English outside the workplace, may greatly contribute to overall comprehension and mastery of the Aviation English standard phraseology. Having a higher level of presumed language proficiency directly correlates to comfort levels inside of the cockpit and performing flight duties.

Recommendations

Participants who struggled with responding indicated common themes of lack of understanding of Aviation English instructions and a lack of vocabulary to provide appropriate and correct responses. These indications display a lack of both Aviation English proficiency and plain language English proficiency. Flight programs should not limit their flight training to just standardized English and ensure the student is being exposed to the English language outside of just the standardized phraseology. Students who responded that they had experienced a situation in which they didn't speak up because they felt they couldn't convey what they needed to in English also tended to have a lower experience with English overall or had flight lessons conducted in their native language.

At a collegiate level, admission into flight programs can base language comprehension solely on the university English tests rather than a flight department's own assessment. While such exams assess a student's ability to perform in English at an academic level, aviation inherently requires more immediate and distinct responses, especially during flight or when communicating with Air Traffic Controllers. Assessing a student's proficiency in Aviation English specifically before they begin the program could save time, frustration, and money, all critical components of a student's potential for future success in the industry. Incorporating English assessments throughout the training could allow students to feel supported throughout their time in the program, as well as ensure they are not falling behind for reasons that relate to language proficiency rather than their flying ability.

Limitations

This research was intentionally limited by narrowing the data pool, as well as by only focusing on pilots rather than other aviation personnel, such as air traffic controllers, who are also required to use English. Rather than focusing on their actual flying ability, information was only gathered based on pilot self-assessment of communication skills. As each case is unique in regard to communication, a larger data pool is needed to provide more accurate results and suggestions going forward. While primary research attempted to permeate the field of Aviation English into the Spanish language, each language has its own nuances and should be studied as well. Secondary research was limited to students in two flight programs in the US, which could be expanded to more collegiate programs as well. Comparing the results of secondary research to those of seasoned pilots would aid in discovering where in the flight training process most language errors are occurring. This would shed light on how they could be prevented from developing and affecting professional aviation environments and lead to a more proactive safety culture throughout the industry. With everyone's language acquisition and aviation experience being unique, follow-up interviews could be a very useful tool to provide concrete examples of what has been most effective as well as aspects that need improvement in relation to English training procedures and standards in the field of aviation. The researchers hope to improve the study, moving forward by both revising the study design and utilizing more robust data analyses techniques in the future; this will create more definitive results that could affirm the correlations presented here.

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Evaluating the Progress of the Liberalization of International Aviation toward Open Skies

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The United States has engaged in well over 100 Open Skies Agreements with other ICAO member state partners reaching all parts of the globe. These Open Skies Agreements have established a practice of liberalization for airlines to have the most freedom to choose when, where, how often, and for how much they fly to locations. Despite a majority of ICAO member state partners engaging in Open Skies, there has been a reluctance of the member states to engage in the same practices with other aviation partners for similar access. A similar pattern is also evident for liberalization through the Freedoms of the Air, a key philosophical understanding set forth through ICAO practices describing the ways in which airlines can fly between the member states in the interest of international aviation. This paper evaluates the trend among the member states to engage in more liberalized aviation through their granted access to reduced government oversight of foreign airline access to sovereign airspace and the number of rights granted to their respective operational international partners. While the overwhelming number of agreements may not be fully liberalized Open Skies, there does appear to be an increasing desire to promote practices that connect member states at greater efficiencies and give travelers more options and more access to airline choice.

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Introduction

The global aviation system has developed significantly over the past century, and international travel is now commonplace. But despite the ease of international travel, the movement of aircraft and people between countries is the product of a very complex system – one that requires navigating a variety of economic and political issues. Ultimately, the operation of international air services is a function of inter-governmental agreements that provide for various activities as framed by the International Civil Aviation Organization (ICAO). In this way, there is essentially a three-tiered approach for the establishment of international air services: a consensus on all possible privileges, an agreement of specific privileges between States, and the allocation of privileges to air carriers to execute the provisions of the agreement. These agreements vary from heavily restrictive bi- and multi-lateral agreements to the more liberal Open Skies Agreements (OSAs). The purpose of this paper is to explore the extent to which these agreements have been forged worldwide and trends in the liberalization of agreements.

Review of Literature

The Chicago Convention of 1944 established a framework for possible air privileges called “the Freedoms of the Air”, which essentially outlined the categories for possible international air activity (Bartsch, 2018). These include the right to overfly another country’s territory, stop for operational purposes (usually refueling), transport passengers to and from another country, and the right to transport passengers between a second and third country as a continuation of a flight to or from the original country. Collectively, the aforementioned rights are considered the “Five Freedoms of the Air” and foundational. ICAO has since outlined additional “so-called” Freedoms, such as the right to transport passengers and cargo between countries without continuing the flight to or from the home country, as well as operating domestic flights within a foreign country. These additional agreements are defined as Freedoms of the Air Rights 6 through 9. The 6th freedom of the air allows the country of registration for an airline to act as an intermediate stop in the carriage of passengers between two other countries. This enhances competition and could, for example, allow passengers to fly on a single itinerary from London to Tokyo on a US-based airline using US 6th freedom rights instead of being required to fly a British-based airline or Japan-based airline. The 7th freedom right expands this idea by allowing a third country’s airline to operate international flights between two other countries. It removes the need for the stopover in the country of registration; however, it does not allow scheduled stops at more than one location within either country. The 8th freedom does allow multiple stops within a single country but requires that airline to either begin or end the scheduled trip in the country of registration. The 9th and final Freedom of the Air, also known as cabotage, is the right of an airline to fly domestic routes in another country that is not the country of registration and without any intention of returning to its country of registration. These additional freedoms are considered to be “so-called” as they have been defined but are not widely adopted, whereas the first five are recognized (though not necessarily extended) by all ICAO signatories (Bartsch, 2018).

The Freedoms of the Air are simply available options that be extended from one state to another, thus offering a standardized approach to the establishment of international air services. They "constitute the core of air services agreements' negotiations, as without their exchange, air transport would only amount to the operation of domestic air services" (Scott & Trimarchi, 2020, p. 93). They form the basis of careful high-level discussion between respective governments to allow any airline to transport passengers and goods in and through their airspace, the second level of the three-tier approach. Because not even all ICAO member-states agree to uphold more than just the first two freedoms, international negotiation and diplomacy are essential to ensuring a successful agreement with the maximum number of freedoms possible. When two States engage in bilateral negotiations, they work to determine the freedoms they will extend and details of how those freedoms must be utilized. This often means outlining approved specific locations of access and associated terms (e.g., frequency of flights, number of gates or slots, terms of reciprocity). Multi-lateral agreements have also been formed among groups of States. For example, the ASEAN Multilateral Agreement on Air Services (MAAS) eliminates restrictions on aircraft operations among capital cities (Ministry of Singapore, 2021).

Open Skies Agreements (OSAs) are a form of air service agreement with minimal restrictions and government interference in the free-market determination of international air operations. The impetus for OSAs is their proposed economic benefits (Button, 2009, and Laplace et al., 2019). However, the term Open Skies itself is not standardized, which presents a logistical challenge for the categorization of air service agreements (Forsyth et al., 2004). Though its name may suggest unrestricted operations, (Scott & Trimarchi, 2020) indicate an OSA is typically characterized by:

- no limitations with regard to capacity;
- opening of all routes;
- unlimited exchange of third and fourth freedom rights, with, occasionally, also the inclusion of fifth freedom rights, subject to approval from the third country involved;
- multiple – that is, unlimited – designation;
- pricing subject to rules of competition; and
- fair and equal opportunity for airlines to compete (p. 104).

The United States offers its own framing of OSA, as facilitating international air travel "by eliminating government interference in commercial airline decisions about routes, capacity, and pricing…" (U.S. Department of State, 2016).

Further complicating the issue of distinguishing an OSA is the challenge of different rights being granted to cargo versus passenger operations, as well as the extent to which the "so-called" sixth, seventh, eighth, and ninth freedoms are included. The liberalization of air service agreements is ultimately a spectrum, and this study relies on the ICAO World Air Services Agreement (WASA) database, which categorizes air service agreements into traditional, transitional, and fully liberalized. A traditional agreement is defined as an agreement between two member states that includes elements of single airline designation, predetermination of capacity, and dual approval of tariffs (i.e., price structure). A fully liberalized (i.e., Open Skies) agreement on the opposite side of the scale included elements of multiple airline designation with no route limitations, at least 5th freedom right designations, the free determination of capacity, a dual disapproval for restrictions, and free pricing tariffs (International Civil Aviation Organization, n.d.). A transitional agreement contains at least one of the elements required in a fully liberalized agreement. At its core, it is still identified as a non-Open Skies agreement because it still requires close government approval of a specific part of the operation, whether that is the pricing structure, frequency of flights, route structure, or other limits that would otherwise be left to an airline to decide based on market conditions. Anyone such limitation means it is not a fully liberalized agreement and therefore cannot be Open Skies, but it can suggest a slow loosening of restrictions in the direction of liberalization.

Research Question

The goal of this study was to document through an exploratory study the current status of ICAO member states' engagement in the liberalization of competition among partner states as indicated through the implementation of Open Skies Agreements. The following research questions were analyzed to provide comparative insights between and among the member states regarding the existence of facilitation of liberalization for airline competition and globalization two decades into the 21st century.

1. Compared to traditional, heavily negotiated, and restrictive operational agreements, as of 2020, how many Open Skies bilateral agreements have been fully executed and documented with the International Civil Aviation Organization by each member state?
2. To what extent does the international community appear to be embracing or rejecting the idea of reduced government interference in international airline competition?
3. In the process of liberalizing airline access to global markets, to what extent are ICAO member states embracing 5th Freedom rights and beyond?

Method

This study was exploratory in nature and a canvas of the ICAO member states' engagement in the liberalization of international airline market competition. Despite the first Open Skies Agreement being signed in 1992 between the United States and the Netherlands, the sovereignty of the airspace within the territory of each member state is a fundamental principle of ICAO standard operation and a necessary philosophical norm for successful participation on the international stage. Therefore, a baseline analysis of participation in the loosening of fundamental principles needed to be conducted.

Data Collection

The primary source of data for this study was the World Air Services Agreement (WASA) database supported by ICAO. This database is the repository for the official bilateral and multi-lateral agreements signed by member states to facilitate international aviation between and among the member states. As a specific part of ICAO Standards and Recommended Practices (SARPs), member states are required to submit their executed agreements to ICAO. Therefore, this database is the most complete and accessible collection of the signed agreements among all the 193 member states.

In addition to the library of air service agreements, the database also provides unique insights and basic analyses of the specific agreements. This includes data on the summary of provisions, route planning criteria as described in the agreements and global maps of international travel information since 2003. While the data is not coded in a downloadable format or synthesized beyond the details of each individual agreement, this information provides accessible details about each agreement as applicable to ICAO operations. For example, the summary of provisions includes an overview of the specific details contained in each agreement describing the specific administrative clauses, the applicable traffic rights (i.e., the number of "Freedoms of the Air" allowed), operational clauses, capacity clauses, and tariff clauses. This summary is how ICAO determines their assessment of whether or not an agreement meets the requirements to be considered a liberalized Open Skies Agreement, a traditional agreement, or somewhere in between (transitional). The summary of provisions also includes a snapshot overview of the types of agreements that have been negotiated between a member state and its respective partners. This summary of provisions section of the database was the primary section of the WASA database used for analysis. This overview is as current as the most recent agreements submitted to ICAO by an individual member state.

The key data collected for this analysis was the type of agreement assessment from the WASA database as traditional, transitional, and full liberalization. In addition to the type of agreements collected for each member state, additional information included the highest Freedom of the Air embraced with each agreement between two member states. While there are a theoretical 9 freedoms, the 8th and 9th freedoms are both a variation of cabotage, or international operation within a domestic market, and were indicated in the database together under the name "cabotage."

Data Analysis

The primary method for analyzing the data collected was through graphs, tables, and descriptive statistics. Presentation of the total numbers of agreements tabulated by the type of agreement or the extent to which beyond 5th Freedoms were allowed by member states were the key indicators to assess the current status of liberalization embraced by the member states and to answer the research questions. Two types of data were collected for the assessment of the status of liberalization. The first assessment was the overall number of agreements that have been submitted to ICAO as executed agreements. The second assessment was the number of member states to which a partner member state flew and of these, which were accessed via traditional, transitional, or liberalized Open Skies Agreements.

Results

Based on an assessment of the bilateral agreements contained in the ICAO WASA database, there has been a trend in the liberalization of agreements. The United States has continually led the world in the facilitation of Open Skies Agreements, with the first being administered with the Netherlands in 1992. By 2003, the first year recorded in the WASA database, the number of Open Skies Agreements entered into force rose to 50 while there were 34 non-Open Skies Agreements on file. In addition, where international procedure limited the completeness of the data, operations to 20 member states occurred in 2003 where no agreement had been submitted to ICAO. Table 1 shows the growth of Open Skies Agreements submitted to ICAO between 2003 and 2020.

Table 1
Growth of US Open Skies Agreements with Partner Member States, 2003-2020

Year	Open Skies	Non-Open Skies	Unrecorded	Year	Open Skies	Non-Open Skies	Unrecorded
2003	50	34	20	2012	82	32	13
2004	56	34	19	2013	86	32	11
2005	61	34	18	2014	86	32	12
2006	62	35	18	2015	89	30	12
2007	67	34	17	2016	90	29	15
2008	70	35	16	2017	94	29	13
2009	71	35	15	2018	94	29	14
2010	74	35	15	2019	93	30	13
2011	78	33	12	2020	94	29	13

*Notes***.** A Non-Open Skies Agreements includes traditional agreements and transitional agreements defined in the WASA database.

Of the 20 non-submitted agreements in 2003, none had achieved an Open Skies status based on Open Skies Partner data reported by the U.S. Department of State (U.S. Department of State, 2021). Only until 2007 did a divergence begin to appear where an implemented Open Skies Agreement was not recorded in the WASA database. However, in no case was there any apparent error in terms of where, if the Open Skies Agreement was ultimately submitted to ICAO, an error was present between recording the Open Skies Agreement at a later date and when it was originally signed. In the case of the United States, only two Open Skies Agreements were signed prior to 2016, where operations were consistently present with the partner member state and the United States. These two countries were the Cook Islands (Open Sky Agreement operations from 2007 through 2020) and Latvia (Open Sky Agreement operations from 2008 through 2018). Between 2016 and 2020, where Open Skies Agreements were signed, operations were routine between the partner states, but ICAO did not update or receive notification of an update were between the US and Azerbaijan (2016), The Bahamas (2020), Belize (2018), Grenada (2018), and Togo (2016).

In contrast to the relatively few instances of a missing update to ICAO where an Open Skies Agreement was facilitated, there were more occurrences where a non-Open Skies Agreement was negotiated or updated but not submitted to ICAO. As indicated earlier, all 20 instances of a non-recorded agreement were Non-Open Skies Agreements, and by 2020, of the 13 non recorded agreements where operations were conducted, eight were non-Open Skies Agreements; however, there was a continual decrease in the overall number of agreements not recorded in the ICAO database between the US and its partner member states. Of the 26 countries unrecorded non-Open Skies Agreements in the WASA database, 13 became Open Skies

Agreements and were subsequently recorded in the database.

A third consideration of the status of Open Skies Agreements were those that were signed, but no operations ever occurred between the United States and the partner member state. Figure 1 shows the status of the overall number of bilateral air service agreements with the United States between 2003 and 2020.

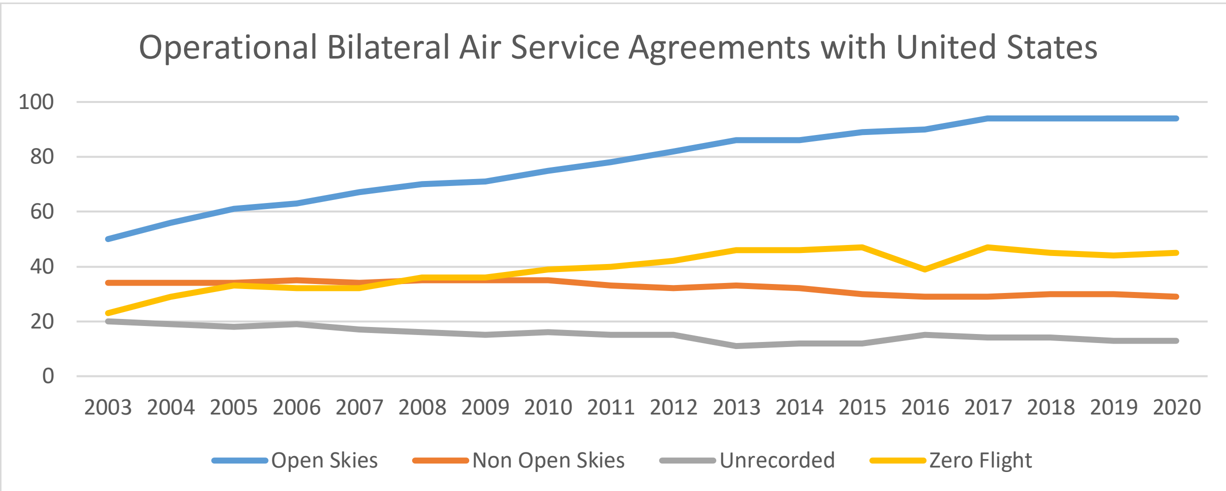

Figure 1. Air Service Agreement Status by Type of Agreement Compared to Agreements that have not facilitated operational commercial service flights.

As can be seen in Figure 1, there is a coinciding increase in the number of total agreements signed between the United States and partner member states. The number of non-Open Skies Agreements have remained relatively unchanged since 2003 and, as of 2020, showed a slight decrease from 34 in 2003 to 29 in 2020. Open Skies Agreements signed have steadily increased each year over the 18 years of this data on an average increase of just over eight Open Skies Agreements per year. In addition, the number of Zero Flight agreements, or signed agreements where no commercial air service flights have been reported to have taken place, have also increased over the same 18-year period. In 2003, 23 agreements with member states were signed and recorded with ICAO, but no commercial service had been conducted by parties of either member states. By 2020 that number had increased to 45 for a yearly increase of 4 agreements on average. Figure 2 shows the comparison zero flight operations of member states with an air service agreement with the United States. There is a noticeable difference in the number of partner states that have engaged in Open Skies Agreements did not yet establish commercial service as of the year shown and the number of partner states who had negotiated limited agreements in the form of non-Open Skies Agreements.

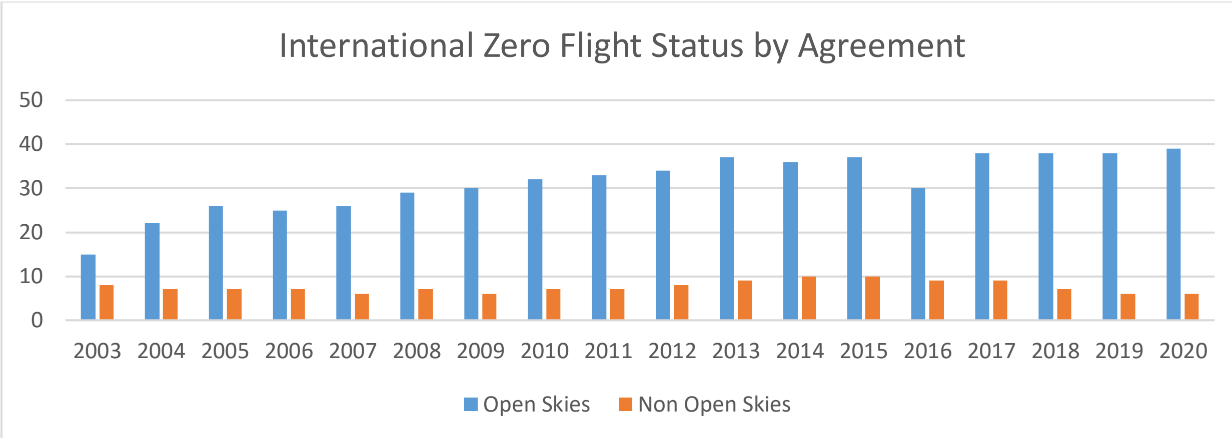

Figure 2. Air Service Agreement Type between the United States and its Partners without Commercial Air Service.

The specific focus of the chart in Figure 2 is to show that there is not always a specific or instantaneous relationship between the implementation of an air service agreement allowing commercial service of any sort and functional implementation of that agreement. If and when a partner country began any commercial service with the United States, it was removed from this interpretation. For instance, Qatar signed its first air service agreement with the United States in 2001. This first agreement was written as a liberalized Open Skies Agreement. However, no flights from the US to Qatar or vice versa were initiated in 2007. Pertaining to Figure 2, Qatar is only represented as a Zero Flight partner in 2003 through 2006. Of the 56 total member states that had zero flights with the United States at the time of initiating an air service agreement, 12 of those partners still have not entered into any commercial service during the 18 years between 2003 and 2020. In 2020, 44 partners with air service agreements did not initialize any commercial service and of those 39 were partners with Open Skies Agreements. Of the 12 US air service partners that had established agreements for the 18 years of observational data, nine had established Open Skies Agreements at some point during that time period, with seven member states establishing their Open Skies Agreements prior to the 2003 period of observation.

While the United States has established itself as the first and continual leader in international aviation regarding the development of Open Skies, member states have not only shown an interest in fostering these agreements with the United States but there is now an ever-rising presence of liberalized Open Skies Agreements among other member states beyond the United States. There are two specific areas of growth that pertain to the opening of partnerships and access to the airspace of partner states. The facilitation of Open Skies Agreements is a key indicator because of the necessity to negotiate an air service agreement outlining the rights of another country to operate within foreign airspace. The Open Skies agreements allow the competition to exist. The second key component of facilitating Open Skies is the access to where airlines can take passengers after they have arrived in the foreign country. These specifically relate to the Freedoms of the Air. Many Open Skies Agreements are facilitated on the basis of 5th Freedom Rights, or the rights to fly into a member state, disembark and board any passengers at that gate, and then fly to another location outside the borders of that partner state. However, there has been increasing facilitation of access to additional Freedoms of the Air embodying the 6ht, 7th, and 8th Freedoms in conjunction with the implementation of the Open Skies Agreement. The

United States has been a leader in both of these key points, but other member states are realizing benefits and slowly following the same trajectory.

Depicted in Table 2, as of 2020, the United States has recorded a total of 107 Open Skies Agreements with ICAO, and as discussed earlier, a number of these agreements have not yet established commercial service. The willingness of other member states to engage in the liberalization of skies with other partner countries has not risen to the same level. The United Arab Emirates (UAE) has the second most Open Skies Agreements with 41. From that point, there is a steady drop off to where the 20th most member states (out of 193 member states) have signed 4 Open Skies Agreements, one of those being with the United States. In contrast, traditional agreements are still a very common way to negotiate international commercial air service. The Netherlands had the most traditional or most restrictive agreement type, with 112 partner agreements. Many countries have 80 or 90 such agreements, with the 20th ranked state having 53 traditional agreements recorded with ICAO. In the traditional agreement rankings, the United States ranks 69th, with 22 traditional agreements still recorded. The WASA categorization of the agreements has established a middle tier, identified in the name "transitional." These transitional agreements remain competitively restrictive compared to Open Skies Agreements but have allowed for a loosening of specific points compared to the traditional agreements. For example, a member state may allow an airline to choose the number of flights it can have on a route but still specify the exact routing allowed. In contrast, the Open Skies Agreement allows the airlines complete freedom to choose how, when, where, and price of their flights. The United Kingdom has embraced more and a loosening of these agreements, although still being a top 10 state in the number of traditional agreements, led the way in 2020 in developing transitional agreements. However, the United States ranked 7th in 2020 in transitional agreements as well with 23. Between the Open Skies Agreements and the transitional agreements, the United States has entered 130 more open agreements where the UAE in second has 63 combined transitional or Open Skies Agreements.

Table 2
Number of Air Service Agreements by Access

Rank	Country	Open Skies	Country	Transitional	Country	Traditional
1	United States	107	United Kingdom	41	Netherlands	112
2	United Arab Emirates	41	Dominican Republic	41	Germany	104
3	Burma	36	India	31	Switzerland	97
4	Singapore	26	Qatar	26	China	94
5	Dominican Republic	17	Germany	25	Belgium	94
6	New Zealand	15	Russia	23	United Kingdom	84
7	Chile	10	United States	23	Austria	83
8	Kuwait	10	South Africa	22	Poland	80
9	Costa Rica	7	United Arab Emirates	22	Spain	73

10	Switzerland	6	Czech	22	France	73
11	Brazil	6	Singapore	21	Sweden	67
12	Australia	6	China	18	Denmark	60
13	Panama	5	Spain	18	Morocco	58
14	Finland	5	Canada	18	Iraq	56
15	Iceland	5	Argentina	18	India	55
16	Qatar	4	New Zealand	16	Israel	54
17	Czech Republic	4	Chile	14	Norway	54
18	Netherlands	4	Israel	13	Japan	53
19	Malta	4	Seychelles	13	Pakistan	53
20	Norway	4	Sweden	12	Italy	52

Lastly, the United States has led the access to international transportation by engaging in the most open agreements and combining that with the most open access through the 5th Freedoms Rights and Beyond. 5th Freedom rights appear not to be uncommon, but a number of countries that have not automatically advanced 5th Freedom Rights as can be seen by the reduction in agreements with 5th, 6th, or7th Freedom Rights shown in Table 3. The United States is nearly alone at the top in allowing routine 6th and 7th Freedom Rights as the United States routinely advances 7th Freedom Rights through cargo airline approvals. As can be seen, the 8th most number of agreements with 7th Freedom Rights was a tie among Switzerland, Iceland, and Trinidad and Tobago with 3 approvals. As of 2020, this extension of liberalization was not readily embraced compared to the number of traditional agreements held by other member states.

Table 3
Freedoms of the Air Allowed by the Member States

Country	5ths	Country	6ths	Country	7ths
United States	145	United States	85	United States	86
Netherlands	99	Dominican Republic	26	Dominican Republic	8
Switzerland	98	United Arab Emirates	13	United Arab Emirates	7
Singapore	85	New Zealand	10	Chile	7
Belgium	78	Chile	9	Singapore	6
Germany	75	Singapore	8	Argentina	6
United Arab Emirates	68	Russia	6	New Zealand	5
France	67	Argentina	6	Switzerland	3
India	56	Colombia	6	Iceland	3
Sweden	55	Brazil	6	Trinidad and Tobago	3

Conclusions

In the 21st century, there has been an opening of competition among international airlines. This opening has been facilitated through a relaxation of the acceptance of traditional, heavily restricted air service agreements in favor of a push towards Open Skies Agreement. Competition has increasingly been advanced over the last decade, and the United States has continued to embrace liberalization with any partner who wishes to negotiate. However, there still appears to be a reluctance and hesitance to embrace the maximum freedom of international airlines. 8th freedom cabotage or the direct competition of a foreign airline with a domestic airline is still a very isolated exception for very specific circumstances that no member state readily embraces. However, even the 7th Freedom Rights are rare. As international aviation continues to grow and recover from the Covid-19 pandemic, there is a unique opportunity for the ICAO member states to assess their international practices and determine how connectivity and liberalization can move the industry forward in an increasingly globalized society in need of increasingly sustainable practices that will maximize growth at the least destructive impact to society. Open Skies Agreement and liberalized access to aviation is potentially a powerful and unique tool to pursue.

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